MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Environmental Statement

Volume 4, Annex 5.3: Offshore ornithology collision risk modelling technical report

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Image of an offshore wind farm

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Glossary

Term	Meaning
Air Gap	The gap between the sea and the lowest point of a wind turbine rotor blade. Expressed in relation to sea level (e.g. MSL, LAT or HAT)
Avoidance	Probability that a bird takes successful evasive action to avoid collision with a wind turbine.
Collision risk	Risk of a bird lethally colliding with a wind turbine within a wind farm.
Collision risk model	A model that calculates collision risk for a species within a wind farm based on a set of wind farm and bird species specific parameters. Collision risk models can be run deterministically or stochastically.
Large array correction	Adjustment to the probability of bird collision to account for the depletion of bird density in later rows of a wind farm with a large array of wind turbines.
Light Detection And Ranging (LiDAR)	A remote sensing method using pulsed lasers to measure distances to the earth.
Lowest Astronomical Tide	The lowest level of the sea surface with respect to the land.
Maximum Design Scenario (MDS)	The scenario within the design envelope with the potential to result in the greatest impact on a particular topic receptor, and therefore the one that should be assessed for that topic receptor.
Mean Sea Level	The average level of the sea surface with respect to the land.
Nocturnal Activity Factor	The percentage of a bird species that is considered active at night.
Ornithology	Ornithology is a branch of zoology that concerns the study of birds.
Parameter	Parameters are the input elements of a model that together affect the output of a model. In collision risk models, examples of parameters are the number of wind turbines and the length of the bird. All input parameters are described in Table 1.3 and Table 1.4.
Stochastic model	Model where the input parameters that go into the model are allowed to vary, leading to a range of output.

Acronyms

Term	Meaning
BCA	Bird Collision Avoidance
EIA	Environmental Impact Assessment
EWG	Expert Working Group
HRA	Habitats Regulations Assessment
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LCI/UCI	Lower/Upper Confidence Interval
LiDAR	Light Detection And Ranging
MDS	Maximum Design Scenario
MMO	Marine Management Organisation
MRSea	Marine Renewables Strategic environmental assessment

Term	Meaning
MSL	Mean Sea Level
NRW	Natural Resource Wales
ORJIP	Offshore Renewables Joint Industry Programme
PEIR	Preliminary Environmental Information Report
RPM	Rotations Per Minute
(s)CRM	(stochastic) Collision Risk Model
SNCB	Statutory Nature Conservation Body
VOR	Valued Ornithological Receptor

Units

Unit	Description
km	Kilometres
km^2	Kilometres squared
m/s	Metres per second
m	Metres
%	Percentage

1 Offshore ornithology collision risk modelling technical report

1.1 Introduction

1.1.1 Background

1.1.1.1 During the operations and maintenance phase of the Morgan Offshore Wind Project: Generation Assets (hereafter referred to as the Morgan Generation Assets), the turning rotors of the wind turbines may present a risk of collision for seabirds. Stationary structures, such as the tower, nacelle or when rotors are not operating, are not expected to result in a material risk of collision. When a collision occurs between the turning rotor blade and the bird, it is assumed to result in direct mortality of the bird, which potentially could result in population level impacts.

1.1.1.2 Species differ in their susceptibility to collision risk, depending on their flight behaviour and avoidance responses, and the vulnerability of their populations (Garthe and Hüppop, 2004; Furness *et al.* 2013; Bradbury *et al.,* 2014; Wade *et al*., 2016). The structure and operation of the wind turbines can also affect the risk to birds, with factors such as rotor speed, blade size, pitch angle and height above the sea surface all influencing the magnitude of risk. Artificial lighting may also change the risk for some species (e.g. shearwaters and petrels), although there is little available evidence to quantify the extent of change to the risk.

1.1.1.3 The ability of seabirds to detect and manoeuvre around wind turbine blades is also a factor that is considered when modelling and assessing the risk. In response to this it is standard practice to calculate differing levels of avoidance for different species or species groups. Avoidance rates are applied to collision risk models to predict levels of impact more realistically, based on available literature and expert advice about seabird behaviour and their flight response to wind turbines.

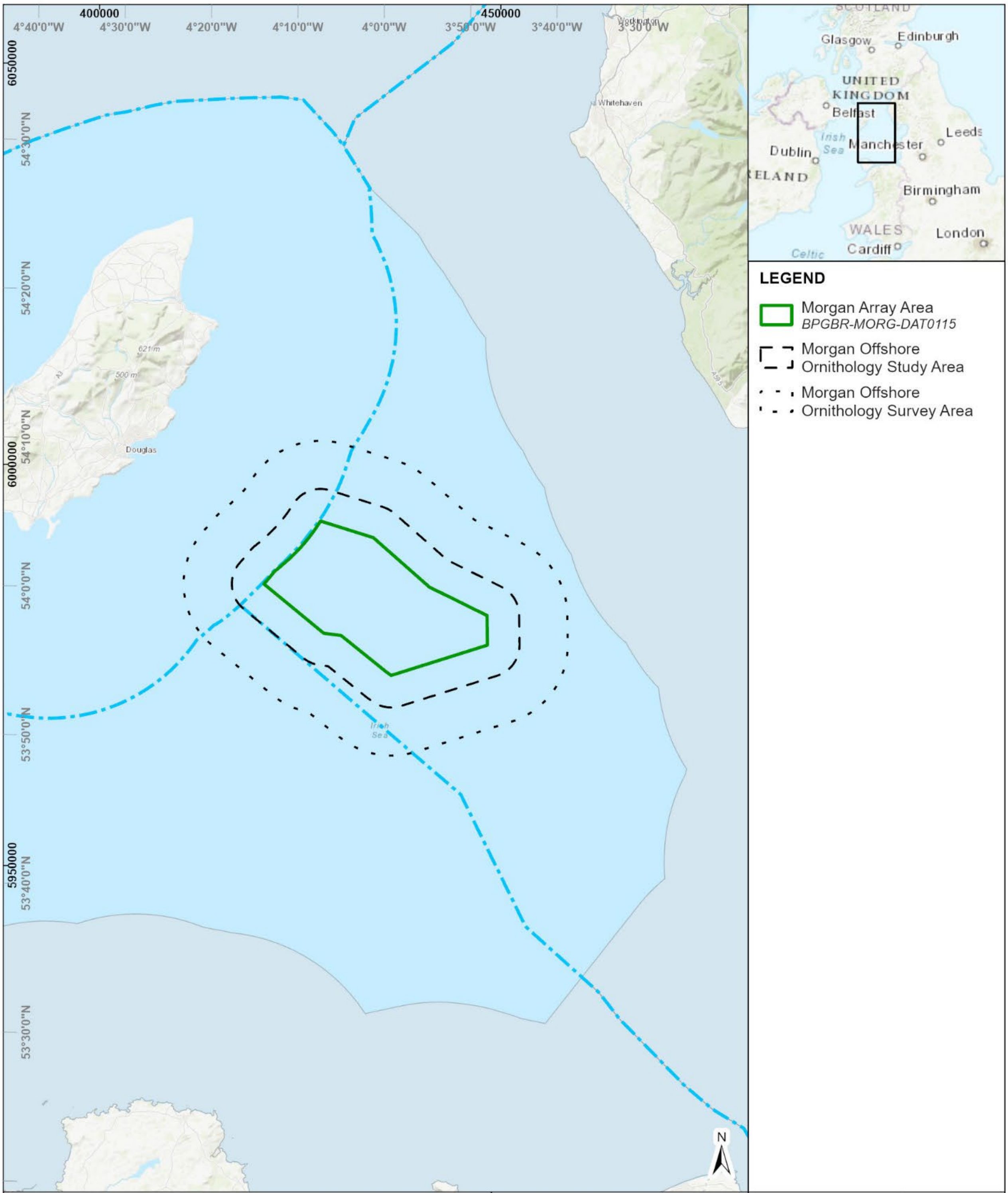
1.1.1.4 In general, the effects of increased mortality on populations due to collisions with turbines are considered to be long-term (i.e. throughout the operational wind farm's lifespan) and it is assumed that in the model, collision rate does not decrease in response to losses in the population. In 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.

1.1.2 Aim of the report

1.1.2.1 This technical report presents the collision risk modelling approach undertaken for the Morgan Generation Assets to inform Volume 2, Chapter 15: Offshore ornithology of the Environmental Statement and the Information to Support Appropriate Assessment (ISAA) (Document Reference E1), incorporating, where relevant site-specific data collected between April 2021 and March 2023. This Annex focusses on collision risk to regularly occurring seabird species, with collision risk modelling for migratory seabirds and waterbirds presented in Volume 4, Annex 5.4: Migratory bird collision risk modelling technical report of the Environmental Statement.

1.1.3 Morgan offshore ornithology study area

1.1.3.1 The collision risk assessment has been carried out using seabird densities within the Morgan Array Area only (Figure 1.1). The Morgan Array Area is located in the east Irish Sea, approximately 22.2 km (12 nm) from the Isle of Man and 37.13 km (20.1 nm) from the northwest coast of England. The Morgan Array Area is 280 km^2 in size. Densities have been derived from aerial surveys undertaken across the Morgan offshore ornithology survey area (as defined in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement). This technical report also utilises abundance data from the Morgan offshore ornithology study area (also defined in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement) to identify if collision risk modelling is required for the Valued Ornithological Receptors (VORs) identified in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement. These areas are illustrated in Figure 1.1.



Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Topographic Map: DoBH, OS, Esri, HERE, Garmin, USGS, NGA

Data Sources: RPS, NIRAS

Project Name: MORGAN OFFSHORE WIND PROJECT

0 1 2 4 6 8 10 12 nm
0 5 10 15 20 25 km

Drawing Number: NIRA-MG-ORN-034-01

Drawing Title: Morgan Generation Assets Study Areas

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:800,000

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01	09/10/23	First Issue	JOSW	HAZ

Figure 1.1: Morgan offshore ornithology study area used for collision risk modelling alongside other areas mentioned within this appendix.

1.2 Consultation

1.2.1 Overview

1.2.1.1 A summary of the key matters raised during consultation activities undertaken to date specific to offshore ornithology is presented in Table 1.1 below, together with how these comments have been considered in the production of this technical report.

1.2.2 Evidence Plan process

1.2.2.1 The purpose of the Evidence Plan process is to agree the information the Morgan Generation Assets needs to supply to the Secretary of State, as part of a Development Consent Order (DCO) application for the Morgan Generation Assets. The Evidence Plan seeks to ensure compliance with Habitats Regulations Assessment (HRA). The development and monitoring of the Evidence Plan and its subsequent progress is being undertaken by the Steering Group. The Steering Group will comprise of the Planning Inspectorate, the Applicant, Natural Resource Wales (NRW), Natural England, Joint Nature Conservation Committee (JNCC) and the Marine Management Organisation (MMO) as the key regulatory and Statutory Nature Conservation Body (SNCBs). To inform the Environmental Impact Assessment (EIA) and HRA process during the pre-application stage of the Morgan Generation Assets, Expert Working Groups (EWGs) were also set up to discuss and agree topic specific issues with the relevant stakeholders. Consultation was undertaken via the Offshore Ornithology EWG, with meetings held in February 2022, July 2022, November 2022, February 2023, June 2023, October 2023 and December 2023.

1.2.2.2 The responses provided and changes suggested by the stakeholders through the EWG are summarized in Table 1.1, together with changes implemented in this technical report.

1.2.3 Section 42 consultation

1.2.3.1 A number of comments were received during the S42 consultation following submission of the Preliminary Environmental Information Report (PEIR) chapter. All the responses provided, and changes suggested by the stakeholders are presented in the Consultation report (Document reference E3) together with changes implemented in the technical reports underpinning the Environmental Statement.

1.2.3.2 A summary of the key responses with changes implemented in this technical report of the Environmental Statement are presented in Table 1.1.

Table 1.1: Consultation responses relevant to the Technical Appendix.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this technical report
June 2022	**Scoping Opinion** The Planning Inspectorate	It is noted that the approach to obtaining density and spatial abundance estimates will be discussed within the Evidence Plan process. The Inspectorate advises that given the fundamental importance of this discussion to the outcomes of the EIA process, the Applicant should seek to agree the modelling parameters used and the methodology applied with the relevant consultees, giving careful consideration to the sharing of information through the Evidence Plan process.	The approach incorporates all parameters recommended by SNCBs. Approach is detailed in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation report of the Environmental Statement.
	Scoping Opinion Natural England	Although Natural England questions the utility of flight height data derived by the 'size-based' and similar methods, if this data has been produced, we would welcome its inclusion for comparison with the generic flight height distributions (Johnston *et al*., 2014), noting that we would not expect it to be used in Collision Risk Modelling (CRM).	Generic flight height data from Johnston *et al.* (2014) have been used in this technical report as site-specific data collected were deemed not to be suitable.
July to August 2022	JNCC and Natural England – collision technical paper provided and agreed as part of the Offshore Ornithology Expert Working Group 2.	Recommend the use of the sCRM for the basic Band model (i.e. Options 1 and 2) with update parameters from the joint SNCB.CRM draft guidance note (SNCB, in prep).	Collision risk modelling was undertaken using the sCRM developed by Marine Scotland (McGregor *et al*., 2018) and using parameters from the joint SNCB CRM draft guidance note (SNCB,in prep). The results are presented in this technical report (section 1.4).
		Advise that collision risk assessment use the information on uncertainty and variability in the input parameters (e.g. bird densities, flight heights, avoidance rates, nocturnal activity) to allow consideration of the range of values predicted impacts may fall within, and to allow an assessment of confidence in the conclusions made regarding adverse effects on site integrity and significance of impacts for populations.	Collision risk modelling was undertaken using the Stochastic Collision Risk Model (sCRM) developed by Marine Scotland (McGregor *et al*., 2018) and the results are presented in this technical report (section 1.4).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this technical report
		Agree with the list of species provided as being expected to require a collision-risk assessment but cannot rule out other species at this stage until density estimates across species for the array plus buffer (based on baseline survey data collection) have been presented.	Density estimates of all species encountered during the digital aerial surveys are presented in the offshore ornithology baseline characterisation (Volume 4, Annex 5.1: Offshore ornithology baseline characterisation report of the Environmental Statement).
July 2022	**Offshore Ornithology Expert Working Group 2 –** Natural England, JNCC, the Royal Society for the Protection of Birds (RSPB) and The Wildlife Trusts (TWT).	Agreement to the approach to stochastic Collision Risk Model (sCRM) as discussed in the EWG02 meeting, which supersede the Morgan CRM technical paper following the Natural England advice.	Approach to the sCRM is presented in this technical report (section 1.3).
December 2022	**Offshore Ornithology Expert Working Group 3 –** Natural England, JNCC, and the RSPB.	Have collision risk impacts on Manx shearwater been screened out?	Although Manx shearwater is considered to have a very low vulnerability to collision risk by Wade *et al.* (2016) there is a high level of uncertainty associated with this vulnerability score. On a precautionary basis Manx shearwater has therefore been included in collision risk modelling.
May 2023	**Response to S42 consultation** North West Wildlife Trusts	Ornithology. Please note due to time restraints, we have not assessed the offshore ornithology section and echo all of RSPB comments. We look forward to the updated assessment once the full 24 months of surveys have been undertaken. We expect that all impacts are minimised through the project design and best use of available technology e.g. minimum tip height of turbines to reduce impacts, minimising moving parts and/or the number of turbine blades, slower rotation speeds, and blunt edges on the structure, slow start procedures for turbines. Given the number of OWF being developed in the Irish Sea, we expect a full cumulative impact assessment to be undertaken, including consideration of transboundary impacts.	The full 24 months of site specific digital aerial surveys have been included in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation of the Environmental Statement. A revised CEA screening (see Cumulative effects screening matrix (Document Reference F3.5.1)) was undertaken to identify and assess projects and plans within the offshore ornithology CEA study area, the cumulative effects assessment for offshore ornithology is presented in Volume 2, Chapter 5: Offshore ornithology of the Environmental Statement.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this technical report
June 2023	**Response to S42 consultation** Natural England	Vol.4, Ann.10.3 Natural England agree with the approach to CRM, and the parameters used. However, we advise that all data used in the assessment process is made available as an appendix, along with all model logs, to enable full review and future utilisation by other projects. Present boot-strapped data in an appendix. Present sCRM log files as an appendix.	All data and information required for CRM is included in this technical report or (Volume 4, Annex 5.1: Offshore ornithology baseline characterisation report of the Environmental Statement).
	Response to S42 consultation Natural Resource Wales	210. Offshore Ornithology. Detailed comments. Assessment of Significant Effects/Impacts at EIA scale (Section 10.8 of Chapter 10, Annexes 10.2-10.4). Collision risk. Seabird collision risk. NRW (A) welcome that the collision risk modelling has been undertaken using the Stochastic Collision Risk Model (sCRM) developed by Marine Scotland (McGregor et al., 2018) and given the lack of robust site-specific flight height data, agree that the impact assessments have been based on Option 2 outputs.	Noted, see section 1.3 for a full overview of the methodology applied. Collision risk estimates have been calculated using the methodology agreed with the EWG.
		211. Offshore Ornithology. Detailed comments. Assessment of Significant Effects/Impacts at EIA scale (Section 10.8 of Chapter 10, Annexes 10.2-10.4). Collision risk. Seabird collision risk. NRW (A) are content with use of the input parameters (biometrics, avoidance rates, nocturnal activity factors) used as presented in Table 1.1 of Annex 10.3, which are consistent with those supplied by Natural England in their draft guidance (which was submitted in Natural England's relevant representations for the Dudgeon and Sheringham Shoal extension projects examination – see Appendix B2 of: EN010109-000540-Natural England - Relevant Representation.pdf (planninginspectorate.gov.uk). The review of avoidance rates by Ozsanlav-Harris et al. (2022) that	Noted, see section 1.3 for a full overview of the methodology applied. Collision risk estimates have been calculated using parameters provided by the EWG.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this technical report
		informed the draft guidance on avoidance rates is now published and available from JNCC's website at: Review of data used to calculate avoidance rates for collision risk modelling of seabirds | JNCC Resource Hub. NRW (A) also agree with the use of a 70% reduction in gannet densities going into the CRM to account for macro avoidance.	
November 2023	JNCC – Avoidance rate technical paper provided and discussed as part of the Offshore Ornithology Expert Working Group 6.	Justification for use of grouped avoidance rates for CRM. Details the rationale behind the advice for using 'grouped' avoidance rates instead of species specific avoidance rates.	Grouped avoidance rates and those provided by the EWG during PEIR have been used. Additionally, species-specific avoidance rates, particularly for the three large gull species; lesser black-backed, great black-backed and herring gull, have been modelled due to having sufficient sample size to do so. The JNCC written advice does acknowledge that the sample size for these three species is enough to estimate species-specific rates, however it does note the data quality. Both rates have therefore been modelled for all species, with focus placed on species specific rates for lesser black-backed gul, great black-backed gull and herring gull. The species-specific avoidance rate for kittiwake has also been modelled due to the differences between this species and other species of gull.
December 2023	**Offshore Ornithology Expert Working Group 7** Natural England, JNCC, NRW, MMO, RSPB, IoM	Discussion around use of species-specific avoidance rates. Agreed that both avoidance rates should be provided to allow the range of potential impacts to be understood, with the EWG likely to focus more on grouped avoidance rates. The EWG acknowledged that the Applicant will be showing both and are in agreement that both can be shown and the EWG acknowledge that the Applicant will focus on species-specific avoidance rates for the three large gull species.	Both avoidance rates have been shown through this technical report and in all other assessments throughout the Environmental Statement.

