MONA OFFSHORE WIND PROJECT

Environmental Statement

Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report

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Glossary

Term	Meaning
Air gap	The gap between the mean sea level and the lowest point of a wind turbine rotor blade.
Avoidance	Probability that a bird takes successful evasive action to avoid collision with a wind turbine.
Biologically Defined Minimum Population Scales	Seasonal subdivision of bird population size. The rationale behind these subdivisions is that the likely origin of a bird in a particular location depends on the time of year.
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.
Deterministic model	Model where a single value for each input parameter that goes into the model is used, leading to a single output without variation.
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	The wind farm design scenario that is considered the worst case from the perspective of collision risk.
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 1.4 and Table 1.5.
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
BDMPS	Biologically Defined Minimum Population Scale
CRM	Collision Risk Model
DAS	Digital Aerial Survey
EIA	Environmental Impact Assessment
JNCC	Joint Nature ~~Coservation~~Conservation Committee (JNCC)
LAT	Lowest Astronomical Tide
LCI/UCI	Lower/Upper Confidence Interval

Term	Meaning
LiDAR	Light Detection And Ranging
MDS	Maximum Design Scenario
MMO	Marine Management Organisation
MSL	Mean Sea Level
NAF	Nocturnal Activity Factor
NRW	Natural Resources Wales
PDE	Project Design Envelope
RPM	Rotations Per Minute
(s)CRM	(stochastic) Collision Risk Model
SNCB	Statutory Nature Conservation Body
SPA	Special Protection Area

Units

Unit	Description
km	Kilometres
m/s	Metres per second
m	Metres

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1 Offshore ornithology seabird collision risk modelling

1.1 Introduction

1.1.1 Background

1.1.1.1 During the operations and maintenance phase of the Mona Offshore Wind Project, 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 and Wade, 2012; 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. shearwater and petrel), although there is no evidence available to quantify that 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.

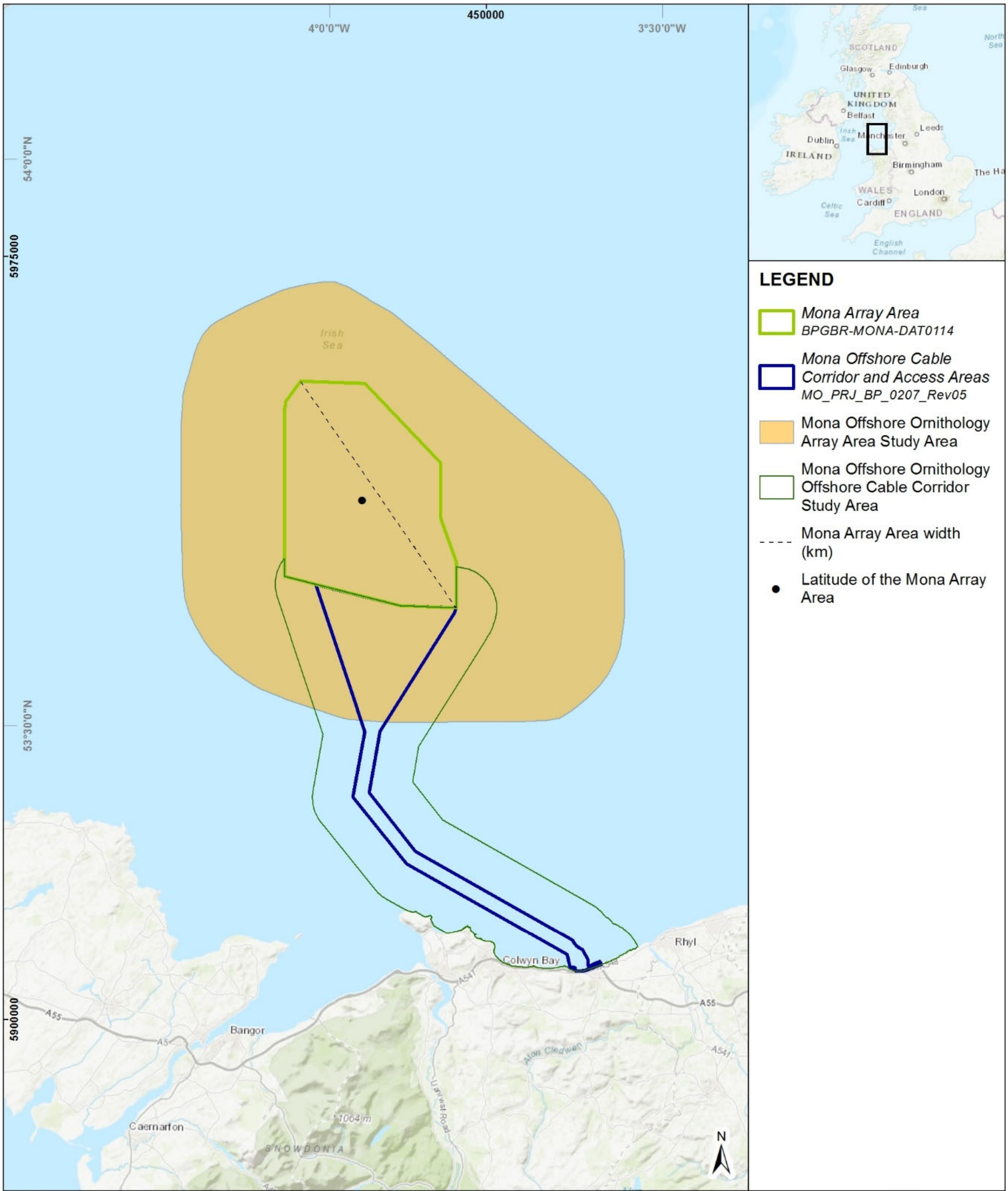
1.1.1.4 In general, the effects of increased mortality on populations due to collisions with turbines are considered to be long-term (i.e. throughout the operational wind farm's lifespan) and it is assumed that in the model, collision rate does not decrease in response to losses in the population. In 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 describes the methods and modelling parameters used to quantify the potential collision risk to seabirds as a result of the Mona Offshore Wind Project using baseline data from the digital aerial surveys described in Volume 6, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement (Document reference F6.5.1). The report considers the most abundant seabird species recorded during the digital aerial surveys carried out between March 2020 and February 2022.

1.1.3 Study area

1.1.3.1 The Mona Array Area (i.e. the area within which the offshore wind turbines will be located) is located 28.2 km from the Anglesey coastline, 46.9 km from the northwest coast of England and 46.6 km from the Isle of Man (when measured from Mean High Water Springs (MHWS)). The Mona Array Area covers an area of 300 km^2. The Mona Offshore Ornithology Array Area Study Area can be seen in Figure 1.1.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community	**Data Sources:** Client	
Project Name: MONA OFFSHORE WIND PROJECT	0 2.5 5 nm 0 5 10 km	**Drawing Number:** RPSE-MN-ES-ORN-006-00
Drawing Title: OFFSHORE ORNITHOLOGY CRM STUDY AREA.	**Geodetic Information:** Datum: ETRS 1989 Projection: ETRS 1989 UTM Zone 30N Scale@160mmx220mm: 1:630,541	

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Figure 1.1: Mona Offshore Ornithology Array Area study area, Mona Array Area used for the collision risk modelling and Mona Offshore Ornithology Offshore Cable Corridor study area.

1.2 Consultation

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

1.2.2 Evidence Plan process

1.2.2.1 The purpose of the Evidence Plan process is to agree the information the Mona Offshore Wind Project needs to supply to the Secretary of State, as part of a DCO application for the Mona Offshore Wind Project. The Evidence Plan seeks to ensure compliance with EIA. 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 Resources Wales (NRW), Natural England, the Joint Nature ~~C~~Conservation ~~C~~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) process during the pre-application stage of the Mona Offshore Wind Project, 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 the collision risk technical report of the Environmental Statement.

Table 1.1: Summary of key topics and issues raised during consultation activities undertaken for the Mona Offshore Wind Project relevant to offshore ornithology collision risk modelling technical report of the Environmental Statement.

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
May 2022	**Scoping Opinion** NRW	NRW are not yet satisfied that flight height calculations based on digital aerial survey data are accurate, so generic flight heights from Johnston *et al.,* (2014) should also be used in assessing collision risk	Generic flight height data from Johnston *et al.,* (2014) were used in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3) as site-specific data collected was deemed not to be suitable.
June 2022	**Scoping Opinion** The planning Inspectorate	The Environmental Statement should confirm the approach taken and also consider use of generic flight heights agreed with the EWG where possible	
	Scoping Opinion Natural England	A revised approach that accounts for macro-avoidance behaviour of gannet by reducing the densities for that species to be considered in the Collision Risk Model (CRM) is likely to be recommended. The most appropriate approach for CRM needs to be agreed by the EWG.	Advice was considered in the producing Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3).
July 2022	**Offshore Ornithology Expert Working Group 2** **Attended by:** Natural England, JNCC, NRW, RSPB, TWT	Agreed on the approach to stochastic Collision Risk Model (sCRM)	Approach to the (sCRM) is presented in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3).
July to August 2022	NRW, JNCC and Natural England	Recommended the use of the sCRM for the basic Band model (i.e. Options 1 and 2).	Collision risk modelling was undertaken using the sCRM developed by Marine Scotland (McGregor et al.,2018) and the results are presented

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
	– collision technical paper provided and agreed as part of the Offshore Ornithology Expert Working Group 2.	Advised 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.	in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3).
June 2023	**S42 Consultation** NRW	How model-based abundance estimates of birds in flight only have been generated for use in collision risk modelling (CRM).	For Environmental Statement additional text has been provided to state how birds in flight have been calculated from model-based estimates utilising the site-specific data.
		The need to provide the bootstrapped abundance data used for the CRM and the log files generated by the sCRM.	Density estimates of species screened into collision risk assessment are presented in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3). All bootstrapped abundances are presented in Volume 6, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement (Document reference F6.5.1). Log files have been generated and saved and are available on request in a digital format.
		NRW (A) recommend that a worked example of the approach for a species assessed by MRSea for collision (for example kittiwake) and for a species assessed for displacement (for example guillemot) be included, that details how unidentified birds and availability bias have been corrected for and how estimates of birds in flight have been made from all birds estimates.	Methodology has been further clarified in response to S42 consultation and therefore the requirement for a worked example is no longer necessary.
		Agree with the use of the non-breeding season(s) Biological Defined Minimum Population Scales (BDMPS) sizes from Furness (2015)	All seasons have been presented based on agreed seasons

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
		It appears that for the species where MRSea estimates have been generated for some of the surveys, the quantitative impact assessments (for example of displacement and collision risk) have been based on a mix of MRSea estimates for months where these are available and design-based estimates where MRSea estimates are not available. Whilst this approach seems sensible and uses the best available data, this hierarchy of approach needs to be clearly stated in the documents.	Monthly species abundances are a mix of MRSea and design-based abundances, with MRSea estimates used instead of design-based estimates wherever possible. Further explanations are provided in Volume 6, Annex 5.2: Offshore ornithology displacement technical report of the Environmental Statement (Document reference F6.5.2) and in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3).
		Agree that the impact assessments have been based on Option 2 outputs.	Option 2 results have been presented
		NRW (A) also agree with the use of a 70% reduction in gannet densities going into the CRM to account for macro avoidance.	Noted. ~~with NE avoidance rates and JNCC Ozsanlav-Harris both used as NE presented large gull rates for great black-backed gull while Ozsanlav-Harris presented species specific rates which were deemed appropriate for use.~~
		NRW (A) understand that the seabird density data used in the sCRM are 1,000 bootstrapped values generated for each month using either MRSea or design-based outputs. Please note our comments in Paragraph 258 of the current document regarding how densities of flying birds only have been generated from MRSea for use in CRM; NRW (A) also request that the bootstrapped data be provided to enable the modelling to be re-run and the outputs checked.	Densities of birds in flight were generated by multiplying the densities of all behaviours within the Mona 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 Mona Array Area to ensure the sample size was sufficient to generate a robust estimate of the proportion of birds in flight. Further explanation is given in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3).

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
		NRW (A) recommend that the log files produced by the sCRM tool be provided as an appendix.	Density estimates of species screened into collision risk assessment are presented in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3). All bootstrapped abundance are presented in Volume 6, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement (Document reference F6.5.1). Log files are available on request in a digital format.
	S42 Consultation Natural England	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.	Density estimates of species screened into collision risk assessment are presented in Volume 6, Annex 5.3: Offshore ornithology collision risk modelling technical report of the Environmental Statement (Document reference F6.5.3). All bootstrapped abundances are presented in Volume 6, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement (Document reference F6.5.1). Log files are available on request in a digital format.
	S42 Consultation JNCC	European herring gull and lesser black-backed gull are both listed as having medium sensitivity to collision and low abundance in the study area and has been assessed for significance. However, common gull is also listed as having medium sensitivity to collision and low abundance in the study area but has not been assessed for significance. Why has common gull not been assessed?	Clarifications on the lack of assessment for common gull have been added.
		We also agree with the use of a 70% reduction in gannet densities going into the CRM to account for macro avoidance.	Results with and without displacement have been presented

Date	Consultee and type of response	Topics and issues raised	Response to issue raised and/or where considered in this chapter
November 2023	JNCC – Avoidance rate technical paper provided and agreed 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 Natural England 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. 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.
December 2023	**Offshore Ornithology Expert** **Working Group 7** **Attended by:** 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

1.3.1.1 Collision risk is an impact associated with the operation of wind turbines and their associated offshore structures. As a result, the offshore cable laid on the seabed will not contribute to any additional collision risk associated with this aspect of the development. The collision risk assessment has therefore been carried out using seabird abundances within the Mona Array Area only as this is the only area containing wind turbines.

