Partners in UK offshore wind

MONA OFFSHORE WIND PROJECT

Preliminary Environmental Information Report

Volume 6, annex 10.3: Offshore ornithology non-migratory seabird collision risk assessment

Image of an offshore wind farm

April 2023
FINAL

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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 1.1 and Table 1.2.
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
LAT	Lowest Astronomical Tide
LCI/UCI	Lower/Upper Confidence Interval
LiDAR	Light Detection And Ranging
MDS	Maximum Design Scenario
MSL	Mean Sea Level
NE	Natural England
NAF	Nocturnal Activity Factor
RPM	Rotations Per Minute
(s)CRM	(stochastic) Collision Risk Model
SPA	Special Protection Area

Units

Unit	Description
MW	Megawatt
km	Kilometres
m/s	Metres per second
m	Metres
cm	Centimetres

1 Offshore ornithology non-migratory 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 little available evidence 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.

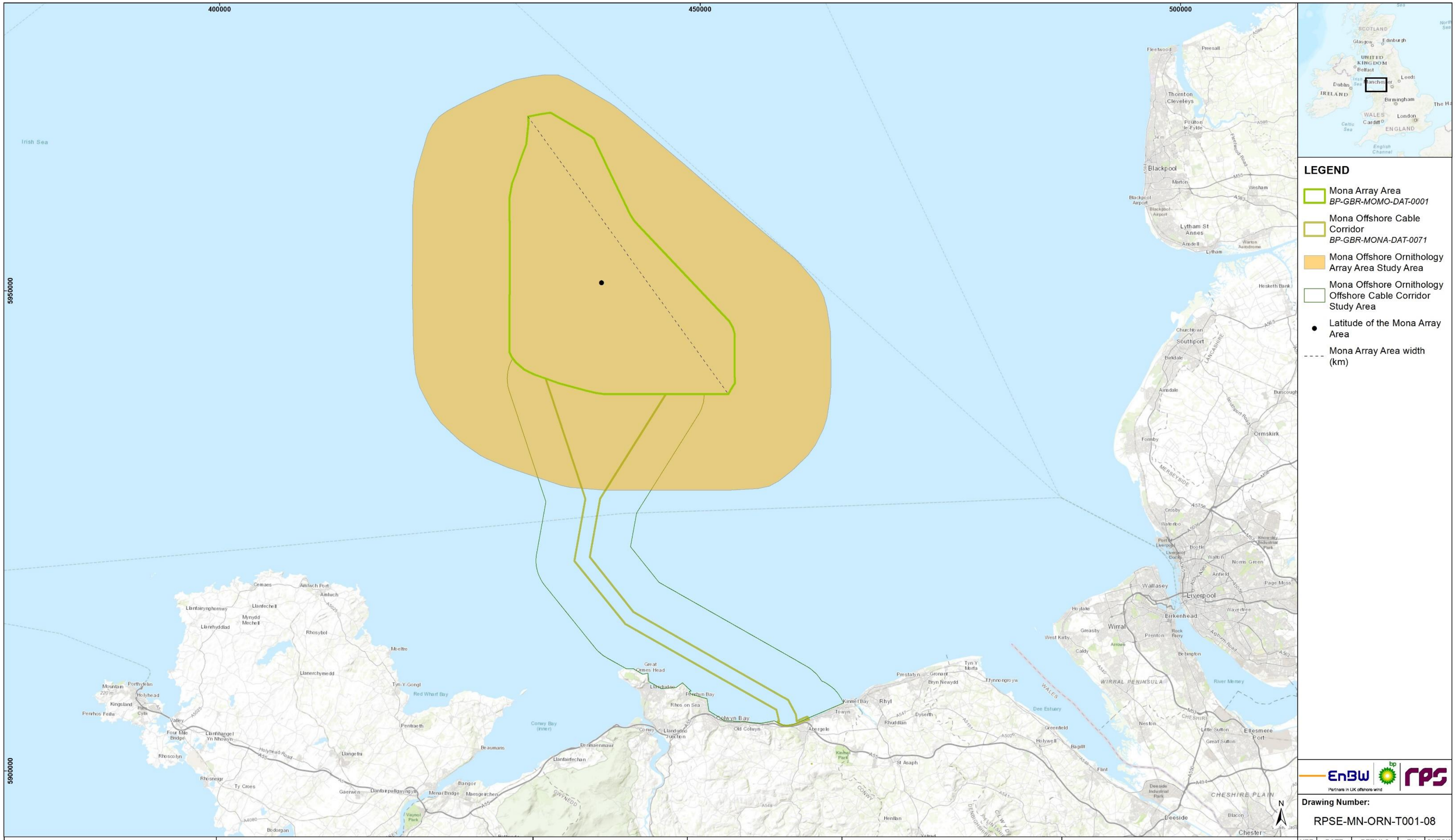
1.1.1.4 The significance of collision mortality within an offshore wind farm on any given species of bird varies in response to the size of its population, the density of the population within the windfarm site, background annual mortality rates and estimated rates of avoidance. As a general rule, a single individual lost from a small population will have an increased significance in comparison to a single individual lost from a large population. The loss of an individual bird will also be more significant if it is lost from a species that occurs at low density, is relatively long-lived and reproduces at a low rate. The opposite is also true where birds are relatively abundant, have high densities within an area, are short lived and have high reproduction rates, where the impact of collision fatality at the population level can be considered to be of negligible magnitude due to only causing a slight difference to the baseline conditions.

1.1.2 Aim of 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 10.1: Offshore ornithology baseline characterisation report of the Preliminary Environmental Information Report (PEIR). 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 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 (Figure 1.1). The Mona Array Area (i.e. the area within which the offshore wind turbines will be located) is located 28.2km (15.2nm) from the Anglesey coastline, 39.9km (21.5nm) from the northwest coast of England and 42.6km (23nm) from the Isle of Man (when measured from Mean High Water Springs (MHWS)). The Mona Array Area covers 449.97km^2.