1.3 Methodology

1.3.1 Species for consideration

1.3.1.1 The process to identify VORs that may be affected by impacts associated with the Morgan Generation Assets is documented in the baseline characterisation report (Volume 4, Annex 5.1: Offshore ornithology baseline characterisation report of the Environmental Statement). 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 1.2) (i.e. a score of moderate or higher) with the uncertainty level associated with the vulnerability scores also taken into account and
- Where the population of the species observed at the Morgan offshore ornithology study area (as defined in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement) (Figure 1.1) is considered to be of importance, when compared against a relevant population scale thresholds (regional, national or international). as described in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation report of the Environmental Statement.

1.3.1.2 Table 1.2 identifies those VORs for which collision risk modelling is required based on the above criteria.

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

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at the Morgan Generation Assets	Collision risk modelling required (Yes/No)
Kittiwake *Rissa tridactyla*	High	Very Low	Regional	Yes – high vulnerability, species recorded in regionally important numbers at the Morgan Generation Assets.
Little gull *Hydrocoloeus minutus*	Moderate	N/A	Regional	No – species recorded in only a few surveys with densities observed considered unlikely to result in a measurable effect. Abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Great black-backed gull *Larus marinus*	Very High	Low	Regional	Yes – very high vulnerability, species recorded in regionally important numbers at the Morgan Generation Assets.
Herring gull	Very High	Very Low	Regional	Yes – very high vulnerability, species recorded in regionally

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at the Morgan Generation Assets	Collision risk modelling required (Yes/No)
Larus argentatus				important numbers at the Morgan Generation Assets.
Lesser black-backed gull *Larus fuscus*	Very High	Very Low	Local	Yes – very high vulnerability.
Sandwich tern *Thalasseus sandvicensis*	Very High	Low	Negligible	No –species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Little tern *Sternula albifrons*	Moderate	Very High	Negligible	No – species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Roseate tern *Sterna dougallii*	High	Very High	Negligible	No – species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Common tern *Sterna hirundo*	Moderate	Very Low	Local	No –species recorded in only one survey however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at the Morgan Generation Assets	Collision risk modelling required (Yes/No)
Arctic tern *Sterna paradisaea*	Moderate	Moderate	Local	No – species recorded in only one survey however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Great skua *Stercorarius skua*	High	Moderate	Local	No – species recorded in only one survey however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Arctic skua *Stercorarius parasiticus*	High	Moderate	Local	No – species recorded in only one survey however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Guillemot *Uria aalge*	Very Low	Low	Regional	No – very low vulnerability, low associated uncertainty, species recorded in regionally important numbers at the Morgan Generation Assets.
Razorbill *Alca torda*	Very Low	Low	Regional	No – very low vulnerability, low associated uncertainty, species recorded in regionally important numbers at the Morgan Generation Assets.
Puffin *Fratercula arctica*	Very Low	Moderate	Local	No – very low vulnerability, moderate associated uncertainty, species occurrence at the Morgan Generation Assets is limited.

VOR	Vulnerability to collision risk impacts	Uncertainty level associated with vulnerability rating	Importance of population at the Morgan Generation Assets	Collision risk modelling required (Yes/No)
European storm petrel *Hydrobates pelagicus*	Low	Very High	Negligible	No – species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Leach's petrel *Oceanodroma leucorhoa*	Low	Very High	Negligible	No – species not recorded during baseline surveys however, abundance of this species is not adequately captured by traditional baseline surveys during migratory periods. Species will be considered in Volume 4, Annex 5.4: Offshore ornithology migratory bird CRM technical report of the Environmental Statement.
Fulmar *Fulmarus glacialis*	Very Low	Low	Local	No – very low vulnerability, low associated uncertainty
Manx shearwater *Puffinus puffinus*	Very Low	High	Local	Yes – although the species has a very low vulnerability, uncertainty is high
Gannet *Morus bassanus*	High	Very Low	Local	Yes – high vulnerability, recorded in majority of baseline surveys

1.3.1.3 The following species were selected for collision risk modelling:

- Kittiwake (high vulnerability, regional population importance)
- Great black-backed gull (very high vulnerability, regional population importance)
- Herring gull (very high vulnerability, regional population importance)
- Lesser black-backed gull (very high vulnerability)
- Manx shearwater (very low vulnerability however, associated uncertainty is high)
- Gannet (high vulnerability and although only of local population importance species recorded in the majority of surveys).

1.3.2 Collison risk modelling

1.3.2.1 Collision risk modelling was undertaken using the Stochastic Collision Risk Model (sCRM) developed by Marine Scotland (McGregor *et al*., 2018). The sCRM provides a user-friendly 'Shiny App' online interface which allows for variability in input parameters to be incorporated into the model, producing predicted collision estimates with associated uncertainty. Additionally, the sCRM provides a useful audit trail of input parameters and outputs, enabling reviewers to easily assess and reproduce the results of any modelling scenario. The User Guide for the sCRM Shiny App provided by Marine Scotland (Donovan, 2018)[1] has been followed for the modelling of collision impacts predicted for the Morgan Array Area.

1.3.2.2 The collision risk models incorporate draft guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores (Natural England, pers. comm., 07 July 2022). In some instances, values for certain species (e.g. Manx shearwater) were not provided within the Natural England guidance document. sCRM parameters therefore for these species followed best available evidence (e.g. Garthe and Hüppop, 2004; Pennycuick, 1997; Gibb *et al*., 2017; Robinson, 2005). In addition, other values that seek to capture the uncertainty associated with various parameters used for collision risk modelling have also been used. All proposed parameters are set out in Table 1.3 and Table 1.4.

1.3.3 Modelling parameters

Species parameters

1.3.3.1 The sCRM incorporates several parameters relating to the birds and their behaviour, as well as physical parameters relating to the wind turbines, to provide the mechanistic prediction of collision risk. It is necessary to incorporate degrees of both variability and uncertainty in some of those parameters to ensure that the risk is not under or over-estimated. It is, however widely acknowledged that additive layers of precaution in all parameters may lead to overestimation of risk. This is particularly the case in relation to avoidance rates, bird flight speed and nocturnal activity factors, which have some of the biggest influences on the predicted magnitude of risk. This is discussed in relevant sections below.

1.3.3.2 The species biometric and behavioural parameters to be used for collision risk modelling are presented in Table 1.3. The modelling approach has incorporated those parameters recommended by Natural England (pers. comm., 07 July 2022) in addition to other values that seek to capture the uncertainty associated with various parameters used for collision risk modelling. A discussion on these parameters is provided in section 1.4.

1.3.3.3 Additionally, the guidance provided by Natural England (pers. comm., 07 July 2022) states that in order to account for macro-avoidance, the densities of gannet used for collision risk modelling should be reduced by 65% to 85% to account for macro-avoidance which is not incorporated into the avoidance rates derived by Ozanlav-Harris *et al.* (2023). To address this Natural England propose reducing input densities by 70% and this has been followed when applying the Ozsanlav-Harris *et al.* (2023) avoidance rates (see section 1.3.4).

[1] https://www.gov.scot/publications/stochastic-collision-risk-model-for-seabirds-in-flight/

Table 1.3: Species biometrics and input parameters for CRM.

Parameter	Source	Kittiwake	Great black-backed gull	Herring gull	Lesser black-backed gull	Manx shearwater	Gannet
Bird length (m)	Robinson (2005)	0.39 (±0.005)	0.71 (±0.0375)	0.60 (±0.0225)	0.58 (±0.03)	0.34 (±0.02)	0.94 (±0.0325)
Wingspan (m)	Robinson (2005)	1.08 (±0.0625)	1.58 (±0.0375)	1.44 (±0.03)	1.42 (±0.0375)	0.82 (±0.0325)	1.72 (±0.0375)
Flight speed (m/s)	Alerstam *et al.* (2007)	13.1 (±0.40)	13.7 (±1.20)	12.8 (±1.80)	13.1 (±1.90)		-
	Pennycuick (1987)	-	-	-	-	-	14.9 (±0.00)
	Skov *et al.* (2018) (standard deviation)	8.71 (3.16)	9.8 (3.63)	9.8 (3.63)	9.8 (3.63)	-	13.33 (4.24)
	Gibb *et al.* (2017)	-	-	-	-	11.46 (± 2.23)	-
Nocturnal activity factor	Wade *et al.* (2016); Furness *et al.*, 2018	0.375 (±0.0637) (25 to 50%)	0.375 (±0.0637) (25 to 50%)	0.375 (±0.0637) (25 to 50%)	0.375 (±0.0637) (25 to 50%)	0.5 (50%)	0.08 (±0.10) (4 to 8%)
Flight type	User-defined	Flapping	Flapping	Flapping	Flapping	Flapping	Flapping
Proportion of flights upwind (%)	50	50	50	50	50	50	50
Avoidance rate (Basic model) (%)	Ozsanlav-Harris *et al.* (2023) (species-specific rate)	0.9979 (±0.0013)	0.9991 (±0.0002)	0.9952 (±0.0003)	0.9954 (±0.0003)	-	N/A
	Ozsanlav-Harris *et al.* (2023) (all gull rate)	0.9928 (±0.0003)	-	-		-	0.9928 (±0.0003)
	Ozsanlav-Harris *et al.* (2023) (large gull rate)	-	0.9939 (±0.0004)	0.9939 (±0.0004)	0.9939 (±0.0004)	-	-
	Ozsanlav-Harris *et al.* (2023) (all gulls and terns rate)	-	-	-	-	0.9907 (±0.0004)	-
	Bowgen and Cook (2018)	0.994	0.997	0.997	0.997	-	-

Flight heights

1.3.3.4 Flight heights for sCRM may take the form of simple species-specific proportions at rotor swept height, or of species-specific flight height distributions. Either can be derived from site-specific data collected during baseline surveys, or from 'generic' flight height distributions in published literature. The application of site-specific flight height data collected by Light Detection And Ranging (LiDAR) survey was considered at the outset of the survey programme but was not undertaken following consultation with the EWG. At the time of consultation, Natural England did not endorse the use of LiDAR as a method for collecting flight height data to parameterise CRMs due to the lack of an established body of scientific evidence. Other methods to collect site-specific flight height data (e.g. derived from aerial imagery) are not currently considered to be sufficiently robust or precise in their estimates and have associated issues with the application of appropriate avoidance rates.