1.3.2 Collison risk modelling

1.3.2.1 ~~Collision risk modelling~~CRM 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, 2017) has been followed for the modelling of collision impacts predicted for the Mona Array Area.

1.3.2.2 The collision risk model incorporated draft guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores (Natural England, pers. comm., 7 July 2022). Throughout the document, outputs will be contrasted with recently published parameters from the JNCC commissioned report by Ozanlav-Harris *et al.,* 2023. In some instances, values for certain species (e.g. northern fulmar *Fulmarus glacialis* and Manx shearwater *Puffinus puffinus*) had not been 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). All proposed parameters are set out in Table 1.4 and Table 1.5.

1.3.2.3 ~~Collision risk models~~CRMs were run using Band Option 2 of the sCRM. The proportion of birds flying at collision risk height was determined using generic flight height data rather than site-based data. These generic data were taken from Johnston *et al*. (2014a; 2014b), who analysed flight height measurements from surveys conducted at 32 sites around the UK.

1.3.3 Screening species for collision risk assessment

1.3.3.1 A review of all species of seabirds recorded during the two years of Digital Aerial Surveys (DAS) undertaken in the Mona Array Area was conducted to identify Valued Ornithological Receptors (VORs) for collision risk modelling based on the abundance of flying birds in surveys and vulnerability to collision impacts. A further step refined this list of VORs based on their inclusion as a feature of any nearby designated sites in order to identify species of importance.

1.3.3.2 To inform the identification of VORs, the following criteria are defined for each species:

- Known to be vulnerable to the risk of collision (based on Bradbury *et al.,* 2014)
- Where the peak population of the species in flight observed is considered to be of importance (i.e. a high flying abundance of the species recorded within the Mona Array Area)
  - Low = < 30 flying birds across surveys

  - Medium = 31 to 200 flying birds across surveys
  - High = > 200 flying birds across surveys.
- Are a feature of a designated site(s) within that species mean-max foraging range.

1.3.3.3 VORs were identified and progressed to the sCRM stage where the population importance of a species was high or medium. However, despite their high and medium importance, common guillemot and razorbill were not progressed to the sCRM stage due to their very low vulnerability risk to collision risk and low uncertainty level (Wade *et al*., 2016). The rest of species with population importance deemed to be low were screened out of the sCRM stage. Species identified and taken forward to the collision risk assessment have been highlighted within Table 1.2 below.

Table 1.2: Species estimated flying abundance within the Mona Array Area, collision risk sensitivity, connectivity to Special Protection Area (SPA) and the result of the screening assessment.

1. Cells highlighted indicate species taken forward for assessment

Species	Population importance	Vulnerability to collision risk	Collision risk uncertainty level	SPA qualifying feature in range	Result of sCRM screening
European shag *Phalacrocorax aristotelis*	Low, no flying birds.	Moderate	High	Yes	Screened out
Great cormorant *Phalacrocorax carbo*	Low, no flying birds.	Low	Moderate	Yes	Screened out
Red-throated diver *Gavia stellata*	Low, no flying birds.	Moderate	Low	Yes	Screened out
Common guillemot *Uria aalge*	High – estimated total of 457 flying birds.	Very Low	Low	Yes	Screened out
Razorbill *Alca torda*	Medium - estimated total of 133 flying birds.	Very Low	Low	Yes	Screened out
Puffin *Fratercula arctica*	Low, no flying birds.	Very Low	Moderate	Yes	Screened out
Northern fulmar	Medium - estimated total of 185 flying birds.	Very Low	Low	Yes	Screened in
Manx shearwater	High - estimated total of 325 flying birds.	Very Low	High	Yes	Screened in
Northern gannet *Morus bassanus*	High - estimated total of 450 flying birds.	High	Very Low	Yes	Screened in
Black-legged kittiwake *Rissa tridactyla*	High - estimated total of 2,841 flying birds.	High	Very Low	Yes	Screened in
European herring gull *Larus argentatus*	Medium - estimated total of 47 flying birds.	Very High	Very Low	Yes	Screened in
Lesser black-backed gull *Larus fuscus*	Medium - estimated total of 63 flying birds.	Very High	Very Low	Yes	Screened in
Great black-backed gull *Larus marinus*	Medium - estimated total of 109 flying birds.	Very High	Low	Yes	Screened in

Species	Population importance	Vulnerability to collision risk	Collision risk uncertainty level	SPA qualifying feature in range	Result of sCRM screening
Black-headed gull *Chroicocephalus ridibundus*	Low - estimated total of 7 flying birds.	Moderate	Moderate	Yes	Screened out
Common gull *Larus canus*	Low - estimated total of 28 flying birds.	High	Low	Yes	Screened out
Little gull *Hydrocoleus minutus*	Low - estimated total of 7 flying birds.	Low	Unknown	Yes	Screened out
Great skua *Stercorarius skua*	Low, no flying birds.	Moderate	Moderate	No	Screened out
Arctic skua *Stercorarius parasiticus*	Low - estimated total of 11 flying birds.	High	Moderate	No	Screened out
Common tern *Sterna hirundo*	Low, no flying birds.	Moderate	Very Low	Yes	Screened out
Sandwich tern *Thalasseus sandvicensis*	Low - estimated total of 15 flying birds.	Moderate	Low	Yes	Screened out
Arctic tern *Sterna paradisaea*	Low, no flying birds.	Moderate	Moderate	No	Screened out

1.3.4 Density estimates

1.3.4.1 Monthly density estimates of seabirds in flight within the Mona Array Area, including upper and lower 95% confidence limits, were generated from the data collected through the site-specific digital aerial surveys carried out in the Mona Offshore Ornithology Array Area study area, which extended up to 16.5 km around the Mona Array Area.

1.3.4.2 Where MRSea based densities were available those were used, and otherwise design-based densities were used, with MRSea being prioritised over design-based whenever available. The full methods and results of the digital aerial surveys are presented in Volume 6, Annex 5.1: Offshore ornithology baseline characterisation technical report of the Environmental Statement (Document reference F6.5.1).

1.3.4.3 Densities of birds in flight were generated by multiplying the densities of all behaviours within the Mona 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 Mona Array Area to ensure the sample size was sufficient to generate a robust estimate of the proportion of birds in flight.

1.3.4.4 For example, assume MRSea generated a density of 10 black-legged kittiwake per km^2 in the Mona Array Area for all behaviours, and assume that 30% of kittiwake in the raw data were flying. The density of flying birds in the Mona Array Area would then be calculated as 30% * 10 (kittiwake per km^2) = 3 kittiwake per km^2.

1.3.4.5 There were two density estimates for each calendar month as the digital aerial surveys spanned 24 monthly samples across two years. For running the stochastic CRM, 1,000 bootstrapped density values were generated for each month using a mix of MRSea and design-based outputs. 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.

1.3.4.6 The density estimates for screened-in species are presented in Table 1.3.

Table 1.3: Density estimates (birds/km²) of species screened into collision risk assessment.

	January	February	March	April	May	June	July	August	September	October	November	December	~~Total~~Average density
Black-legged kittiwake	0.59	0.84	0.86	0.30	0.10	0.29	0.42	0.02	0.00	0.03	0.31	1.04	**0.40**
Great black-backed gull	0.02	0.09	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	**0.02**
European herring gull	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
Lesser black-backed gull	0.00	0.01	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	**0.01**
Northern gannet	0.04	0.02	0.06	0.11	0.04	0.01	0.10	0.09	0.18	0.06	0.03	0.02	**0.06**
Northern gannet (70% displacement)	0.01	0.01	0.02	0.03	0.01	0.00	0.03	0.03	0.05	0.02	0.01	0.01	**0.02**
Northern fulmar	0.00	0.08	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	**0.03**
Manx shearwater	0.00	0.00	0.01	0.02	0.00	1.18	0.66	0.41	0.03	0.00	0.00	0.00	**0.16**

1.3.5 Modelling parameters

Species biometrics

1.3.5.1 The sCRM incorporates a number of parameters relating to the bird characteristics 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 uncertainty in some of those parameters to ensure that the risk is not underestimated. At the same time, it is widely acknowledged that additive layers of precaution in all parameters may lead to overestimation of risk and therefore alternative values may also be presented where emerging evidence indicates it is appropriate to do so. This is the case in relation to avoidance rates and nocturnal activity factors, which have some of the biggest influences on the predicted magnitude of impact.

1.3.5.2 Following advice from the Offshore Ornithology ~~Expert Working Groups~~EWG (Natural England, NRW, JNCC, RSPB, Isle of Man), the sCRM has incorporated the updated species-group avoidance rates presented in Ozsanlev-Harris *et al*. (2023). With use of Band Option 2, these included a range incorporating variability or uncertainty (±1 SD) (Table 1.4). It should be noted, that the SNCBs prefer the species-group avoidance rates to be used within assessments (see D.3.13 of Technical Engagement Plan Appendices Part 1 (A to E), Document reference E~~.~~4.1) The ~~Aplicant~~Applicant has used both ~~speices~~species-group and species-specific ~~avodiance~~avoidance rates within the EIA and HRA.

1.3.5.3 Nocturnal Activity Factors (NAFs) also have a large influence on the CRM outputs. They are applied to account for a level of flight activity at night when it is not possible to sample bird flight density in the survey area. Nocturnal activity is generally considered to be lower than during the day, so a percentage reduction is applied to the diurnal densities derived from the digital aerial surveys. Natural England (pers. comm., 7 July 2022) states that NAFs are currently under review and in the meantime recommend the NAFs shown in Table 1.4 are used for CRM. A previous study by Wade *et al.* (2016) suggested that Manx shearwater nocturnal activity was around half of their daylight activity. The collision risk modelling for manx shearwater using a rate of 1 instead of 0.5 therefore may result in collision risk being overestimated for this species.

1.3.5.4 Various other biometric parameters of each bird species are needed for species-specific sCRM, including bird length, wingspan, flight speed and flight type. The parameters are shown in Table 1.4, complying with draft recommendations provided by Natural England (agreed in EWG meeting, 13 July 2022). For the sCRM, all species are assumed to use ‘flapping’ flight and have 50% proportions of flights upwind/downwind.

1.3.5.5 Additionally, the guidance provided by Natural England (pers. comm., 7 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. A specific scenario where densities within the Mona Array Area were reduced by 70% for northern gannet is therefore also presented.

1.3.5.6 The values derived from the sCRMs are presented in full, including all variations that incorporate variability and uncertainty in input parameters as described above for bird densities, flight heights, nocturnal activity factors and avoidance rates.

Table 1.4: Species biometrics and input parameters for CRM.

a Body length and wing-span values from BTO Bird Facts (Robinson, 2005).

b Flight speeds for black-legged kittiwake, great black-backed gull, European herring gull and lesser black-backed gull are derived from Alerstam *et al.* (2007), with northern gannet and northern fulmar derived from Pennycuick (1987). These are the sources specified in Natural England (2021). Manx shearwater flight speed is the mean ground speed reported by Gibb *et al.* (2017) for flapping flight.

c Standard NAF derived from Natural England (agreed in EWG meeting, 13 July 2022) and King *et al.* (2009).

d Species-group and species-specific Aavoidance rates taken from Ozanlav-Harris *et al* (2023). Natural England (agreed in EWG meeting, 13 July 2022). The species-group avoidance rate Conservatively, generic avoidance rates were used, which were "all gulls" (black-legged kittiwake and northern gannet), "large gulls" (herring gull, lesser and great black-backed gull), and "otherall gulls and terns" (northern fulmar and Manx shearwater).

e Avoidance rates taken from JNCC commissioned report by Ozsanlev-Harris *et al.* (2023).

Species	Body length (m)[a]	Wing-span (m)[a]	Flight speed (m/s)[b]	Nocturnal Activity Factor[c]	Grouped Species-group Avoidance rate NE[d]	Species-specific Avoidance rate[d] Ozanlav-Harris *et al*[e]
Black-legged kittiwake	0.39 (±0.005)	1.08 (±0.0625)	13.10 (±0.40)	0.375 (±0.0637)	0.9928 (±0.0003)	0.9979 (±0.0013)
Great black-backed gull	0.71 (±0.0375)	1.58 (±0.0375)	13.70 (±1.20)	0.375 (±0.0637)	0.9939 (±0.0004)	0.9991 (±0.0002)
European herring gull	0.60 (±0.0225)	1.44 (±0.030)	12.80 (±1.80)	0.375 (±0.0637)	0.9939 (±0.0004)	0.9952 (±0.0003)
Lesser black-backed gull	0.58 (±0.030)	1.42 (±0.0375)	13.10 (±1.90)	0.375 (±0.0637)	0.9939 (±0.0004)	0.9954 (±0.0003)
Northern fulmar	0.48 (±0.0125)	1.07 (±0.025)	13.00 (±1.98)	0.750	0.9910 (±0.0004)	N/A
Manx shearwater	0.34 (±0.020)	0.82 (±0.0325)	11.46 (± 2.23)	1.000	0.9910 (±0.0004)	N/A
Northern gannet	0.94 (±0.0325)	1.72 (±0.0375)	14.90 (±0.00)	0.080 (±0.01)	0.9928 (±0.0003)	Species specific = N/A Alternative avoidance rate (Large gull) = 0.9939 (±0.0004)

Turbine model

1.3.5.7 The wind farm and wind turbine parameters that represent the Maximum Design Scenario (MDS) in relation to collision risk were incorporated into the sCRM. The wind turbine parameters representing the MDS for the Mona Offshore Wind Project were taken from Project Design Envelope (PDE) (Table 1.5). The maximum design scenario taken forward to the assessment was the smallest, most numerous wind turbine option from the range of project parameters, as this option has the potential for the greatest level of collision risk effects.