1.3.3.5 The proportion of birds flying at collision risk height was therefore determined using generic flight height data rather than site-based data. These generic data were taken from Johnston *et al*. (2014). Collision risk models were therefore run using Option 2 of the sCRM.

Wind farm and turbine parameters

1.3.3.6 The parameters for the turbine scenario represented by the Maximum Design Scenario (MDS) as required for collision risk modelling are presented in Table 1.4. The MDS represents the turbine scenario that provides the highest number of collisions and therefore a worst case The large array correction feature of the sCRM 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).

Table 1.4: Wind turbine parameters in the MDS for CRM.

a Maximum parameter values presented are specific to the wind turbine option one model (Volume 1, Chapter 3: Project description of the Environmental Statement).

Parameter[a]	Parameter value (standard deviation, where relevant)
Wind farm	
Latitude	54.00
Max. number of wind turbines	96
Tidal offset (m) (Mean Sea Level (MSL))	- 4
Turbine	
Number of rotor blades per wind turbine	3
Max. chord width (m)	6.8 (0)
Average blade pitch (degrees)	10 (0)
Max. rotor radius (m)	125
Average rotation speed (rpm)	6.2 (0)
Lower blade tip height above Lowest Astronomical Tide (LAT) (m)	34
Air gap (MSL) (m)	30
Monthly proportion of time operational (%) (all months)	94

1.3.4 Density estimates

1.3.4.1 Project-specific data for the Morgan Generation Assets has been collected by two years of digital aerial surveys carried out between April 2021 and March 2023 encompassing the Morgan Array Area plus a 10 km buffer. Further information on the aerial surveys undertaken for the Morgan Generation Assets and the methodologies used to derive population estimates is provided in the Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement.

1.3.4.2 Model-based estimates using the Marine Renewables Strategic environmental assessment (MRSea) package were produced in order to predict numbers across the survey area alongside 95% confidence intervals to provide a level of uncertainty. Design based estimates for bird numbers and densities in each month were also generated and compared to the MRSea estimates to provide additional validation of the MRSea outputs and provide estimates for months where low raw abundances prevented the use of the MRSea model.

1.3.4.3 MRSea-based densities were used where available, otherwise design-based densities were used. The full methods and results of the digital aerial surveys are presented in Volume 4, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement.

1.3.4.4 Densities of birds in flight were generated by multiplying the densities of all behaviours within the Morgan Array Area (generated from MRSea or design-based) by the proportion of birds in flight. The proportion of birds in flight of each species was calculated for each month separately, across the entire survey area using the raw data. The proportion was calculated across the entire digital aerial survey area rather than just the Morgan Array Area to ensure the sample size was sufficient to generate a robust estimate of the proportion of birds in flight.

1.3.4.5 For example, if MRSea generated a density of 10 black-legged kittiwake per km^2 in the Morgan Array Area for all behaviours, and there were a total of 2,000 black-legged kittiwake in the raw data for the Morgan Array Area, 600 of which were in flight. The density of flying birds in the Morgan Array Area would then be calculated as 600/2000 * 10 = 3 kittiwake per km^2.

1.3.4.6 There were two density estimates for each calendar month as the digital aerial surveys spanned 24 monthly samples across two years. Under the assumption that overdispersion does not vary much among years, each of the two monthly estimates and confidence limits were averaged. This approach was taken as opposed to generating separate outputs for each aerial survey, because ultimately those outputs would need to be averaged to generate an average impact, resulting in the same outcome.

1.3.4.7 Following Natural England guidance, densities for gannet have been reduced by 70% to account for macro-avoidance behaviour exhibited by this species. This is to account for macro-avoidance not being incorporated into the calculation of avoidance rates presented in Table 1.3. Uncorrected density estimates for gannet are presented in Appendix A.

Table 1.5: Density estimates used for collision risk modelling.

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kittiwake	Mean	0.47	0.35	1.06	0.47	0.18	0.08	0.06	0.13	0.10	0.21	0.73	1.75
	LCL	0.33	0.22	0.73	0.34	0.06	0.01	0.00	0.04	0.07	0.12	0.51	1.34
	UCL	0.65	0.53	1.57	0.65	0.33	0.17	0.12	0.44	0.17	0.36	1.07	2.33
Great black-backed gull	Mean	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.08
	LCL	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	UCL	0.14	0.04	0.02	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.18
Herring gull	Mean	0.18	0.02	0.06	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.19
	LCL	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	UCL	0.35	0.05	0.11	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.47
Lesser black-backed gull	Mean	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
	LCL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	UCL	0.00	0.04	0.03	0.03	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Gannet	Mean	0.01	0.00	0.03	0.04	0.02	0.06	0.06	0.16	0.10	0.05	0.04	0.02
	LCL	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.15	0.21	0.02	0.01	0.00
	UCL	0.03	0.00	0.06	0.07	0.04	0.13	0.12	0.19	0.06	0.07	0.09	0.04
Manx shearwater	Mean	0.00	0.00	0.00	0.01	0.02	0.23	0.10	0.31	0.26	0.00	0.00	0.00
	LCL	0.00	0.00	0.00	0.05	0.00	0.69	0.50	0.93	0.66	0.00	0.00	0.00
	UCL	0.00	0.00	0.00	0.00	0.04	0.08	0.04	0.12	0.12	0.00	0.00	0.00

1.4 Results

1.4.1 Kittiwake

1.4.1.1 The predicted number of collisions for black-legged kittiwake are presented in Table 1.6. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.6: Predicted collisions for kittiwake associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	13.1	99.28	3.1	2.2	8.3	3.8	1.6	0.8	0.5	1.4	0.8	1.6	4.8	11.1	40.0
	8.71	99.79	0.7	0.5	1.9	0.9	0.4	0.2	0.1	0.3	0.2	0.4	1.1	2.6	9.4
		99.28	2.4	1.7	6.5	3.0	1.3	0.6	0.4	1.1	0.7	1.2	3.8	8.7	31.2
		99.40	2.0	1.5	5.4	2.5	1.1	0.5	0.3	0.9	0.5	1.0	3.2	7.3	26.2

1.4.2 Great black-backed gull

1.4.2.1 The monthly expected number of collisions for great black-backed gull are presented in Table 1.7. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.7: Predicted collisions for great black-backed gull associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	13.7	99.39	2.0	0.5	0.3	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	2.1	5.7
	9.8	99.91	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.7
		99.39	1.7	0.4	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.7	4.7
		99.70	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.8	2.3

1.4.3 Herring gull

1.4.3.1 The monthly expected number of collisions for herring gull are presented Table 1.8. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.8: Predicted collisions for herring gull associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	12.8	99.39	3.6	0.4	1.4	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.9	10.1
	9.8	99.52	2.5	0.3	1.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.6	6.8
		99.70	1.5	0.2	0.6	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.7	4.2
		99.39	3.2	0.3	1.2	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.4	8.7

1.4.4 Lesser black-backed gull

1.4.4.1 The monthly expected number of collisions for lesser black-backed gull are presented in Table 1.9. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.9: Predicted collisions for lesser black-backed gull associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	13.1	99.39	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.2
	9.8	99.54	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.8
		99.70	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.5
		99.39	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.1

1.4.5 Manx shearwater

1.4.5.1 The monthly expected number of collisions for Manx shearwater are presented in Table 1.10. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.10: Predicted collisions for Manx shearwater associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	11.46	99.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1.4.6 Gannet

1.4.6.1 The monthly expected number of collisions for northern gannet are presented Table 1.11. Confidence metrics associated with these estimates are presented in Appendix B.

Table 1.11: Predicted collisions for gannet associated with the Morgan Generation Assets.

Model Option	Flight speed (m/s)	Avoidance rate (%)	Collision risk estimates												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	14.9	99.28	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.2	0.1	0.1	0.0	1.5
	13.33	99.28	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.2	0.1	0.1	0.0	1.4

1.5 Consideration of uncertainty

1.5.1 Flight speeds

1.5.1.1 For the species that have been identified for inclusion in collision risk modelling, with the exception of Manx shearwater, there are essentially two alternative sources for bird flight speed. The first source being either Alerstam *et al.* (2007) or Pennycuick

(1987) with the second source being Skov *et al.* (2018). Natural England have previously raised concerns with the flight speed values estimated in Skov *et al.* (2018) (Natural England, 2018):

- *'Data was collected from a single site during the non-breeding season*
- *Flight speeds from Skov et al. (2018) are markedly lower than those from other published studies (e.g. Alerstam et al., 2007, Pennycuick, 1987)'.*

1.5.1.2 Alerstam *et al.* (2007) provides flight speed data collected using tracking radar measurements from five sites in southern Sweden and on two expeditions to the Arctic between 1979 and 1999. This dataset was supplemented with an extensive additional dataset again of tracking radar measurements of birds in migratory flight in Switzerland, Germany, Israel and Spain.

1.5.1.3 Pennycuick (1987) provides flight speed data estimated using an ornithodolite. Observations of birds were made during the breeding season on the island of Foula, Shetland specifically from the southern tip of the island where *'continuous streams of birds could usually be seen flying around the South Ness, between the main breeding areas on the western cliffs and feeding areas to the east'* (Pennycuick, 1987).

1.5.1.4 Skov *et al.* (2018) reports on data from the Offshore Renewables Joint Industry Programme (ORJIP) Bird Collision Avoidance (BCA) study. This study generated one of the most extensive datasets of observations of seabird behaviour in and around an operational offshore wind farm (Thanet Offshore Wind Farm, Kent, England). This includes species-specific data gathered throughout the year on flight speed which can inform the estimation of more realistic flux of birds through rotor swept areas.

1.5.1.5 A comparison of each of these sources for each species is provided in Table 1.12 in relation to sample size, location of studies, seasonality and location. The following sections discuss this information for each species.

Table 1.12: Comparison of data sources for bird flight speed.

Dataset feature	Species	Alerstam *et al.* (2007) / Pennycuick (1987)	Skov *et al.* (2018)
Sample size	Kittiwake	2 tracks	287 tracks
	Great black-backed gull	4 tracks	790 tracks
	Herring gull	18 tracks	
	Lesser black-backed gull	11 tracks	
	Gannet	32 observations	683 tracks
Location	Kittiwake	Northeast Passage	Thanet offshore wind farm, south North Sea, offshore of Kent, England
	Great black-backed gull	Sweden and the Arctic	
	Herring gull	Two tracks in the northeast Passage. Other tracks in Sweden and the Arctic	
	Lesser black-backed gull	Sweden and the Arctic	
	Gannet	Pennycuick: Foula, Shetland	
Seasonality	Kittiwake	July and August 1994 (Alerstam and Gudmundsson, 1999)	Fieldwork undertaken between July 2014 and April 2016 covering all months. The occurrence of
	Great black-backed gull	Unknown	

Dataset feature	Species	Alerstam *et al.* (2007) / Pennycuick (1987)	Skov *et al.* (2018)
	Herring gull	July and August 1994 (Alerstam and Gudmundsson, 1999)	each species on a monthly basis is discussed below
	Lesser black-backed gull	Mainly during the autumn (August to October) and spring (March to May) migration periods and also some in the winter (November and February). Migratory flights	
	Gannet	Pennycuick: 28 June to 9 July 1986	

Kittiwake

1.5.1.6 The study with the largest sample size for kittiwake was the ORJIP BCA study (Skov *et al.* 2018) with a sample size of 287 tracks compared to two tracks in Alerstam *et al.* (2007). The flight speed data used by Alerstam *et al.* (2007) to estimate flight speeds for kittiwake was collected in the Northeast Passage an area of sea between the Atlantic and Pacific oceans along the Arctic coasts of Norway and Russia in July and August. Kittiwake do breed in various places in the northeast passage but due to the limited number of kittiwake detected it is likely that radar observation sites were not located near to a breeding colony. The Skov *et al.* (2018) data was collected at the Thanet offshore wind farm which is within the foraging range of kittiwake (mean-maximum and mean-maximum plus one standard deviation; Woodward *et al.,* 2019) from a number of breeding colonies, albeit colonies consisting of fewer than 1,000 birds. Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of datapoints for kittiwake presented in Figure 1.1. The kittiwake breeding season runs from March to August (full UK breeding season) with a migration-free breeding season running from May to July. The limited number of breeding birds in close proximity to the Thanet offshore wind farm is reflected in the distribution of datapoints. However, there are still more datapoints in both the migration-free and full UK breeding season than in the Alerstam *et al.* (2007) study.

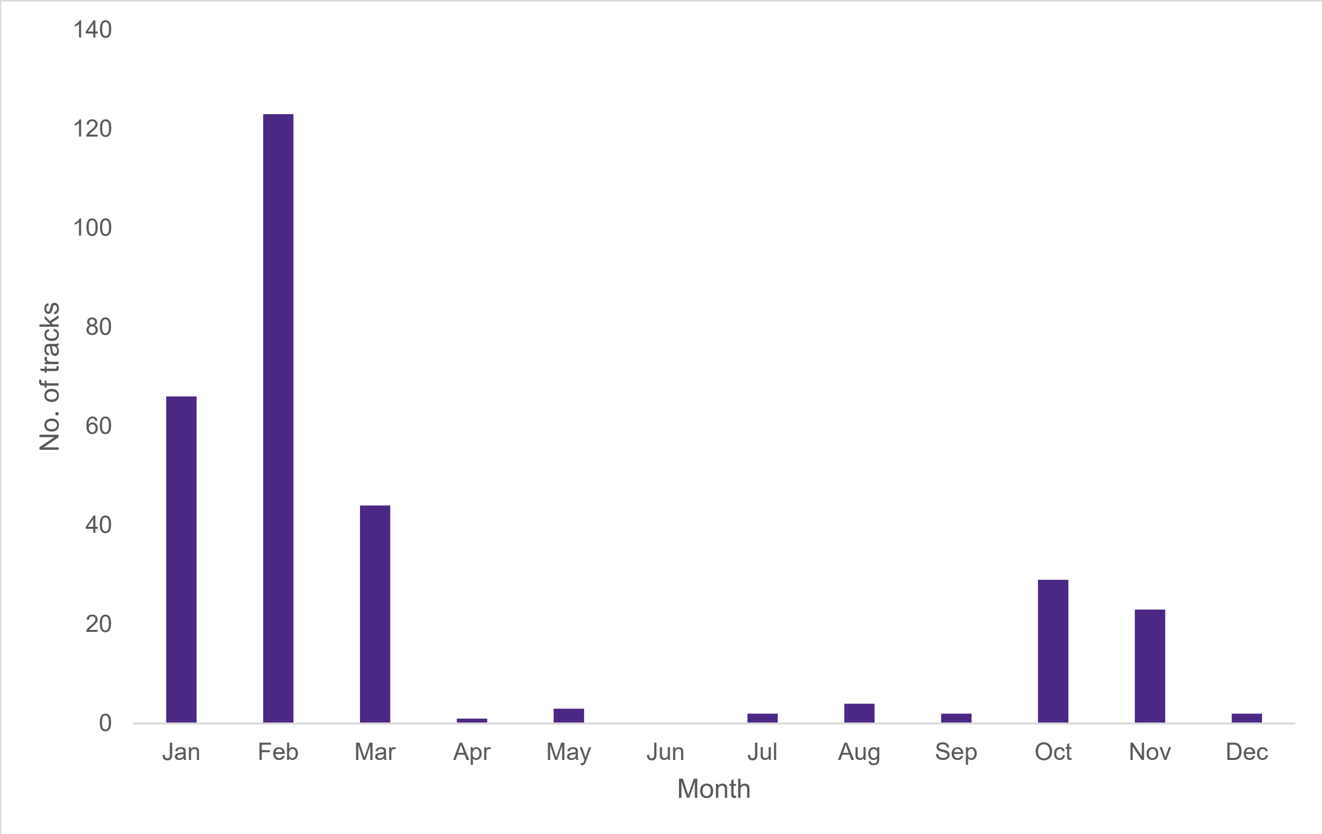

Figure 1.2: Number of kittiwake tracks in each month from Skov *et al.* (2018).

1.5.1.7 A thorough review of studies, that provided flight speed estimates for kittiwake, was undertaken by Royal HaskoningDHV (2020) which determined a range of flight speeds of 7.26 to 15.9 m/s. Of the studies reviewed all had sample sizes of less than 20 birds, except Skov *et al.* (2018) and Elliott *et al.* (2014; both in terms of the number of tracks) with all providing limited coverage of the annual cycle of kittiwake. In addition, the techniques used to estimate flight speed differ between the studies. Techniques included ornithodolite, tracking radar, seawatch timing, GPS transmitters, laser rangefinder and car speedometer. Royal HaskoningDHV (2020) suggests that kittiwake exhibit an average flight speed of 10.8 m/s. However, this average does not take account of the limitations or the sample size associated with each study.

1.5.1.8 Royal HaskoningDHV (2020) also highlights that the Band (2012) CRM requires that the flight speed input reflects the ground speed of birds and not the air speed. The flight speed value from Alerstam *et al.* (2007) refers to air speed and is therefore not suitable for use in collision risk modelling undertaken using the Band (2012) CRM.

1.5.1.9 Two studies that provide flight speed data in the breeding season are Kotzerka *et al.* (2010) and Elliott *et al.* (2014). These studies estimated flight speed values of 9.2 m/s and 10.6 m/s respectively. Both studies were conducted at the same breeding colony (Middleton Island, Alaska) using GPS data loggers with the Elliot *et al.* (2014) study also using accelerometers. Kotzerka *et al.* (2010) collected data from 14 birds between 01 July and 11 August 2007. Elliot *et al.* (2014) collected data from 10 incubating birds (30 May to 16 June 2013). The flight speeds estimated from these two studies provide flight speed values closer to that estimated by Skov *et al.* (2018) compared to Alerstam *et al.* (2007).

1.5.1.10 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for kittiwake is the value presented by Skov *et al.*

(2018) with this value supported by a larger sample size collected across all seasons than the value presented by Alerstam *et al.* (2007). The data associated with Skov *et al.* (2018) were also collected in UK waters in an area of sea that is considered similar to that in which the Morgan Generation Assets are located (i.e. not close to large breeding colonies). The value presented by Alerstam *et al.* (2007) is not considered representative of the flight speed of kittiwake due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling.