Table 1.5: Wind turbine parameters in the MDS for CRM.

[a] Maximum parameter values presented are specific to one wind turbine option in the PDE.

Parameter[a]	Parameter value (SD)	Source/Reference
Max. number of wind turbines	96	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Number of rotor blades per wind turbine	3	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Max. chord width (m)	6.8 (0)	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Average blade pitch (degrees)	10 (0)	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Max. rotor radius (m)	125	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Average rotation speed (rpm)	6.2 (0)	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Tidal offset (m) (MSL)	+/- 4	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Lower blade tip height above Lowest Astronomical Tide (LAT) (m)	34	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)
Air gap (MSL) (m)	30	Air gap relative to Mean Sea Level (MSL) allowing for -4 m tidal offset between LAT and MSL
Wind farm width (km)	27.0	Calculated in RStudio
Latitude	53.7	Calculated in RStudio
Large array correction	YES	Standard procedure
Operational time	94% (0)	Volume 1, Chapter 3: Project description of the Environmental Statement (Document reference F1.3)

Flight heights

1.3.5.8 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 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, the EWG 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. Generic flight height distributions published by Johnston *et al.* (2014a; 2014b) were therefore used in sCRM for the Mona Offshore Wind Project. Flight height distributions used within sCRM for each species are presented within Appendix A.

1.3.5.9 To account for levels of uncertainty in flight heights, the estimated mortality was presented for the median values and the upper and lower confidence interval limits of the flight height distributions.

1.4 Results

1.4.1.1 All monthly expected collision mortality outputs, including lower and upper confidence intervals, are presented below. These have been calculated using precautionary rates for flight speeds in line with SNCB advice. See section 1.5.1 for further details

1.4.2 Black-legged kittiwake

1.4.2.1 The monthly expected number of collisions for black-legged kittiwake are presented in Figure 1.2 and Table 1.6.

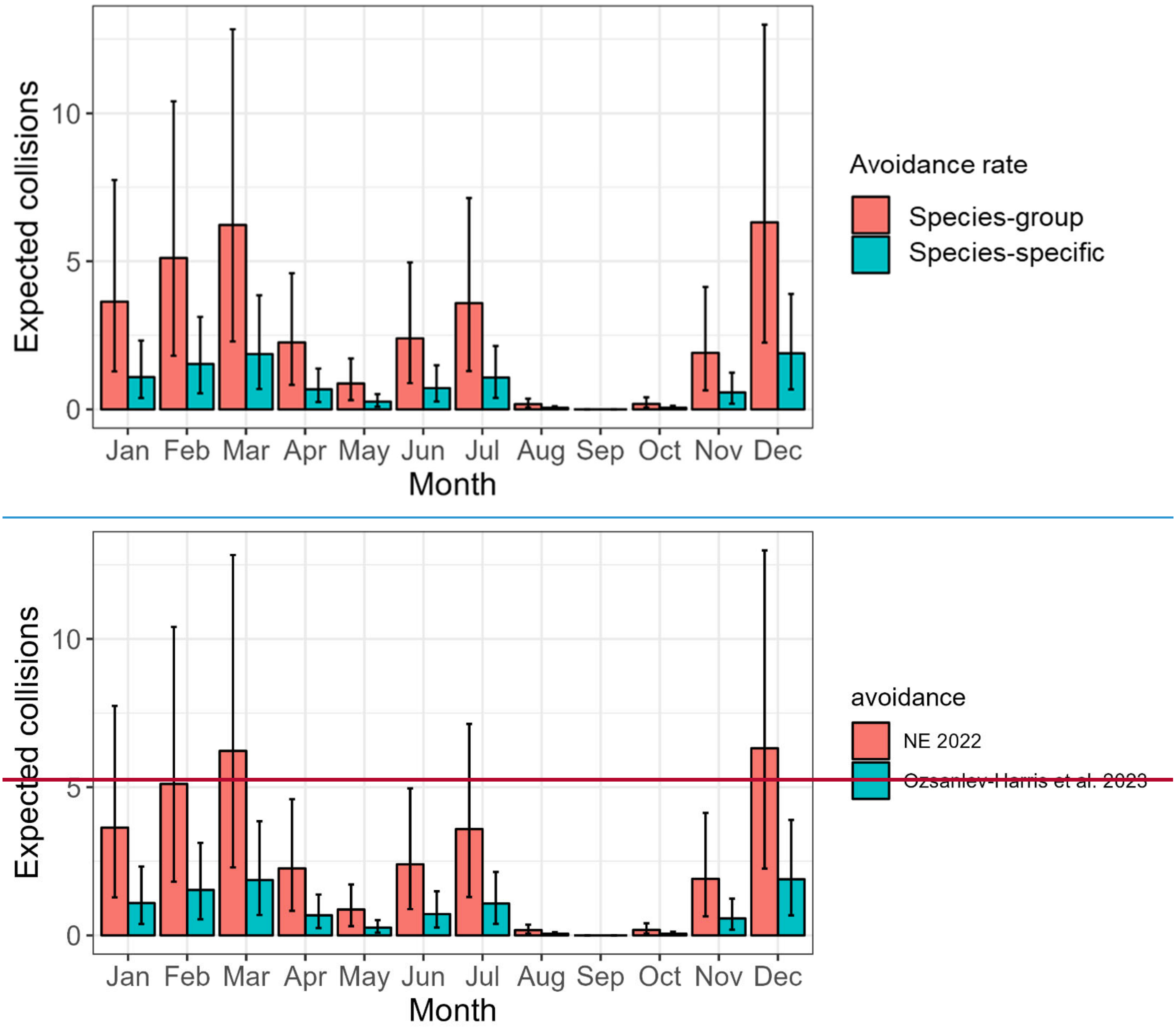


Figure 1.2: Black-legged kittiwake expected collisions ~~across~~ per month~~s, contrasting a 0.9928 avoidance rate (NE) with a 0.9979 rate (Ozanlav-Harris et al.)~~.

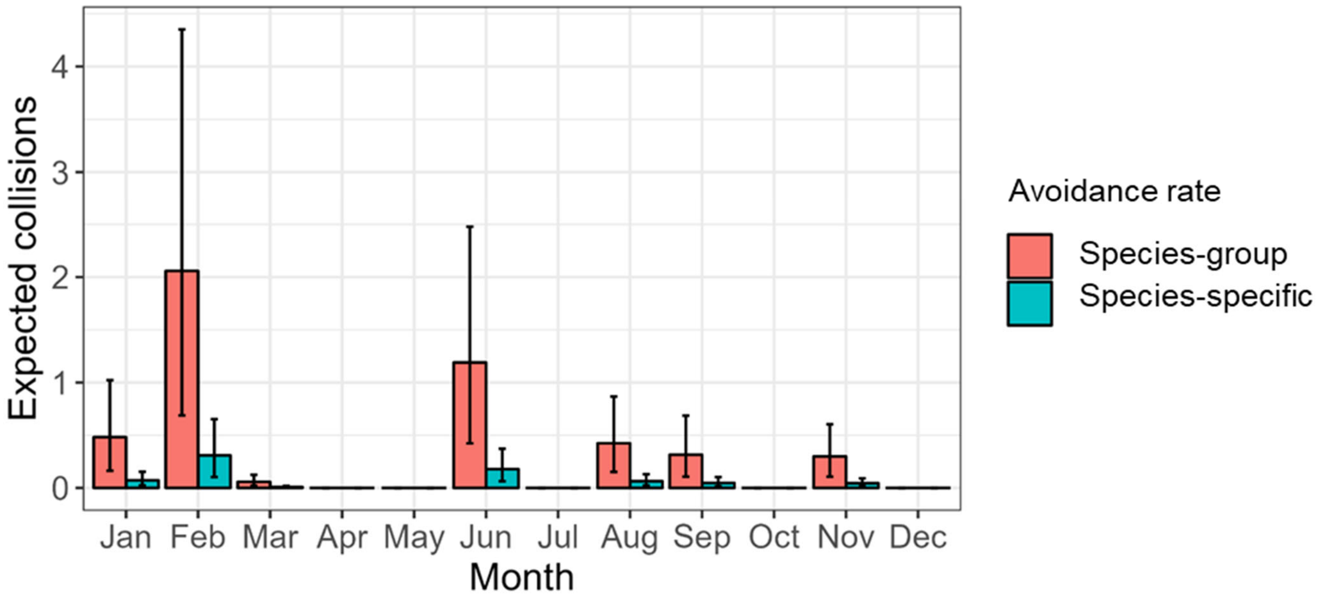
Table 1.6: Black-legged kittiwake expected collisions ~~across~~ per month~~s~~ including the lower confidence interval (LCI) and upper ~~(UCI)~~ confidence interval~~s~~ (UCI).

	~~NE avoidance rates~~Species-group avoidance rate (99.28)			~~Ozanlav-Harris *et al* avoidance rates~~Species-specific avoidance rate (99.79)		
Month	**Expected collisions**	**LCI**	**UCI**	**Expected collisions**	**LCI**	**UCI**
January	3.63	1.28	7.74	1.09	0.38	2.32
February	5.11	1.81	10.41	1.53	0.54	3.12
March	6.22	2.29	12.83	1.87	0.69	3.85

Month	NE avoidance ratesSpecies-group avoidance rate (99.28) Expected collisions	LCI	UCI	Ozanlay-Harris et al avoidance ratesSpecies-specific avoidance rate (99.79) Expected collisions	LCI	UCI
April	2.26	0.83	4.60	0.68	0.25	1.38
May	0.87	0.31	1.72	0.26	0.09	0.52
June	2.40	0.89	4.96	0.72	0.27	1.49
July	3.59	1.29	7.13	1.08	0.39	2.14
August	0.18	0.06	0.36	0.05	0.02	0.11
September	0.00	0.00	0.00	0.00	0.00	0.00
October	0.19	0.07	0.41	0.06	0.02	0.12
November	1.91	0.64	4.13	0.57	0.19	1.24
December	6.31	2.25	12.99	1.89	0.68	3.90
TOTAL	**32.67**	**11.73**	**67.27**	**9.80**	**3.52**	**20.18**

1.4.3 Great black-backed gull

1.4.3.1 The monthly expected number of collisions for great black-backed gull are presented in Figure 1.3 and Table 1.7.



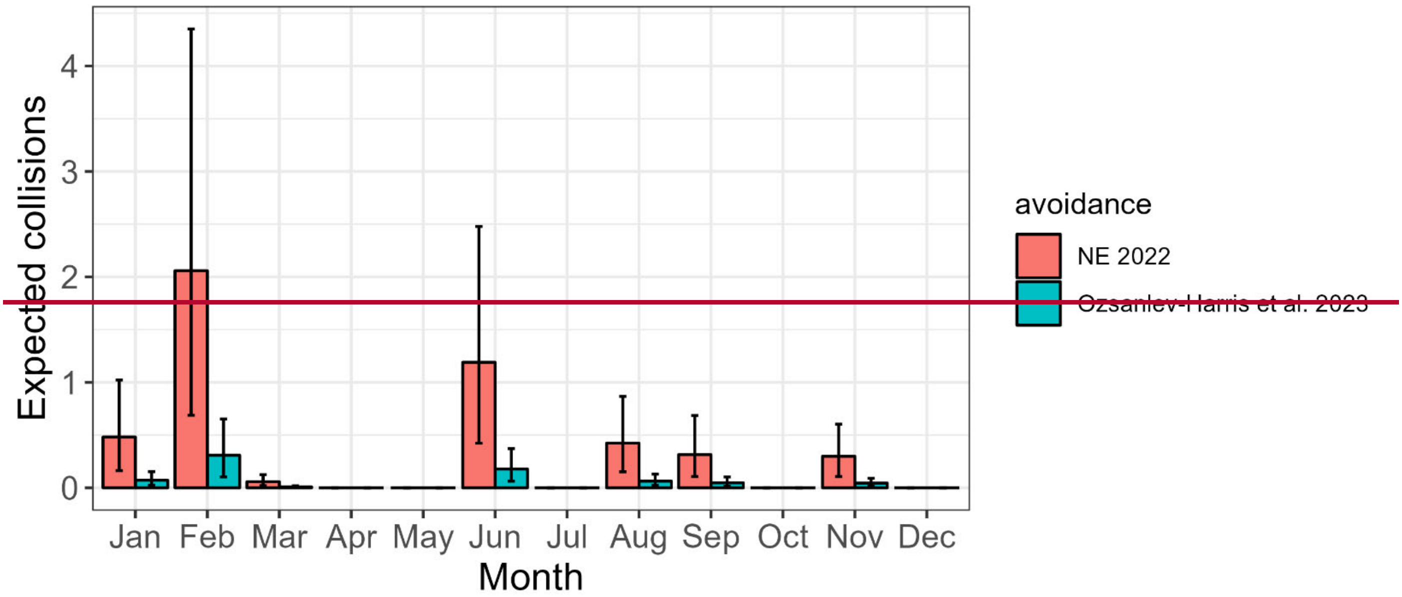


Figure 1.3: Great black-backed gull expected collisions ~~across~~ per month~~s, contrasting a 0.9939 avoidance rate (NE) with a 0.9991 rate (Ozanlav-Harris et al)~~.

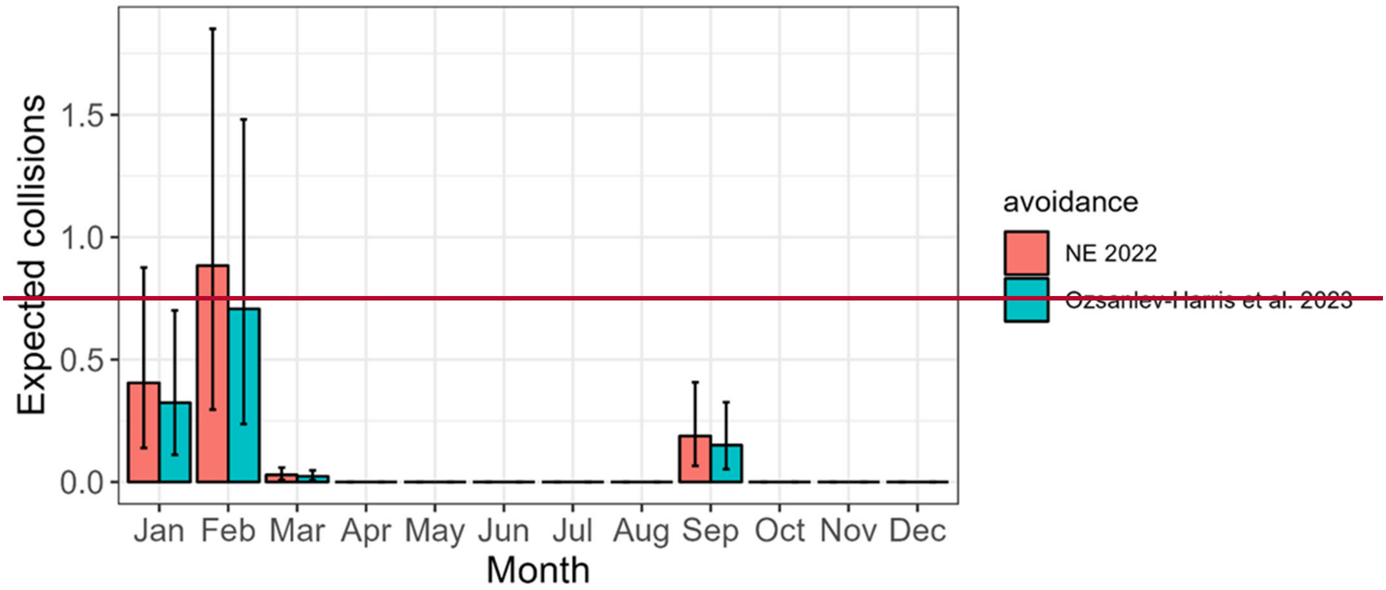
Table 1.7: Great black-backed gull expected collisions ~~across~~ per month~~s~~ including ~~lower (~~LCI ~~)~~ and ~~upper (~~ UCI~~) confidence intervals~~.

Month	Species-group avoidance rate (99.39)~~NE avoidance rates~~ Expected collisions	LCI	UCI	Species-specific avoidance rate (99.91)~~Ozanlav-Harris et al avoidance rates~~ Expected collisions	LCI	UCI
January	0.48	0.16	1.02	0.07	0.02	0.15
February	2.06	0.69	4.35	0.31	0.10	0.65
March	0.06	0.02	0.13	0.01	0.00	0.02

Month	Species-group avoidance rate (99.39)~~NE avoidance rates~~ Expected collisions	LCI	UCI	Species-specific avoidance rate (99.91)~~Ozanlav-Harris et al avoidance rates~~ Expected collisions	LCI	UCI
April	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00
June	1.19	0.42	2.48	0.18	0.06	0.37
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.42	0.15	0.87	0.06	0.02	0.13
September	0.32	0.11	0.69	0.05	0.02	0.10
October	0.00	0.00	0.00	0.00	0.00	0.00
November	0.30	0.11	0.60	0.04	0.02	0.09
December	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**4.83**	**1.66**	**10.13**	**0.72**	**0.25**	**1.52**

1.4.4 European herring gull

1.4.4.1 The monthly expected number of collisions for European herring gull are presented in Figure 1.4 and Table 1.8.



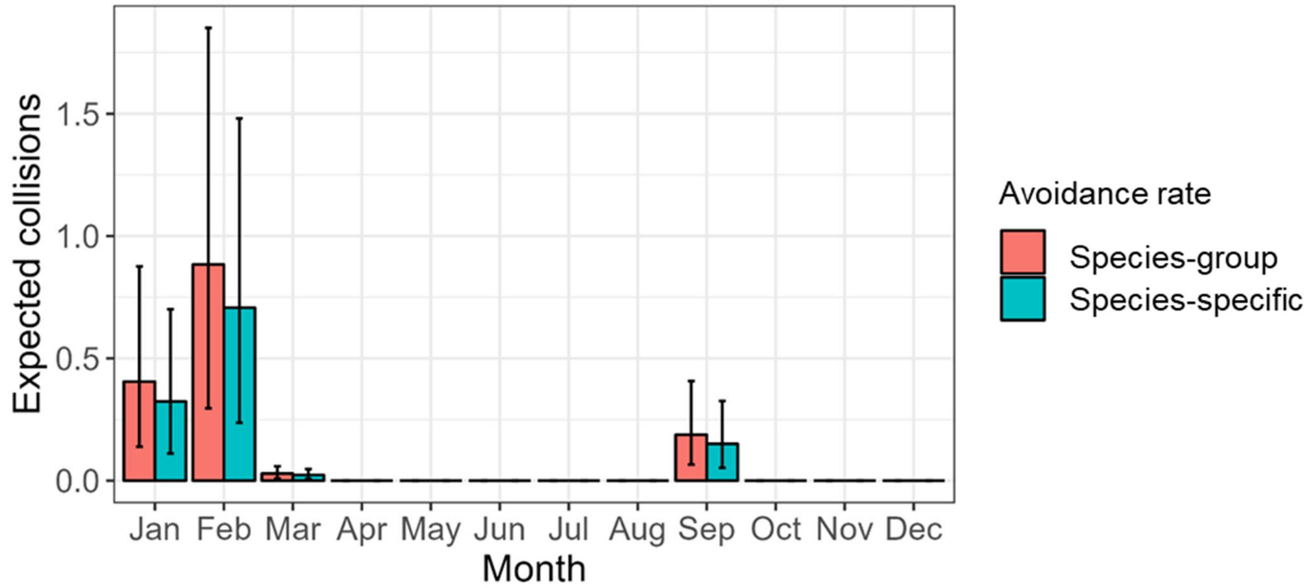


Figure 1.4: European herring gull expected collisions ~~across~~ per month~~s, contrasting a 0.9939 avoidance rate (NE) with a 0.9952 rate (Ozanlav-Harris et al.)~~.

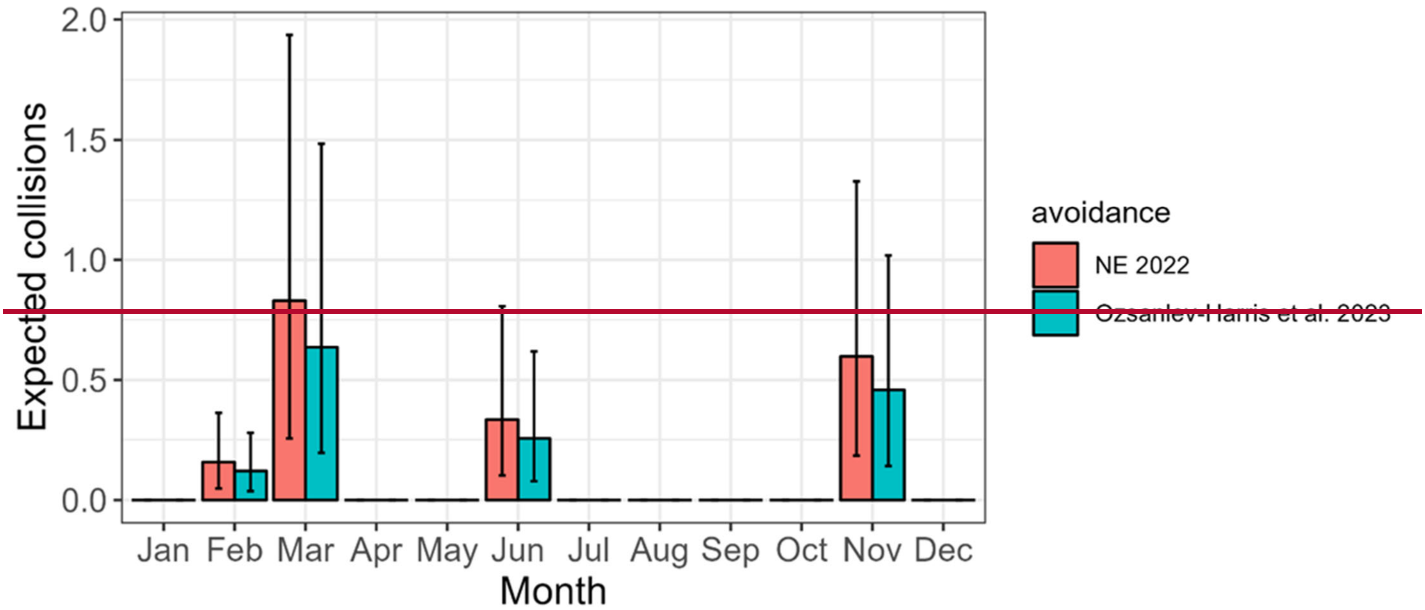
Table 1.8: Herring gull expected collisions ~~across~~ per month~~s~~ including ~~lower (~~LCI~~)~~ and ~~upper (~~UCI~~) confidence intervals~~.

	Species-group avoidance rate (99.39)~~NE avoidance rates~~			Species-specific avoidance rate (99.52)~~Ozanlav-Harris et al avoidance rates~~		
Month	**Expected collisions**	**LCI**	**UCI**	**Expected collisions**	**LCI**	**UCI**
January	0.41	0.14	0.88	0.32	0.11	0.70
February	0.88	0.30	1.85	0.71	0.24	1.48
March	0.03	0.01	0.06	0.02	0.01	0.05
April	0.00	0.00	0.00	0.00	0.00	0.00

Month	Species-group avoidance rate (99.39)~~NE avoidance rates~~			Species-specific avoidance rate (99.52)~~Ozanlav-Harris et al avoidance rates~~		
	Expected collisions	LCI	UCI	Expected collisions	LCI	UCI
May	0.00	0.00	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.19	0.07	0.41	0.15	0.05	0.33
October	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**1.51**	**0.51**	**3.19**	**1.20**	**0.41**	**2.55**

1.4.5 Lesser black-backed gull

1.4.5.1 The monthly expected number of collisions for lesser black-backed gull are presented in Figure 1.5 and Table 1.9.



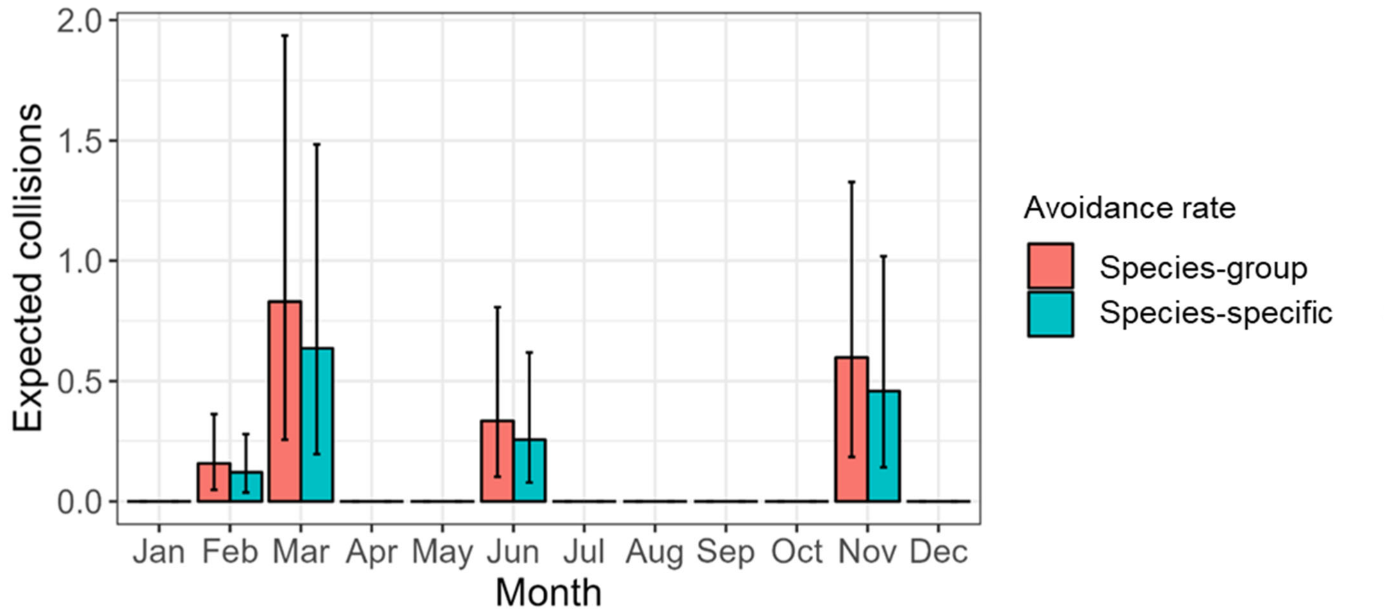


Figure 1.5: Lesser black-backed gull expected collisions ~~across~~ per month~~s, contrasting a 0.9939 avoidance rate (NE) with a 0.9954 rate (Ozanlav-Harris et al.)~~.