Great black-backed gull

1.5.1.11 Skov *et al.* (2018) provides a single flight speed for large gull species. This value has an associated sample size of 790 tracks. This is considerably larger than the sample size associated with the flight speed value from Alerstam *et al.* (2007) which is comprised of four tracks for herring gull and only 33 tracks if the flight speed values for lesser black-backed gull, herring gull and great black-backed gull were combined. The flight speed data used by Alerstam *et al.* (2007) to estimate flight speeds for great black-backed gull is based on birds observed in Sweden and the Arctic and it is not known when during the annual cycle these tracks were observed. The Skov *et al.* (2018) dataset was collected at the Thanet Offshore Wind Farm which is not within the foraging range of great black-backed gull from any significant breeding colonies.

1.5.1.12 Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of datapoints for all three large gulls (both individually and combined) presented in Figure 1.3. The great black-backed gull breeding season runs from late March to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore datapoints across all seasons relevant to great black-backed gull, albeit with fewer datapoints during the migration-free breeding season but still more than that included in Alerstam *et al.* (2007) dataset. However, a dataset comprising mainly of datapoints in the non-breeding season will likely reflect the behaviour of great black-backed gull at the Morgan Generation Assets more accurately (if indeed a difference between seasons exists) with few breeding colonies in close proximity to the Morgan Generation Assets.

1.5.1.13 Another study that investigated flight speeds of great black-backed gull was by Gyimesi *et al.* (2017). This study reports results from two GPS transmitter studies, the first from three great black-backed gulls tagged on Swedish Islands in the Baltic Sea (including a single bird migrating to the UK) and the second from five great black-backed gulls tagged in the Kattegat. The first of these datasets estimated a flight speed of 12.1 to 12.5 m/s with the second predicting a flight speed of 10.3 to 10.8 m/s. The studies reviewed by Gyimesi *et al.* (2017) comprised low sample sizes with at least some of the data from the breeding season, potentially limiting comparability with Skov *et al.* (2018). In addition, a recent study suggests that great black-backed gulls are adversely affected when tagged (Lopez *et al.,* 2023) and although this observation is based on breeding success (and mortality in one case) it is possible that this may also influence other behaviours.

1.5.1.14 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for great black-backed gull is the value presented by Skov *et al.* (2018) with this value supported by a larger sample size collected across all seaons than the value presented by Alerstam *et al.* (2007). The data associated with Skov *et al.* (2018) were also collected in UK waters in an area of sea that is considered similar to that in which the Morgan Generation Assets are located (i.e. not close to large breeding colonies) and more is known about the methodology employed to capture flight speed data. The value presented by Alerstam *et al.* (2007) is not considered representative of the flight speed of great black-backed gull due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling.

Herring gull

1.5.1.15 Skov *et al.* (2018) provides a single flight speed for large gull species. This value has an associated sample size of 790 tracks. This is considerably larger compared to the sample size associated with the flight speed value from Alerstam *et al.* (2007) of 18 tracks for herring gull and only 33 tracks if the flight speed values for lesser black-backed gull, herring gull and great black-backed gull were combined. The data used by Alerstam *et al.* (2007) to estimate flight speeds for herring gull is based on birds observed in Sweden and the Arctic. Two tracks were obtained during the breeding season (Alerstam and Gudmundsson, 1999) but it is not known when the remaining tracks were observed. The Skov *et al.* (2018) dataset was collected at the Thanet Offshore Wind Farm which is within the foraging range of herring gull (mean-maximum plus one standard deviation; Woodward *et al.,* 2019) from a number of breeding colonies, including one of considerable significance for the species (Havergate Island).

1.5.1.16 Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of datapoints for all three large gulls (both individually and combined) presented in Figure 1.3. The herring gull breeding season runs from March to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore datapoints across all seasons relevant to herring gull.

1.5.1.17 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for herring gull is the value presented by Skov *et al.* (2018) with this value supported by a larger sample size collected across all seaons than the value presented by Alerstam *et al.* (2007). The data associated with Skov *et al.* (2018) were also collected in UK waters in an area of sea that is considered similar to that in which the Morgan Generation Assets are located (i.e. not close to large breeding colonies) and more is known about the methodology employed to capture flight speed data. The value presented by Alerstam *et al.* (2007) is not considered representative of the flight speed of herring gull due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling.

Lesser black-backed gull

1.5.1.18 Skov *et al.* (2018) provides a single flight speed for large gull species. This value has an associated sample size of 790 tracks. This is considerably larger compared to the sample size associated with the flight speed value from Alerstam *et al.* (2007) of 11 tracks for lesser black-backed gull and only 33 tracks if the flight speed values for lesser black-backed gull, herring gull and great black-backed gull were combined. The data used by Alerstam *et al.* (2007) to estimate flight speeds for lesser black-backed gull was collected from birds observed in Sweden and the Arctic, presumably in the breeding season, based on the migratory movements of lesser black-backed gull, although this is not stated in Alerstam *et al.* (2007). The Skov *et al.* (2018) dataset was collected at the Thanet Offshore Wind Farm which is within the foraging range of lesser black-backed gull (mean-maximum; Woodward *et al.,* 2019) from a number of breeding colonies, including one of considerable significance for the species (Havergate Island).

1.5.1.19 Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of datapoints for all three large gulls (both individually and combined) presented in Figure 1.3. The lesser black-backed gull breeding season runs from April to August (full UK breeding season) with a migration-free breeding season running from May to July. There are therefore datapoints across all seasons relevant to lesser black-backed gull, with fewer in winter months due many birds leaving UK waters, and more data in the breeding season compared to the Alerstam *et al.* (2007) study.

1.5.1.20 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for lesser black-backed gull is the value presented by Skov *et al.* (2018) with this value supported by a larger sample size collected across all seaons than the value presented by Alerstam *et al.* (2007). The data associated with Skov *et al.* (2018) were also collected in UK waters in an area of sea that is considered similar to that in which the Morgan Generation Assets are located (i.e. not close to large breeding colonies) and more is known about the methodology employed to capture flight speed data. The value presented by Alerstam *et al.* (2007) is not considered representative of the flight speed of lesser black-backed gull due to the limited sample size and restricted seasonal coverage and it is therefore considered that it should not be used for collision risk modelling. No tracks were recorded in June.

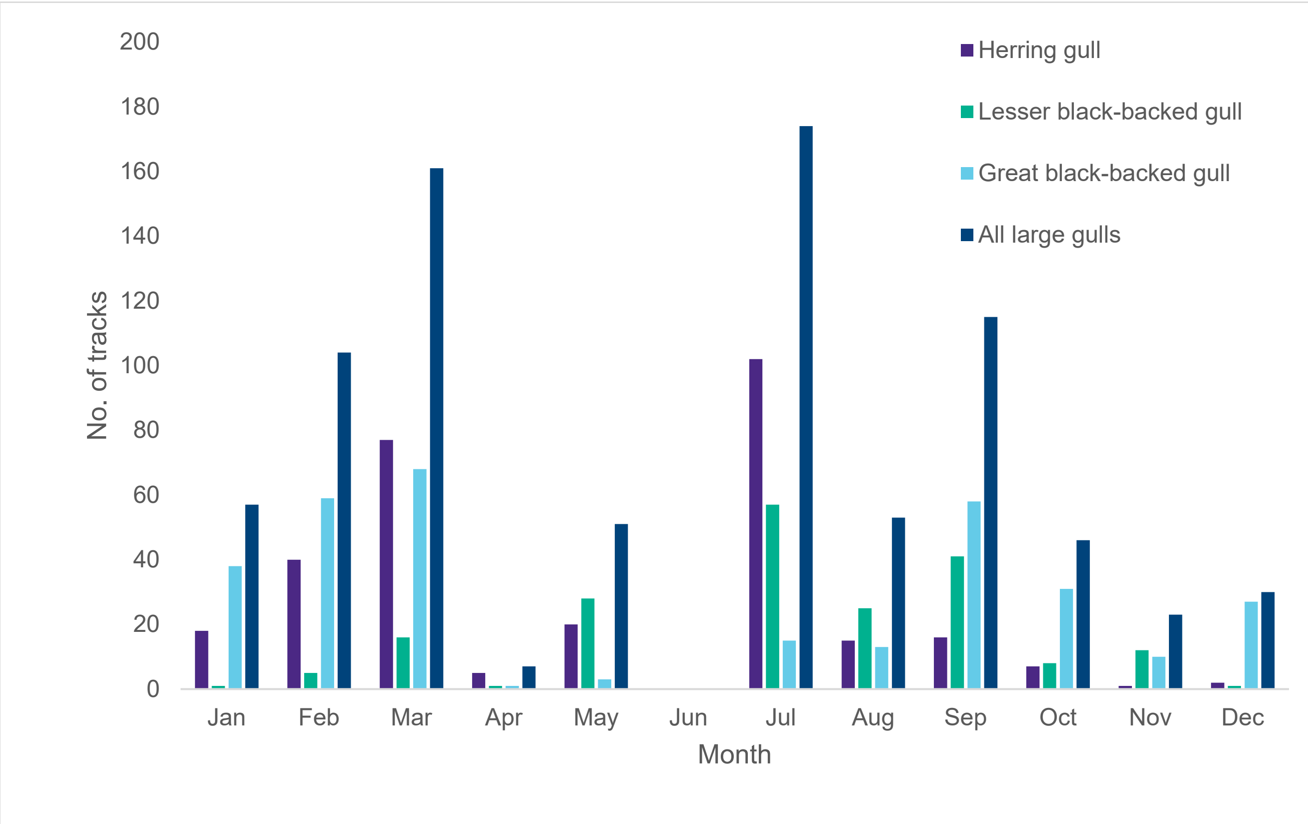

Figure 1.3: Number of large gull tracks in each month from Skov *et al.* (2018).