Table 1.9: Lesser black-backed gull expected collisions across months including ~~lower (~~LCI~~)~~ and ~~upper (~~UCI~~) confidence intervals~~.

	Species-group avoidance rate (99.39)~~NE avoidance rates~~			Species-specific avoidance rate (99.54)~~Ozanlav-Harris et al avoidance rates~~		
Month	**Expected collisions**	**LCI**	**UCI**	**Expected collisions**	**LCI**	**UCI**
January	0.00	0.00	0.00	0.00	0.00	0.00
February	0.16	0.05	0.36	0.12	0.04	0.28
March	0.83	0.26	1.94	0.64	0.20	1.48
April	0.00	0.00	0.00	0.00	0.00	0.00

Month	Species-group avoidance rate (99.39)NE avoidance rates			Species-specific avoidance rate (99.54)Ozanlav-Harris et al avoidance rates		
	Expected collisions	LCI	UCI	Expected collisions	LCI	UCI
May	0.00	0.00	0.00	0.00	0.00	0.00
June	0.33	0.10	0.81	0.26	0.08	0.62
July	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00
November	0.60	0.18	1.33	0.46	0.14	1.02
December	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**1.92**	**0.59**	**4.43**	**1.47**	**0.45**	**3.40**

1.4.6 Northern gannet

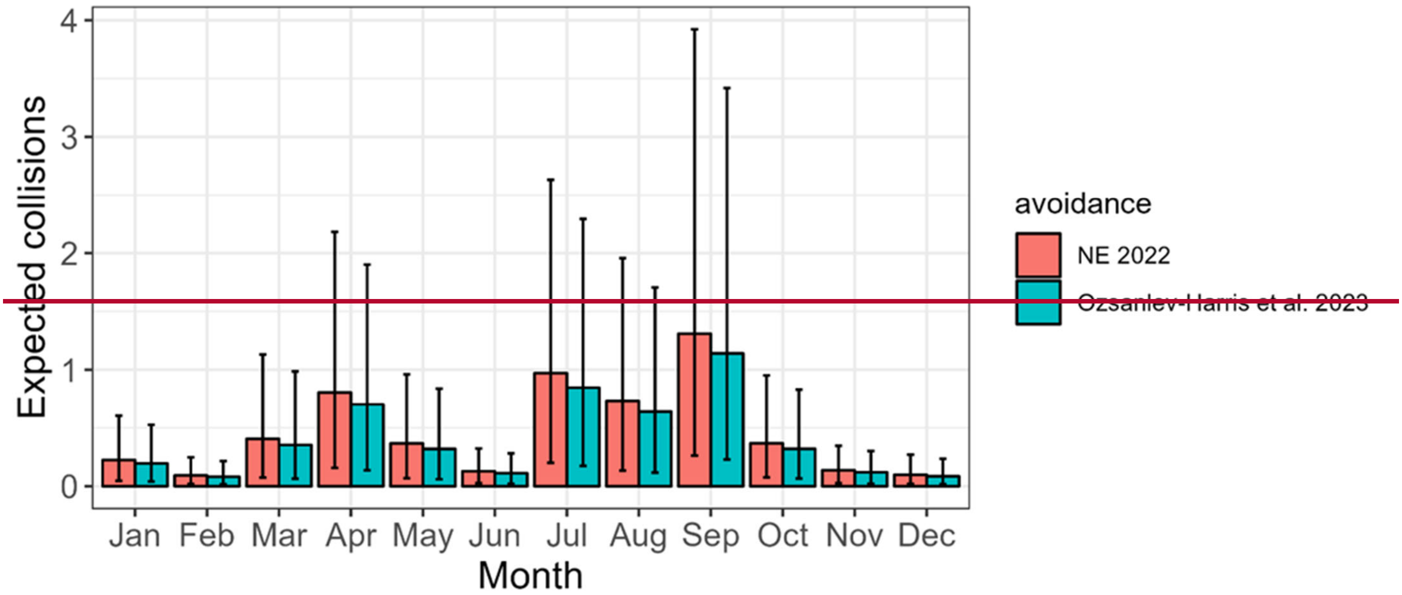
1.4.6.1 As detailed in paragraph 1.3.5.5, northern gannet was specifically recommended to be modelled using both a 'no displacement' and a '70% displacement' scenario (agreed in EWG meeting 2, 13 July 2022). Both scenarios are presented below.

No displacement scenario

1.4.6.2 The precautionary approach assumes that gannets will not be displaced by the wind farm, resulting in no changes in the densities of flying birds pre- and post-construction.

1.4.6.3 For this scenario, the monthly expected number of collisions for northern gannet are presented in Figure 1.6 and Table 1.10

1.4.6.41.4.6.3 Table 1.10.



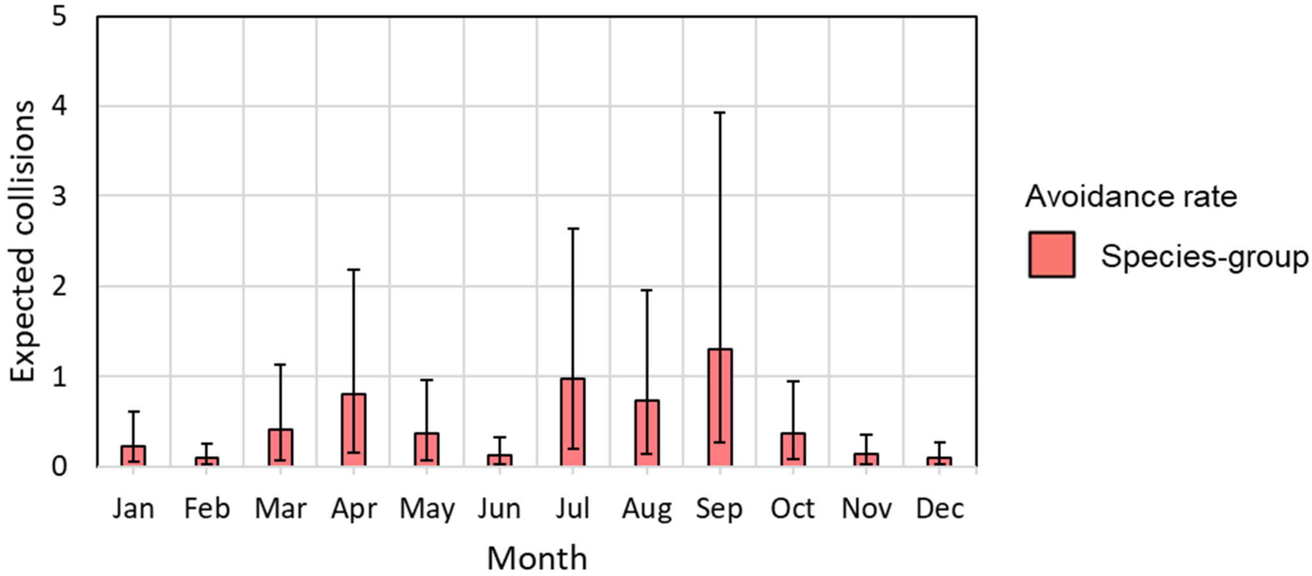


Figure 1.6: Northern gannet expected collisions ~~across~~ per month~~s~~, assuming no displacement.

Table 1.10: Northern gannet expected collisions ~~across~~ per monthss including lower ~~(~~LCI~~)~~ and ~~upper (~~UCI~~)~~ ~~confidence intervals~~, assuming no displacement.

	~~NE~~ Species-group avoidance rate~~s~~		
Month	**Expected collisions**	**LCI**	**UCI**
January	0.22	0.05	0.60
February	0.09	0.02	0.25
March	0.41	0.07	1.13
April	0.81	0.16	2.18
May	0.37	0.07	0.96

	~~NE~~ Species-group avoidance rate~~s~~		
Month	**Expected collisions**	**LCI**	**UCI**
June	0.13	0.03	0.32
July	0.97	0.20	2.63
August	0.73	0.13	1.96
September	1.31	0.26	3.92
October	0.37	0.08	0.95
November	0.14	0.03	0.35
December	0.10	0.02	0.27
TOTAL	**5.65~~4~~**	**1.12~~1~~**	**15.53**

70% displacement scenario

~~1.4.6.5~~1.4.6.4 Natural England interim guidance (agreed in EWG meeting, 13th July 2022) recommends the densities of flying birds in the array area to be discounted by the expected displacement rate of 70%, as detailed in section 1.3.5.

~~1.4.6.6~~1.4.6.5 For the 70% displacement scenario, the monthly expected number of collisions for northern gannet are presented in Table 1.11.

Table 1.11: Northern gannet expected collisions ~~across~~ per month~~s~~ including ~~lower (~~LCI~~s)~~ and ~~upper (~~UCIs~~) confidence intervals~~, assuming 70% displacement.

	~~NE~~ Species-group avoidance rates		
Month	**Expected collisions**	**LCI**	**UCI**
January	0.07	0.02~~1~~	0.18
February	0.03	0.01	0.07
March	0.12	0.02	0.34
April	0.24	0.05	0.65
May	0.11	0.02	0.29
June	0.04	0.01	0.10
July	0.29	0.06	0.79
August	0.22	0.04	0.59
September	0.39	0.08	1.18
October	0.11	0.02	0.29
November	0.04	0.01	0.10
December	0.03	0.01	0.08
TOTAL	**1.70~~69~~**	**0.34~~3~~**	**4.66**

1.4.7 Northern fulmar

1.4.7.1 The monthly expected number of collisions for northern fulmar are presented in Figure 1.7 and Table 1.12.

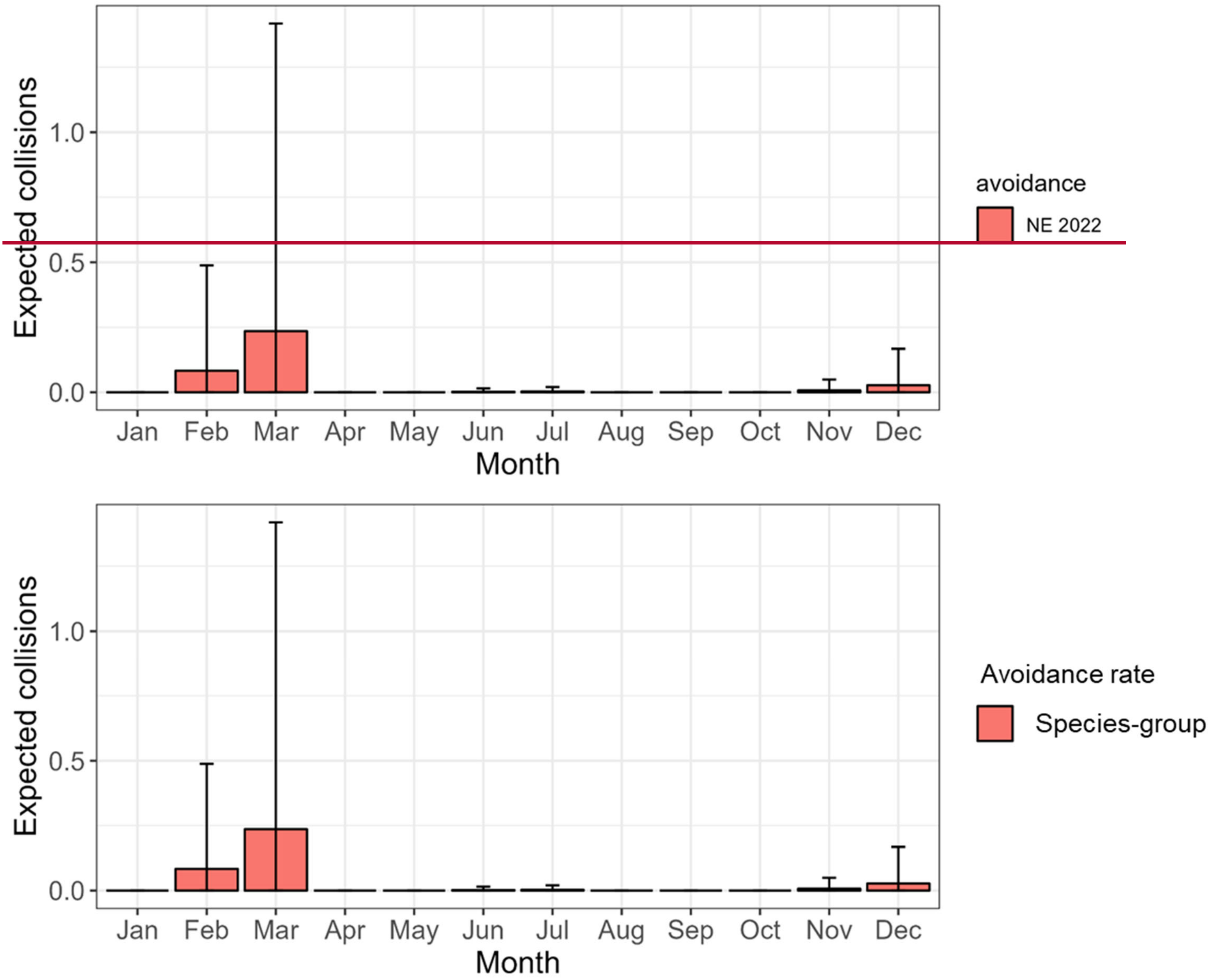


Figure 1.7: Northern fulmar expected collisions ~~across~~ per month~~s contrasting a 0.991 avoidance rate (NE)~~

Table 1.12: Northern fulmar expected collisions ~~across~~ per month~~s~~ including ~~lower (~~LCI~~)~~ and ~~upper (~~UCI~~) confidence intervals~~.

	~~NE~~ Species-group avoidance rates		
Month	**Expected collisions**	**LCI**	**UCI**
January	0.00	0.00	0.00
February	0.08	0.00	0.49
March	0.24	0.00	1.42

	NE Species-group avoidance rates		
Month	**Expected collisions**	**LCI**	**UCI**
April	0.00	0.00	0.00
May	0.00	0.00	0.00
June	0.00	0.00	0.02
July	0.00	0.00	0.02
August	0.00	0.00	0.00
September	0.00	0.00	0.00
October	0.00	0.00	0.00
November	0.01	0.00	0.05
December	0.03	0.00	0.17
TOTAL	**0.36**	**0.00**	**2.16**

1.4.8 Manx shearwater

1.4.8.1 The monthly expected number of collisions for Manx shearwater are presented in Table 1.13. Because collisions are expected to be zero across each month, no figure is presented.

Table 1.13: Manx shearwater expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

	NE Species-group avoidance rates		
Month	**Expected collisions**	**LCI**	**UCI**
January	0.00	0.00	0.00
February	0.00	0.00	0.00
March	0.00	0.00	0.00
April	0.00	0.00	0.00
May	0.00	0.00	0.00
June	0.00	0.00	0.00
July	0.00	0.00	0.00
August	0.00	0.00	0.00
September	0.00	0.00	0.00
October	0.00	0.00	0.00
November	0.00	0.00	0.00
December	0.00	0.00	0.00
TOTAL	**0.00**	**0.00**	**0.00**

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 sources being Alerstam *et al.*, (2007) and Pennycuick (1987), and 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 and 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 1.14 in relation to sample size, location of studies, seasonality and location. The following sections discuss this information for each species.

Table 1.14: Comparison of data sources for bird flight speed.

Dataset feature	Species	Alerstam *et al.* (2007) and 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	

Dataset feature	Species	Alerstam *et al.* (2007) and Pennycuick (1987)	Skov *et al.* (2018)
	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 each species on a monthly basis is discussed below
	Great black-backed gull	Unknown	
	Herring gull	July and August 1994 (Alerstam and Gudmundsson, 1999)	
	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. 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.

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 1st July and 11th 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 Mona Offshore Wind Project is 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.

1.5.1.11 For the Mona Offshore Wind Project, CRM was carried out using the advocated Natural England flight speeds from Alerstam *et al.* (2007). It is therefore concluded that the CRM results are overestimates and therefore are precautionary.

Great black-backed gull

1.5.1.12 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.

1.5.1.13 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 1.8. 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.

1.5.1.14 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.

1.5.1.15 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 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 Mona Offshore Wind Project is 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.

1.5.1.16 For the Mona Offshore Wind Project, CRM was carried out using the advocated Natural England flight speeds from Alerstam *et al.* (2007). It is therefore concluded that the CRM results are overestimates and therefore are precautionary

Herring gull

1.5.1.17 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).

1.5.1.18 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 1.8. 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.

1.5.1.19 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 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 Mona Offshore Wind Project is 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.

1.5.1.20 For the Mona Offshore Wind Project, CRM was carried out using the advocated Natural England flight speeds from Alerstam *et al.* (2007). It is therefore concluded that the CRM results are overestimates and therefore are precautionary.

Lesser black-backed gull

1.5.1.21 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).

1.5.1.22 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 1.8. 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.

1.5.1.23 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).

1.5.1.24 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 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 Mona Offshore Wind Project is 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.

1.5.1.25 For the Mona Offshore Wind Project, CRM was carried out using the advocated Natural England flight speeds from Alerstam *et al.* (2007). It is therefore concluded that the CRM results are overestimates and therefore are precautionary.

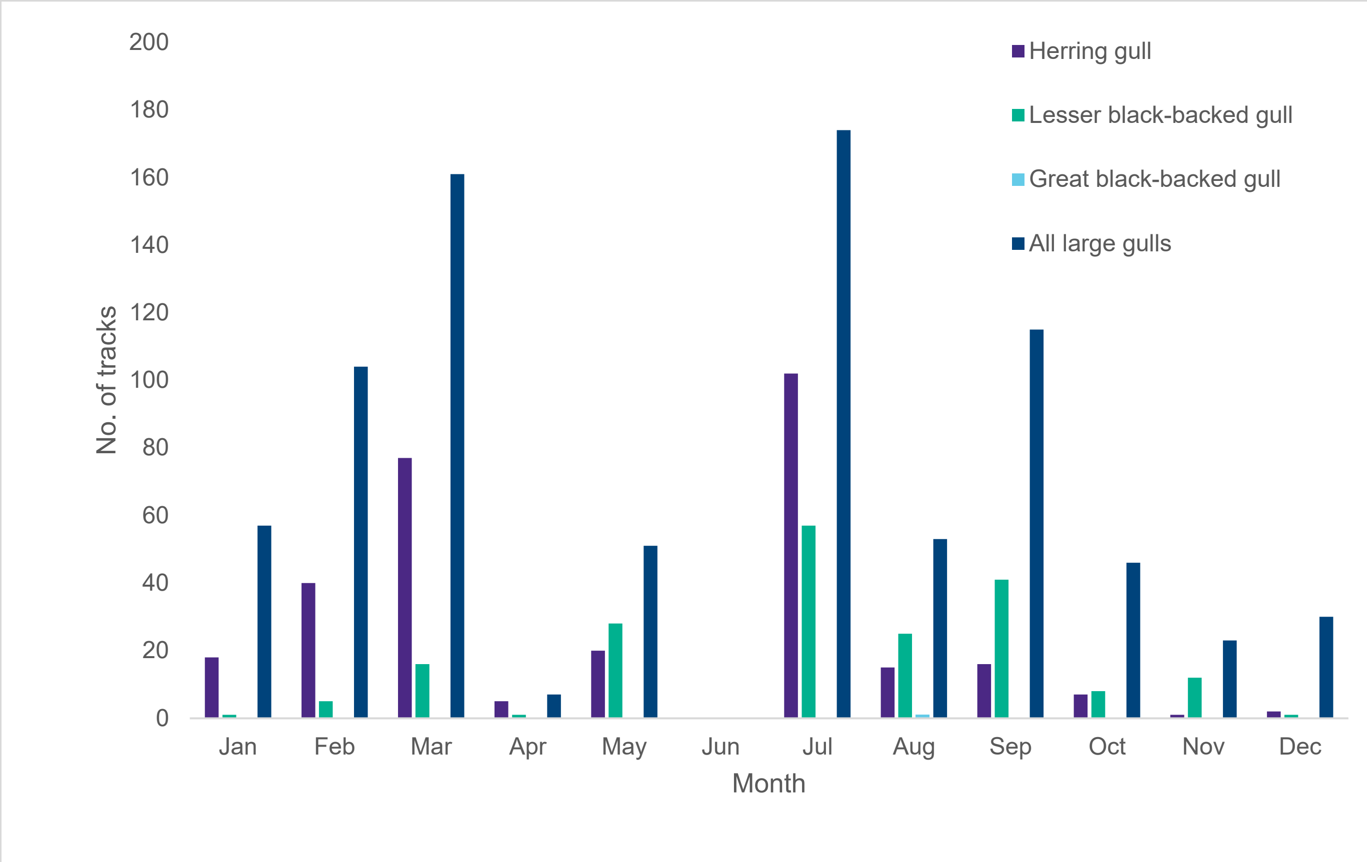


Figure 1.8: Number of large gull tracks in each month from Skov *et al.* (2018)

Gannet

1.5.1.26 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 1.9. 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.

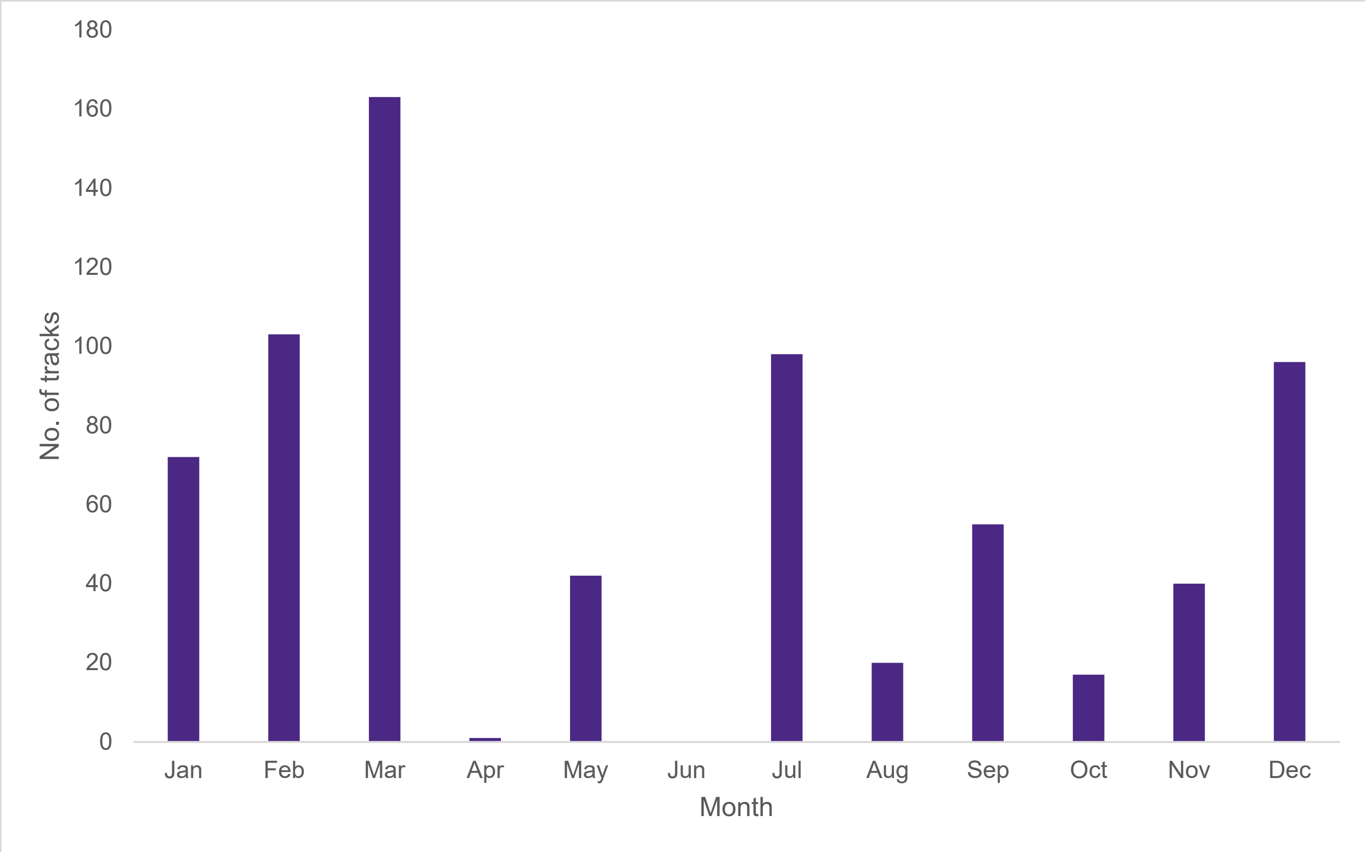


Figure 1.9: Number of gannet tracks in each month from Skov *et al.* (2018).

1.5.1.27 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).

1.5.1.28 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 seasons 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 Mona Offshore Wind Project is 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 concluded that it will provide collision risk modelling results that are precautionary.

1.5.1.29 For the Mona Offshore Wind Project, CRM was carried out using the advocated Natural England flight speeds from Pennycuick (1987). It is therefore concluded that the CRM results are overestimates and therefore are precautionary.

Other considerations

1.5.1.30 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

1.5.1.31 The collision risk modelling undertaken for the Mona Offshore Wind project was undertaken in alignment with SNCB advice. 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, as set out in section 1.5.1.

1.5.1.32 It has previously been suggested that the values from Alerstam *et al.* (2007) and Pennycuick (1987) are precautionary, however, based on the information presented in section 1.5.1, 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 overestimates and do not represent the likely impact from the Mona Offshore Wind project. The Mona Offshore Wind project CRM assessments will therefore have a high level of associated uncertainty and precaution due to utilising the Alersam *et al.* (2007) and Pennycuick (1987) values.