1.5.1.21 Another study that investigated flight speeds of lesser black-backed gull was by Klaassen *et al.* (2012), which provides a flight speed on 10.7 m/s. Eight birds were fitted with GPS transmitters with data available between 31 May 2007 and 1 June 2008, with a focus on migratory periods. The flight speed value estimated by Klaassen *et al.* (2012), is closer to that estimated by Skov *et al.* (2018) than the value estimated by Alerstam *et al.* (2007) and is also considered to be supported by more robust data than the flight speed estimated by Alerstam *et al.* (2007).

Gannet

1.5.1.22 The study with the largest sample size for flight speed for gannet is the ORJIP BCA study (Skov *et al.,* 2018) with a sample size of 683 tracks compared to 32 observations in Pennycuick (1987). The flight speed data collected by Pennycuick was collected on the island of Foula, Shetland, close to a breeding colony of gannet during the breeding season. Therefore, this dataset does not provide any flight speed data relevant to gannet in non-breeding seasons. In addition, the data collected may be confounded due to the proximity of the breeding colony with birds flying at different speeds, perhaps due to being on approach or having just left the colony The Skov *et al.* (2018) data was collected at the Thanet offshore wind farm which, although not located close to a breeding colony is within the foraging range (mean-maximum plus one standard deviation which is used to identify connectivity for the purposes of Habitat Regulations Assessment screening) of gannet (Woodward *et al.,* 2019) of a breeding colony. Fieldwork associated with Skov *et al.* (2018) was conducted across two years with the monthly distribution of datapoints for gannet presented in Figure 1.1. The gannet breeding season runs from March to September (full UK breeding season) with a migration-free breeding season running from April to August. Therefore, there are datapoints across all seasons relevant to gannet with more in the breeding season than in the Pennycuick (1987) study. No tracks were recorded in June.

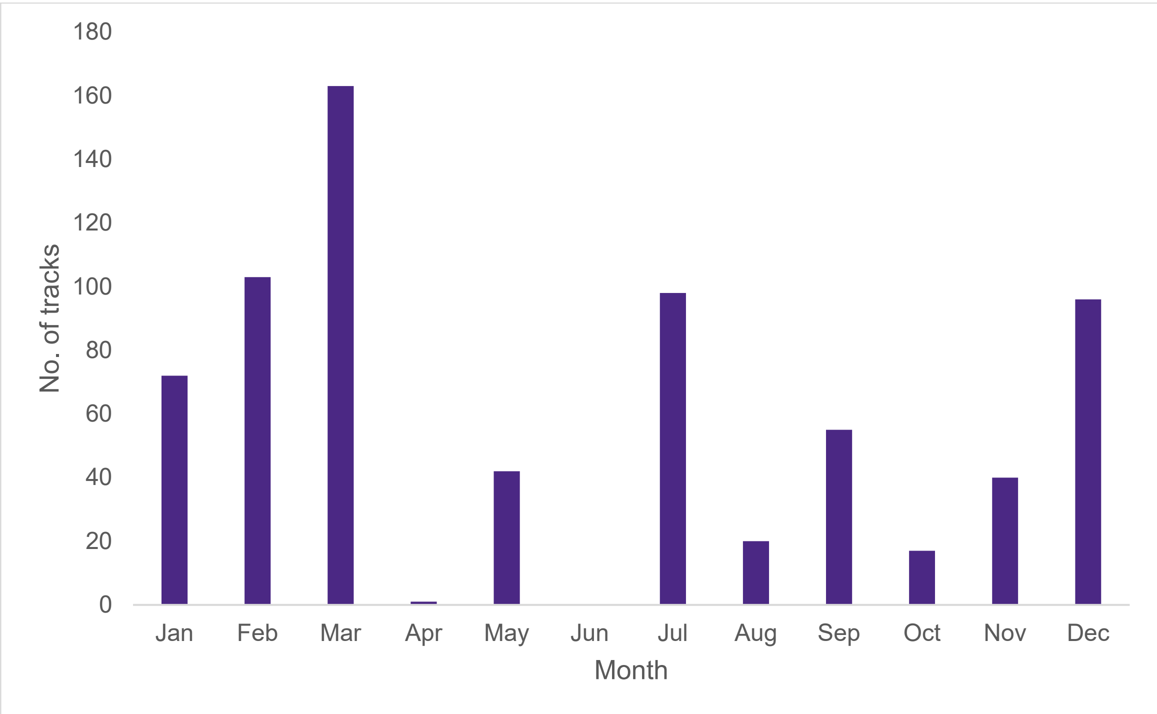

Figure 1.4: Number of gannet tracks in each month from Skov *et al.* (2018).

1.5.1.23 Another study that investigated flight speed of gannet, Pettex *et al.,* (2012) estimated a flight speed of 13.5 m/s. This study deployed GPS data loggers on breeding gannet. This study therefore has the same limitations as Pennycuick (1987) providing data in the breeding season only, however, does provide a much larger dataset (341 foraging trips undertaken by 101 birds). This value, despite the associated limitations albeit with a larger sample size than Pennycuick (1987), is closer to that estimated by Skov *et al.* (2018) than the value estimated by Penncuick (1987).

1.5.1.24 Based on the evidence presented above it is considered that the best available evidence in relation to flight speed for gannet is the value presented by Skov *et al.* (2018) with this value supported by a larger sample size collected across all seaons than the value presented by Pennycuick (1987). The data associated with Skov *et al.* (2018) were also collected in UK waters in an area of sea that is considered similar to that in which the Morgan Generation Assets are located (i.e. not close to large breeding colonies). The value from Skov *et al.* (2018) also reflects the behaviour of gannet throughout the annual cycle and not the behaviour of birds close to a breeding colony as in Pennycuick (1987). The value presented by Pennycuick (1987) is not considered representative of the flight speed of gannet due to the limited sample size, restricted seasonal coverage and the location of the study which is biased towards birds at a breeding colony it is therefore considered that it should not be used for collision risk modelling.

Other considerations

1.5.1.25 A sample size of 100 birds is considered adequate to provide a representative value for use in collision risk modelling for the proportion of birds at collision height (Natural England, 2013). A robust sample size has not been defined for bird flight speed, mainly as data for this parameter are not collected on a site-specific basis. However, as flight speed is an in-flight behaviour similar to flight-height, it is considered reasonable to apply this 100-bird threshold to the derivation of flight speed values. If this were to be applied, then only the flight speed from Skov *et al.* (2018) would reach this threshold and be considered representative of flight speed behaviour.

Conclusion

1.5.1.26 In order to ensure assessments are presented that align with Statutory Nature Conservation Bodies advice, collision risk estimates calculated using the flight speed values recommended by these organisations will form part of the assessment. However, it is considered that these values do not fully represent the best available evidence for any of the species for which collision risk modelling is required. It has previously been suggested that the values from Alerstam *et al.* (2007) and Pennycuick (1987) are precautionary, however, based on the information presented here it is considered that the flight speed values from Alerstam *et al.* (2007) and Pennycuick (1987) are not representative of the flight speed behaviour of the species for which CRM is required. Modelling conducted utilising these values will therefore provide collision risk estimates that are not accurate and do not represent the likely impact from the Morgan Generation Assets. Any assessments based on these values will therefore have a high level of associated uncertainty.

1.5.2 Avoidance rates

1.5.2.1 The most recent review of avoidance rates for use in the Band (2012) CRM is provided by Ozsanlav-Harris *et al.* (2023). The avoidance rates associated with this review are provided in Table 1.3. Ozsanlav-Harris *et al.* (2023) identifies a key limitation in relation to the use of the these avoidance rates in the Band (2012) CRM:

- The data is still primarily collected at onshore and coastal sites with very little offshore data therefore these avoidance rates may not fully capture the offshore behaviour of seabirds.

1.5.2.2 As stated in Oszanlav-Harris *et al.* (2023), behaviour of birds offshore and onshore can differ affecting flight height distributions. To provide a comparison with avoidance rates calculated using offshore data, those presented in Bowgen and Cook (2018) have also been applied in modelling. Bowgen and Cook (2018) used data from the ORJIP BCA study (Skov *et al.,* 2018) and therefore represent avoidance rates calculated using data in the offshore environment only. Limitations are highlighted with these avoidance rates, however these create no more uncertainty than that associated with the avoidance rates from other studies. Assessments presented in the Volume 2, Chapter 15: Offshore ornithology of the Environmental Statement and the Information to Support Appropriate Assessment (ISAA) (Document Reference E1) will therefore take due account of all available evidence to determine the magnitude of effect for relevant species at the Morgan Generation Assets.

1.5.2.3 The research conducted by Ozsanlav-Harris et al. (2023) reviews the approach to calculate the avoidance rate of specific species and groupings, comparing this to the approach by Cook (2021). The Ozsanlav-Harris et al. (2023) dataset (Table 1.13) contains information on collision data from 23 monitoring reports of 19 wind farms (including one offshore), encompassing 11 species or species groups spanning the years 2000 to 2019. Cook (2021) suggests that a minimum of 10 sites may be used as an arbitrary threshold sample size to inform the selection of species-specific avoidance rates over group-specific estimates. The species-specific rates calculated for all species in Table 1.13 reaches this threshold for all species except kittiwake. However, the EWG has recommended that the all gull rate be used for kittiwake. The all gull rate is calculated using data from all species of gull and may therefore not reflect the behaviour of kittiwake, a much more marine-based species, that all other gulls for which data is available.

1.5.2.4 Using the grouped species avoidance rates result in higher predicted collision mortalities. However, as species-specific rates are calculated from robust analysis, it is considered that the species-specific rate, specifically for herring gull, lesser black-backed gull and great black-backed gull, represents the best available evidence for use in collision risk modelling. The species-specific rates create no more uncertainty than that associated with the grouped avoidance rates, which incorporate data from species that although superficially similar, may exhibit differences in flight behaviour that can affect avoidance behaviour. This is illustrated by the differences in species-specific avoidance rates for the three species of large gull. For kittiwake, it is considered appropriate to present collision risk estimates calculated applying both the all gull rate and species-specific rate. By doing so the assessments will capture the uncertainty with both the all gull rate, which is calculated based on data from species that exhibit different flight behaviour than the more marine-based kittiwake and the species-specific rate for kittiwake which has a lower associated sample size than suggested as being appropriate for a robust rate.

1.5.2.5 Uncertainty associated with all avoidance rates, and especially species-specific rates, is captured as part of the modelling process through the use of the stochastic collision risk model and standard deviation values.

Table 1.13: Species-specific Avoidance Rates from Ozsanlav-Harris et al. (2022). AR presented as a median rate (standard deviation; 95% confidence interval). Sample size presented as number of report-years and number of bird flights through turbine rotor-swept area contributing data to calculate avoidance rate from CRM.

Species/species group	Basic sCRM AR	Sample size (no. of report years contributing data to avoidance rate calculation)
Kittiwake	0.9979 (0.0013; 0.9955 – 0.9993)	3
Black-headed gull	0.9923 (0.0005; 0.9913 – 0.9931)	28
Herring gull	0.9952 (0.0003; 0.9946 – 0.9958)	26
Lesser black-backed gull	0.9954 (0.0003; 0.9946 – 0.996)	21
Great black-backed gull	0.9991 (0.0002; 0.9987 – 0.9994)	10
Gull	0.9928 (0.0003; 0.9921 – 0.9934)	36
Large gull	0.9939 (0.0004; 0.9931 – 0.9947)	31
Small gull	0.9949 (0.0002; 0.9944 – 0.9954)	29
Gulls & terns	0.9907 (0.0004; 0.9899 – 0.9914)	38

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Appendix A: Uncorrected density estimates for gannet

Table A.1: Uncorrected density estimates for gannet.

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gannet	Mean	0.01	0.00	0.03	0.04	0.02	0.06	0.06	0.16	0.10	0.05	0.04	0.02
	LCL	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.15	0.21	0.02	0.01	0.00
	UCL	0.03	0.00	0.06	0.07	0.04	0.13	0.12	0.19	0.06	0.07	0.09	0.04

Appendix B: Confidence metrics associated with collision risk estimates

B.1 Kittiwake

Table B.1: Collision risk estimates for kittiwake including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2			mean	3.1	2.2	8.3	3.8	1.6	0.8	0.5	1.4	0.8	1.6	4.8	11.1	40.0
			sd	0.8	0.7	2.3	0.9	0.7	0.4	0.3	1.0	0.3	0.6	1.3	2.5	11.7
	13.1	99.28	median	3.0	2.1	8.1	3.7	1.6	0.7	0.5	1.1	0.8	1.5	4.7	11.0	38.8
			pctl_2.5	1.8	1.2	4.7	2.2	0.5	0.1	0.0	0.3	0.4	0.7	2.7	7.0	21.7
			pctl_97.5	4.7	3.7	13.2	5.8	3.1	1.5	1.1	3.7	1.4	2.7	7.5	16.5	64.9
			mean	2.4	1.7	6.5	3.0	1.3	0.6	0.4	1.1	0.7	1.2	3.8	8.7	31.2
			sd	0.8	0.6	2.1	0.9	0.6	0.3	0.3	0.8	0.2	0.5	1.3	2.5	11.1
		99.28	median	2.2	1.6	6.1	2.8	1.2	0.6	0.4	0.8	0.6	1.1	3.6	8.3	29.4
			pctl_2.5	1.3	0.8	3.4	1.6	0.4	0.1	0.0	0.2	0.3	0.5	1.9	4.8	15.2
			pctl_97.5	4.3	3.1	11.6	5.3	2.7	1.3	0.9	3.1	1.2	2.4	6.9	14.1	57.0
			mean	0.7	0.5	1.9	0.9	0.4	0.2	0.1	0.3	0.2	0.4	1.1	2.6	9.4
	8.71		sd	0.5	0.4	1.5	0.6	0.3	0.2	0.1	0.4	0.1	0.3	0.9	1.9	7.2
		99.79	median	0.6	0.4	1.6	0.7	0.3	0.1	0.1	0.2	0.2	0.3	0.9	2.2	7.6
			pctl_2.5	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.3
			pctl_97.5	2.1	1.5	5.7	2.5	1.3	0.6	0.4	1.3	0.6	1.1	3.4	7.5	28.0
			mean	2.0	1.5	5.4	2.5	1.1	0.5	0.3	0.9	0.5	1.0	3.2	7.3	26.2
		99.4	sd	0.6	0.5	1.8	0.8	0.5	0.3	0.2	0.7	0.2	0.4	1.1	2.1	9.2
			median	1.9	1.4	5.2	2.3	1.0	0.5	0.3	0.7	0.5	1.0	3.0	7.0	24.6

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
			pctl_2.5	1.1	0.7	2.8	1.3	0.3	0.1	0.0	0.2	0.3	0.4	1.6	3.9	12.7
			pctl_97.5	3.5	2.6	9.6	4.2	2.4	1.1	0.8	2.5	1.0	1.9	5.6	12.1	47.3

B.2 Great black-backed gull

Table B.2: Collision risk estimates for great black-backed gull including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	13.7	99.39	mean	2.0	0.5	0.3	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	2.1	5.7
			sd	1.0	0.3	0.2	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.3	3.4
			median	2.0	0.5	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.9	5.3
			pctl_2.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8
			pctl_97.5	4.0	1.0	0.8	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	4.8	12.8
	9.8	99.39	mean	1.7	0.4	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.7	4.7
			sd	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.1	2.9
			median	1.6	0.4	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	1.6	4.3
			pctl_2.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6
			pctl_97.5	3.7	0.9	0.7	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	4.1	11.2
		99.91	mean	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.7
			sd	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.5
			median	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.6
			pctl_2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
			pctl_97.5	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.7	1.8
		99.7	mean	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.8	2.3
			sd	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.5	1.5
			median	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.8	2.1
			pctl_2.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
			pctl_97.5	1.8	0.4	0.3	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	1.9	5.4

B.3 Herring gull

Table B.3: Collision risk estimates for herring gull including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	12.8	99.39	mean	3.6	0.4	1.4	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.9	10.1
			sd	2.0	0.3	0.7	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.8	6.3
			median	3.4	0.4	1.4	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	3.5	9.2
			pctl_2.5	0.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.6
			pctl_97.5	8.1	1.0	3.0	0.6	0.0	0.0	0.0	1.2	0.0	0.0	0.0	10.1	24.0
	9.8	99.39	mean	3.2	0.3	1.2	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.4	8.7
			sd	1.9	0.2	0.6	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.4	5.6
			median	2.8	0.3	1.1	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	3.0	7.7
			pctl_2.5	0.7	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3
			pctl_97.5	7.3	0.8	2.7	0.6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	8.7	21.2
		99.52	mean	2.5	0.3	1.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.6	6.8
			sd	1.5	0.2	0.5	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.9	4.4
			median	2.2	0.2	0.9	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	2.4	6.0
			pctl_2.5	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0
			pctl_97.5	5.8	0.7	2.1	0.5	0.0	0.0	0.0	0.8	0.0	0.0	0.0	6.9	16.6
		99.7	mean	1.5	0.2	0.6	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.7	4.2
			sd	0.9	0.1	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.2	2.7
			median	1.4	0.1	0.6	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.4	3.7
			pctl_2.5	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
			pctl_97.5	3.6	0.4	1.3	0.3	0.0	0.0	0.0	0.5	0.0	0.0	0.0	4.4	10.5

B.4 Lesser black-backed gull

Table B.4: Collision risk estimates for lesser black-backed gull including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	13.1	99.39	mean	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.2
			sd	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.0
			median	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.0
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			pctl_97.5	0.0	0.8	0.9	0.9	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	3.7
	9.8	99.39	mean	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.1
			sd	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.9
			median	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.9
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			pctl_97.5	0.0	0.8	0.8	0.8	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	3.4
		99.54	mean	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.8
			sd	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.7
			median	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.6
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			pctl_97.5	0.0	0.6	0.6	0.6	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	2.6
		99.7	mean	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.5
			sd	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4
			median	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
			pctl_97.5	0.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.6

B.5 Gannet

Table B.5: Collision risk estimates for gannet including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	14.9	99.28	mean	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.2	0.1	0.1	0.0	1.5
			sd	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.1	0.0	1.0
			median	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.4	0.2	0.1	0.0	0.0	1.2
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.3
			pctl_97.5	0.1	0.0	0.2	0.2	0.2	0.6	0.5	0.9	0.6	0.2	0.2	0.1	3.7
	13.33	99.28	mean	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.2	0.1	0.1	0.0	1.4
			sd	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.1	0.0	1.0
			median	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.4	0.2	0.1	0.0	0.0	1.1
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2
			pctl_97.5	0.1	0.0	0.2	0.2	0.2	0.5	0.5	0.9	0.6	0.2	0.2	0.1	3.7

B.6 Manx shearwater

Table B.6: Collision risk estimates for Manx shearwater including confidence metrics.

Model option	Flight speed (m/s)	Avoidance rate (%)	Confidence metric	Collision risk estimates												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2	11.46	99.07	mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			sd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			pctl_2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			pctl_97.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0