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 section 1.3.5. Ozsanlav-Harris *et al.* (2023) identifies a key limitation in relation to the use of theses avoidance rates in the Band (2012) CRM: data used is primarily collected at onshore and coastal sites with very little offshore data.

1.5.2.2 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 1.15) 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.

~~1.5.2.2~~1.5.2.3 Within Table 1.15 ~~AR~~ avoidance~~diance~~ rates are presented as a median rate (standard deviation (SD); 95% confidence intervals (CI)). The standard deviation and 95% confidence interval were calculated using the delta method (Powell 2007). The ~~S~~sample sizes presented as the number of report-years and number of bird flights through turbine rotor-swept area contributing data to calculate avoidance rate from CRM.

Table 1.15: Species-specific a~~A~~voidance r~~R~~ates ~~(AR)~~ from ~~Collision Risk Modelling~~CRM using basic band ~~stochastic~~ sCRM from Ozsanlav-Harris et al. (202~~2~~3). ~~AR presented as a median rate (standard deviation; 95% confidence interval). The standard deviation and 95% confidence interval were calculated using the delta method (Powell 2007). 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	Median ~~B~~basic sCRM ~~Ar~~avoidance~~diacne~~ rate (SD; 95% CI)	Sample size (no. of report years contributing data to avoidance rate calculation)	Sample size (number of bird flights through turbine rotor swept area taken from reports to Band CRM)
Black-legged ~~K~~kittiwake	0.9979 (0.0013; 0.9955 – 0.9993)	3	4,283.58
Black-headed gull	0.9923 (0.0005; 0.9913 – 0.9931)	28	127,946.11 (data not made public for 3 reports)
Herring gull	0.9952 (0.0003; 0.9946 – 0.9958)	26	149,874.96 (data not made public for 2 reports)
Lesser black-backed gull	0.9954 (0.0003; 0.9946 – 0.996)	21	87,763.75 (data not made public for 2 reports)
Great black-backed gull	0.9991 (0.0002; 0.9987 – 0.9994)	10	12,123.55
Gull	0.9928 (0.0003; 0.9921 – 0.9934)	36	539,239.28 (data not made public for 3 reports)
Large gull	0.9939 (0.0004; 0.9931 – 0.9947)	31	281,068.01 (data not made public for 3 reports)
Small gull	0.9949 (0.0002; 0.9944 – 0.9954)	29	205,429.87 (data not made public for 3 reports)

1.5.2.4 Using the species-group~~ed species~~ avoidance rates would result in higher predicted collision mortalities compared to species-~~-~~specific avoidance rates. However, as species-specific ~~avodiacne~~avoidance rates are calculated from robust analysis, it is considered that the species-specific ~~avoaidacne~~avoidance 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~~CRM.

~~1.5.2.3~~1.5.2.5 Taking great black-backed gull as a representative example, the difference in basic Band (2012) model avoidance rate between the large gull group rate of 0.9936 (recommended by the SNCBs) and the species-specific rate of 0.9991 represents an avoidance rate difference of 0.0055. The species-group avoidance rate estimate for large gulls is lower (0.9936) than the three large gull species-specific rates (lesser black-backed gull 0.9954, herring gull 0.9952, great black-backed gull 0.9991) within Oszanlav-Harris *et al.* (2023). The difference is explained in Cook *et al*. (2021) as being due to the identification of birds to group level rather than species level in surveys for two reports used in the analysis by Cook (2021) and subsequently Oszanlav-Harris *et al.* (2023).

~~1.5.2.4~~1.5.2.6 The species-specific ~~avodiance~~avoidance rates for herring gull, lesser black-backed gull and great black-backed gull create no more uncertainty than that associated with the species-group~~ed~~ avoidance rates or l~~L~~arge gull, which incorporate data from species that although superficially similar, may exhibit differences in flight behaviour that can affect avoidance behaviour. Using the species-group~~ed~~ avoidance rate for these species would represent a more precautionary approach to estimating collision mortality. However, it is clear from Table 1.15, that a wide range of avoidance exists between these gull species and therefore the use of a species-group avoidance~~ed~~ rate would be overestimating impacts for these species.

~~1.5.2.5~~1.5.2.7 Where the sample size is drastically below the minimum threshold (Cook, 2021), for example black-legged kittiwake, it is considered appropriate to place emphasis on the all gull rate instead of the species-specific rate. This is in line with JNCC written advice (note provided 30 November 2023). By doing the assessments for black-legged kittiwake using the all gull rate it will capture the associated uncertainty as it is calculated using data from species that exhibit different flight behaviour than the more marine-based kittiwake

~~1.5.2.6~~1.5.2.8 In either case, 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.

~~1.5.2.7~~1.5.2.9 For the Mona Offshore Wind project, CRM results based on both species-specific and species-group~~ed~~ avoidance rates have been presented. CRM results based on species-specific avoidance rates for herring gull, lesser black-backed gull, and great black-backed gull have been used in further assessments. However, due to limited sample size and insufficient evidence supporting species-specific rates, CRM results based on grouped avoidance rates have been used for black-legged kittiwake, northern gannet, northern fulmar, and Manx shearwater in subsequent assessments.

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Appendix A: Flight Height Distributions

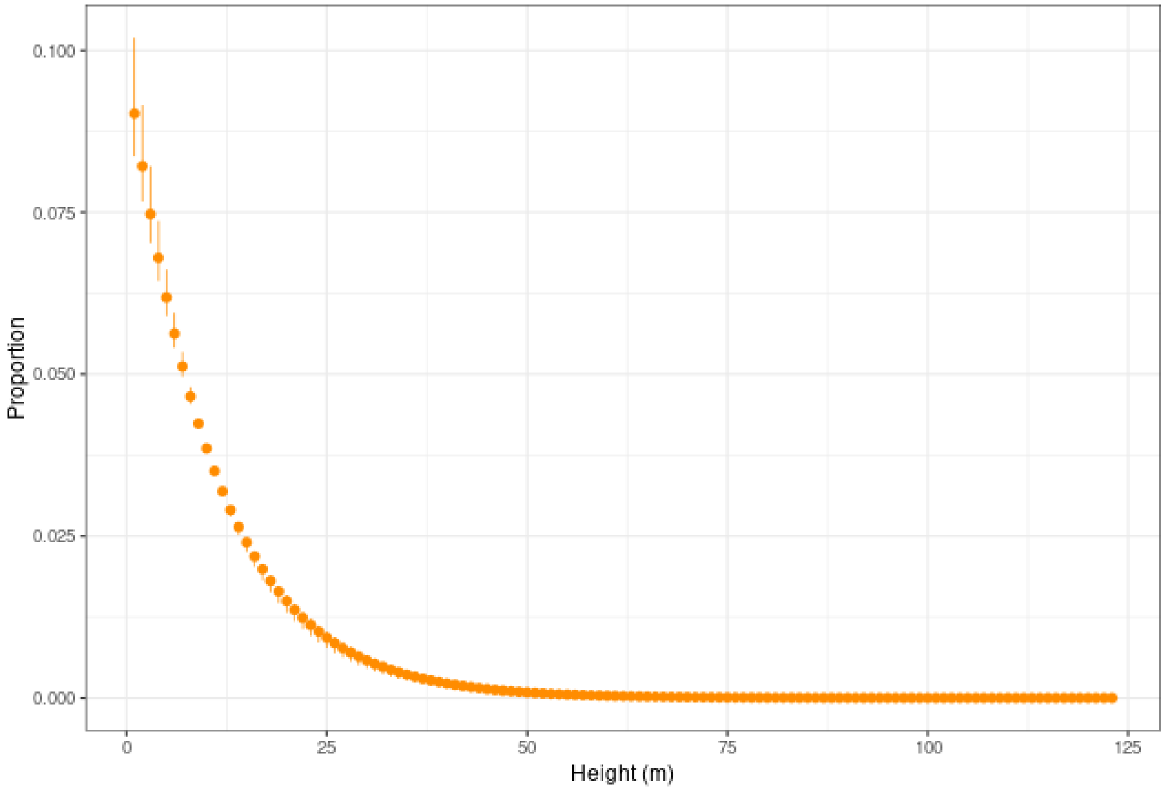

Figure A. 1: Proportion of black-legged kittiwake flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

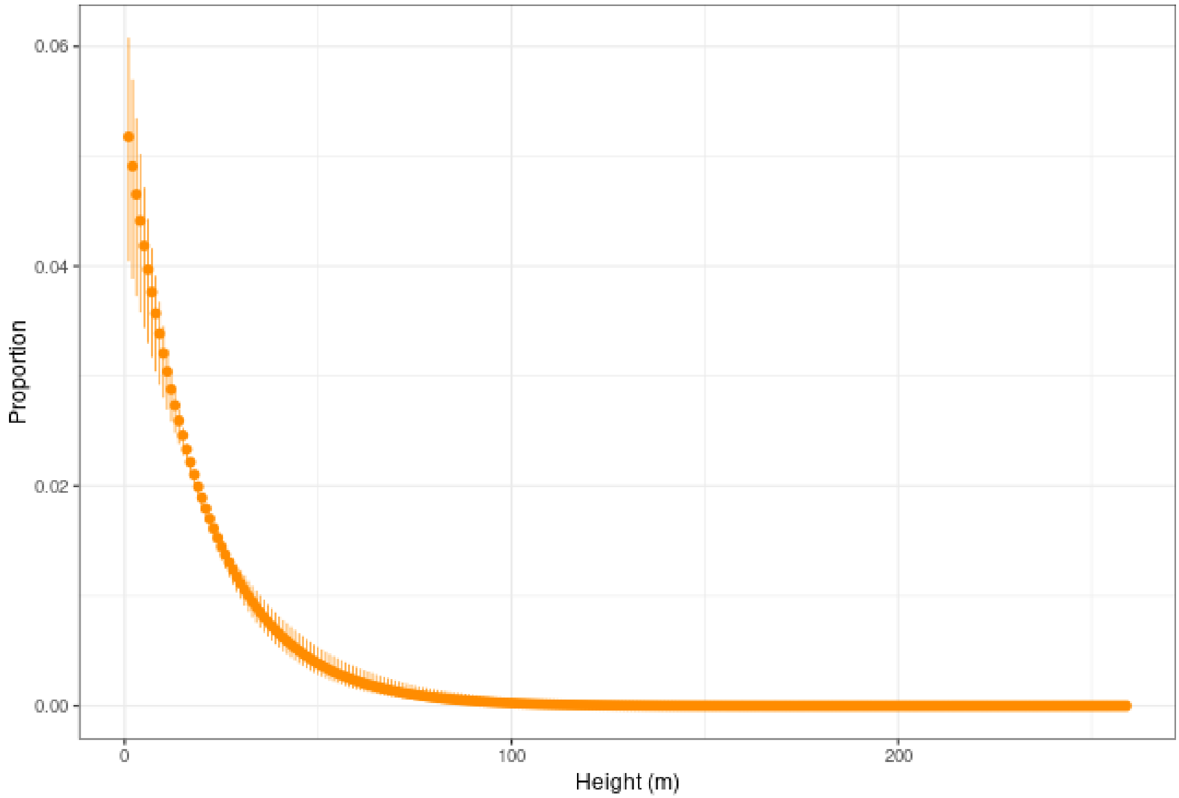

Figure A. 2: Proportion of great black-backed gull flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

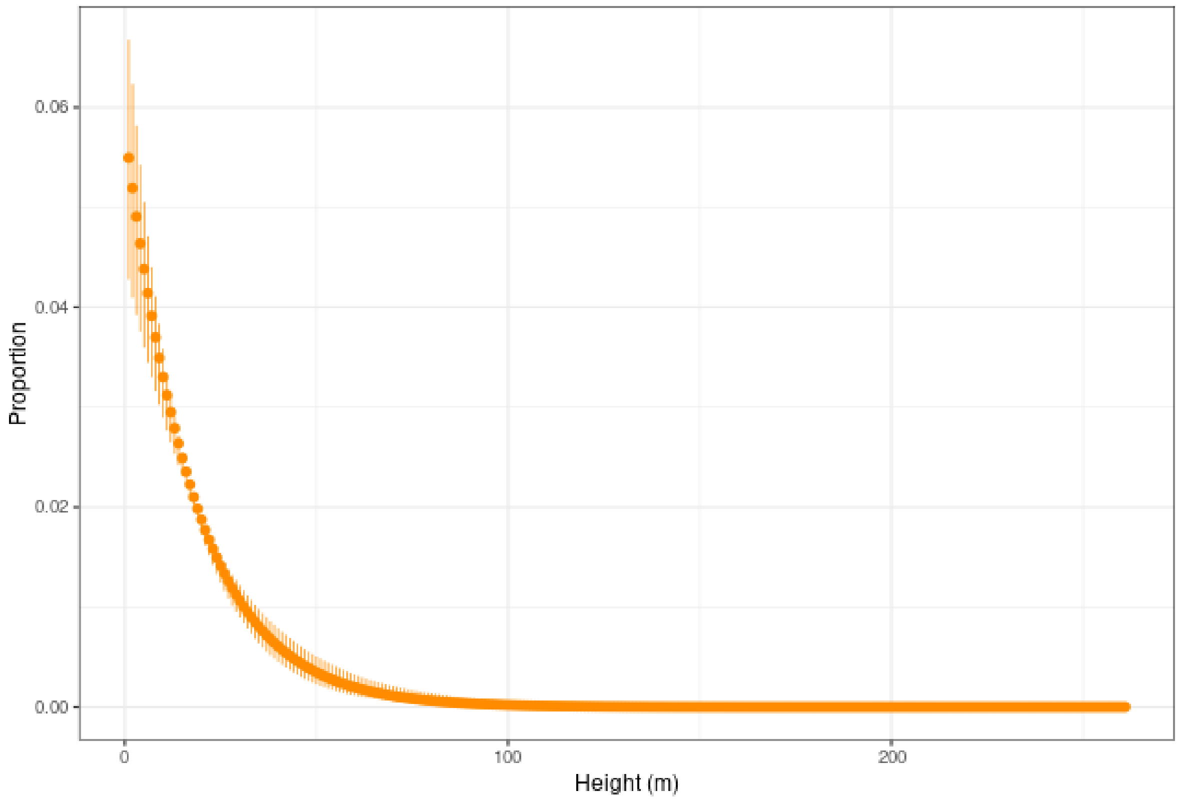

Figure A. 3: Proportion of European herring gull flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

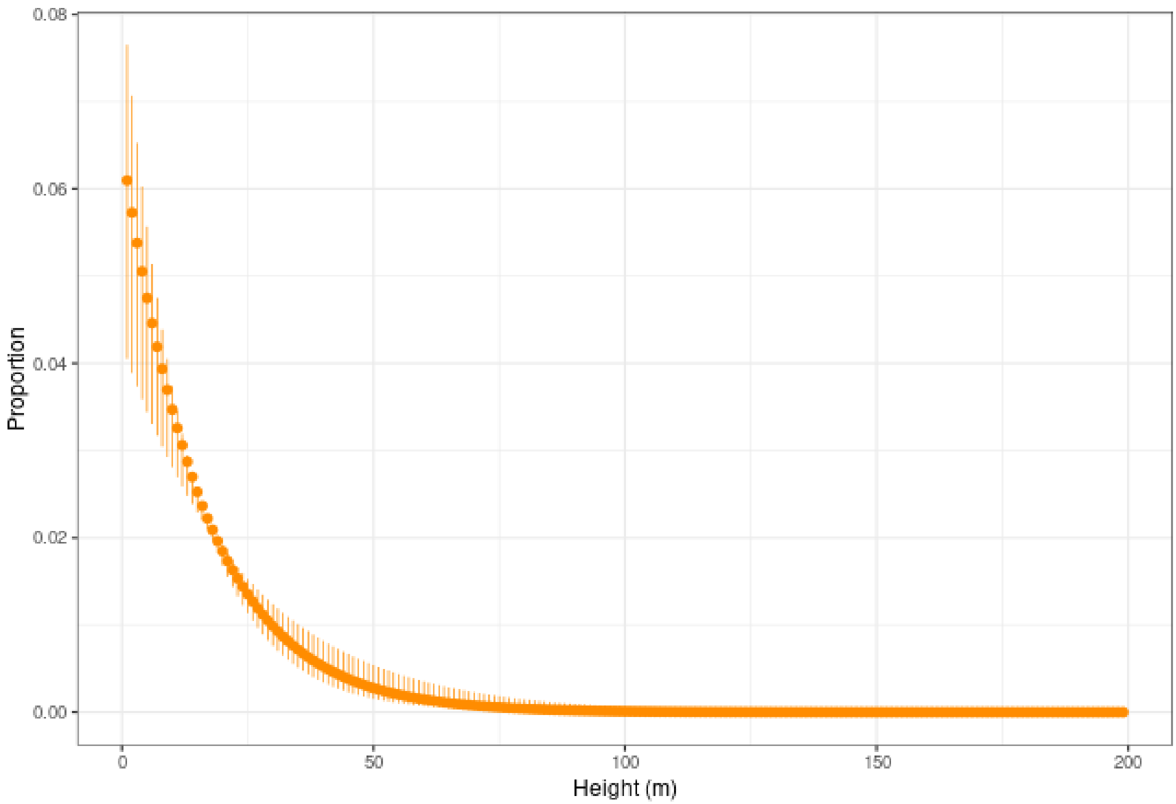

Figure A. 4: Proportion of lesser black-backed gull flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

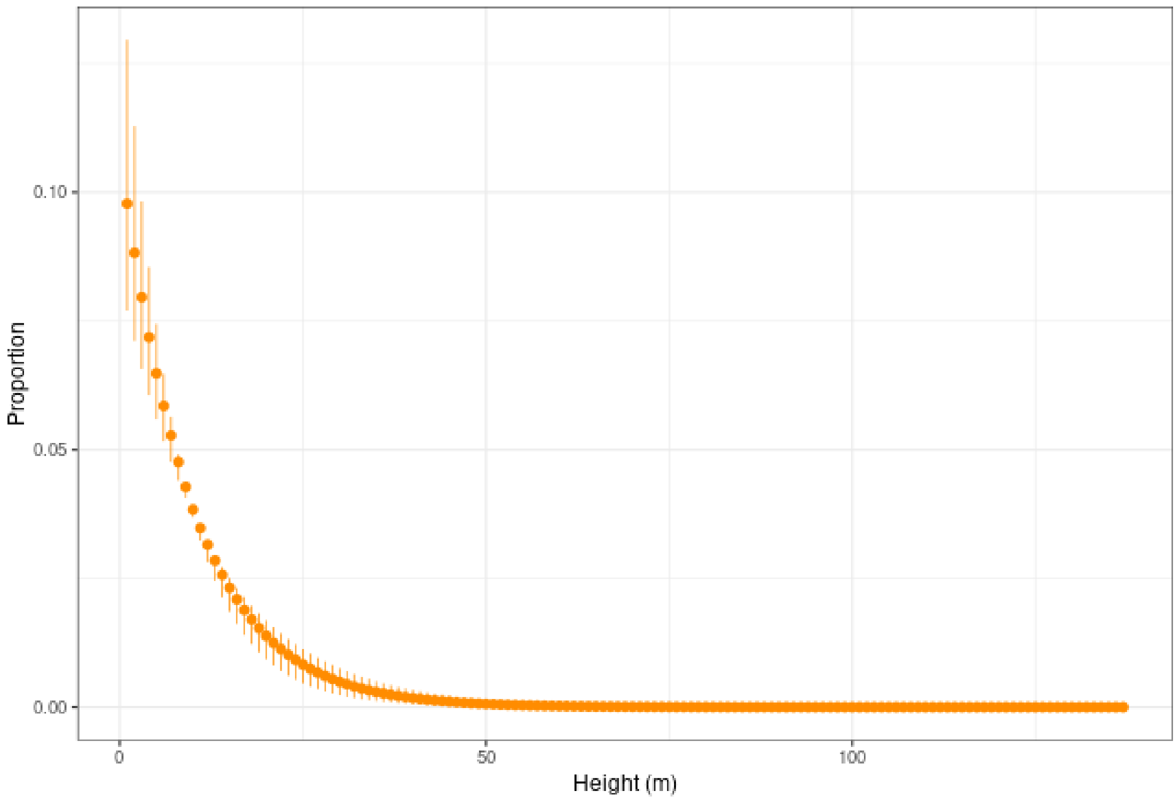

Figure A. 5: Proportion of Northern gannet flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

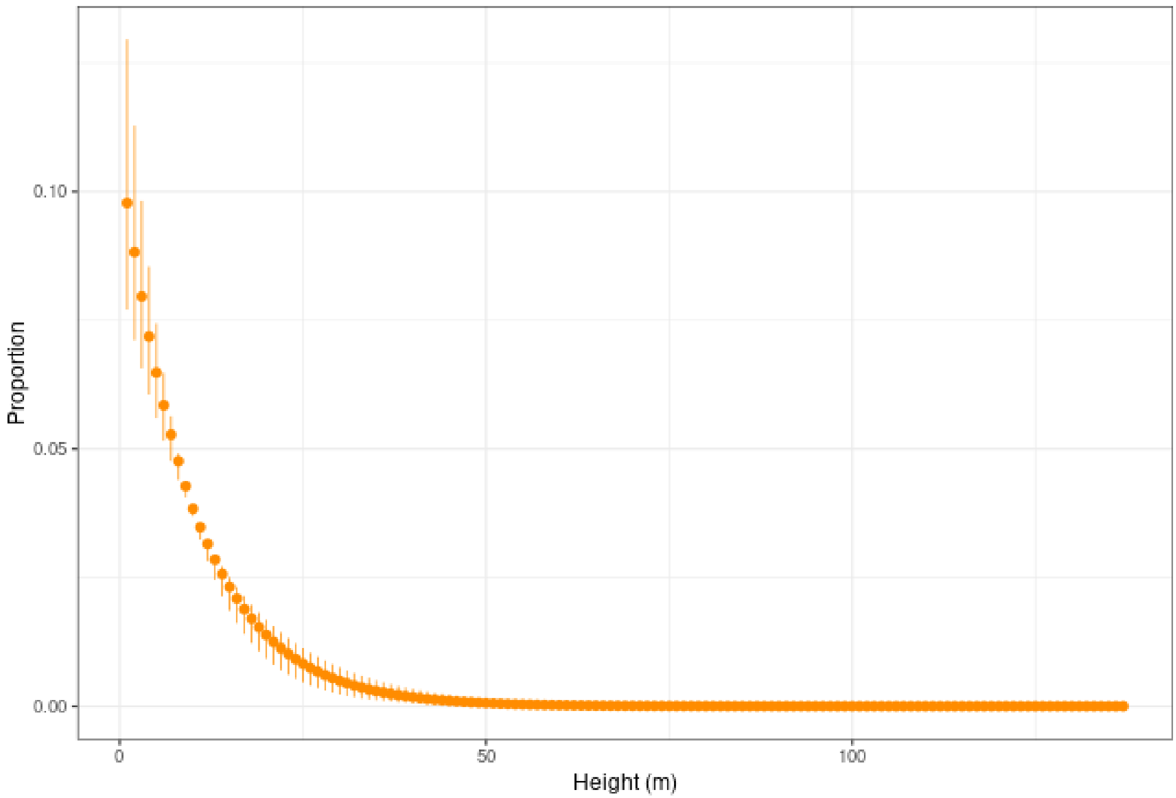

Figure A. 6: Proportion of Northern fulmar flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

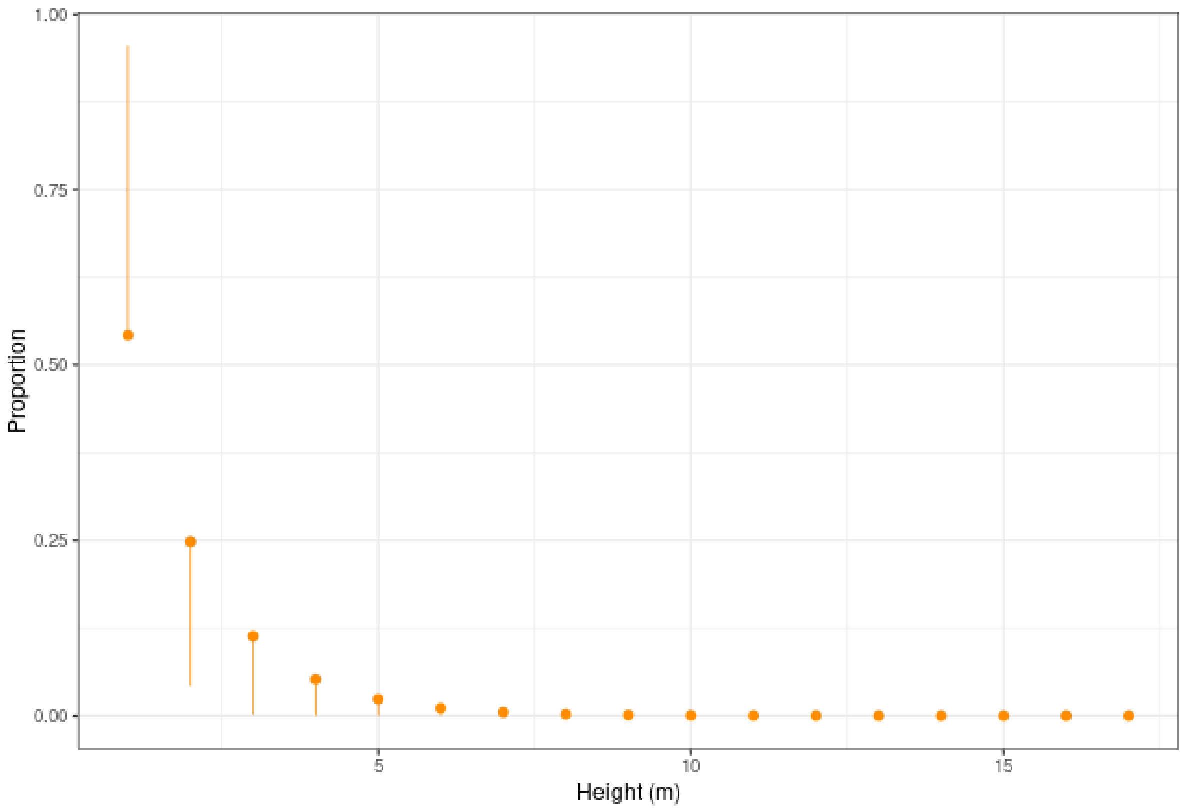

Figure A. 7: Proportion of Manx shearwater flying at 1 m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).