Project Name: MONA OFFSHORE WIND PROJECT

Drawing Title: OFFSHORE ORNITHOLOGY STUDY AREA

0 1 2 4 6 nm
0 2.5 5 10 km

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@379mmx231mm: 1:401,898

Data Sources: Client,

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

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08	09/11/22	Revision	NA	JS

Figure 1.1: Mona offshore ornithology array area study area, Mona Array Area for collision risk modelling.

1.2 Methodology

1.2.1 Collison risk modelling

1.2.1.1 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, 2017)[1] has been followed for the modelling of collision impacts predicted for the Mona Array Area.

1.2.1.2 The collision risk models incorporated draft guidance on recommended avoidance rates, bird size, flight speed, flight type and nocturnal activity scores (Natural England, pers. comm., 7 July 2022). 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 1.1 and Table 1.2.

1.2.1.3 Collision risk models 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.

1.2.2 Screening species for collision risk assessment

1.2.2.1 sCRM has been carried out for ornithological receptors that are potentially vulnerable to collision with offshore wind turbines. A screening process was undertaken based on the density of flying birds recorded within the Mona Array Area and consideration of their perceived risk from collision (Garthe and Hüppop, 2004; Furness and Wade, 2012; Wade *et al*., 2016). Five seabird species were identified as potentially at risk due to their recorded abundance in the Mona Array Area and their likelihood of flying at potential collision height between the lowest and highest sweep of the wind turbine rotor blades above sea level. Additionally, consideration was given to species that may not have been accurately captured during baseline digital aerial surveys due to the diurnal timing of the surveys, with such species likely to be more active during the nocturnal, dusk and dawn periods (e.g. Manx shearwater and Northern fulmar). In total, sCRM was carried out on seven species:

- Black-legged kittiwake *Rissa tridactyla*
- Great black-backed gull *Larus marinus*
- European herring gull *Larus argentatus*
- Lesser black-backed gull *Larus fuscus*
- Northern gannet *Morus bassanus*
- Northern fulmar
- Manx shearwater.

1.2.2.2 Despite being recorded in high numbers, auk species (e.g. common guillemot *Uria aalge*, Atlantic puffin *Fratercula arctica* and razorbill *Alca torda*) are not considered to be vulnerable to collision risk impacts due to flying at low altitudes (flying below 20m) and therefore were excluded from the collision risk assessment.

1.2.3 Density estimates

1.2.3.1 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 programme of digital aerial surveys carried out in the Mona Offshore Ornithology Array Area study area, which extended from 4km up to 10km around the Mona Array Area. The full methods and results of the digital aerial surveys are presented in volume 6, annex 10.1: Offshore ornithology baseline characterisation report of the PEIR.

1.2.3.2 There were two density estimates for each calendar month as the baseline survey programme spanned 24 monthly samples across two years. For running a stochastic CRM, 1,000 bootstrapped values were generated for each month using either MRSea or design-based outputs.

1.2.4 Modelling parameters

Species biometrics

1.2.4.1 The sCRM incorporates a number of 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 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 particularly the case in relation to avoidance rates and nocturnal activity factors, which have some of the biggest influences on the predicted magnitude of risk.

1.2.4.2 Following advice from the Offshore Ornithology Expert Working Group, the sCRM has incorporated the updated avoidance rates presented in draft guidance (Natural England, pers. comm., 7 July 2022), which was based on a review by Ozsanlev-Harris *et al*. (in prep). With use of Band Option 2, these included a range incorporating variability or uncertainty (±1S.D.) (Table 1.1).

1.2.4.3 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

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

considered to be lower than during the day, therefore a percentage uplift 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 1.1.

1.2.4.4 Various other biometric parameters of each bird species are needed for species-specific sCRM, including bird length, wing-span, flight speed and flight type. The parameters are shown in Table 1.1, complying with draft recommendations provided by Natural England (pers. comm., 7 July 2022). For the purpose of sCRM, all species are assumed to use ‘flapping’ flight and have 50% proportions of flights upwind/downwind.

1.2.4.5 Additionally, the updated guidance from Natural England (pers. comm., 7 July 2022) states that the suggested approach to northern gannet sCRM involves the reduction of the density of birds in flight by an agreed macro-avoidance rate. Macro-avoidance is accounted for this species due to an expected high level of macro-avoidance to offshore wind farms being displayed by northern gannet. A project has currently been commissioned by Natural England to inform this rate using best available evidence, however in the meantime, Natural England has recommended the use of a macro-avoidance rate of 70%. Densities within the Mona Array Area therefore were reduced by 70% for northern gannet.

Table 1.1: 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, lesser black-backed gull and northern gannet are as specified in Natural England (2021), derived from Pennycuick (1987, 1997) and Alerstam *et al.* (2007). Northern fulmar flight speed from Pennycuick (1997). Manx shearwater flight speed is the mean ground speed reported by Gibb *et al*. (2017) for flapping flight.

c Specific avoidance rates are not provided in advice documents for northern fulmar and Manx shearwater, therefore the default 99.1% avoidance rate applies (pers. comm., 7 July 2022). Evidence based NAF for gannet based on 8% nocturnal flight activity during the breeding season and 4% during the non-breeding season (Furness et al., 2018). Standard NAF derived from Natural England (pers. comm., 7 July 2022) and King *et al*. (2009).

d Updated avoidance rates taken from Natural England draft guidance, which was based on Ozsanlev-Harris *et al.* (in prep).

Species	Body length (m)[a]	Wing-span (m)[a]	Flight speed (m/s)[b]	Nocturnal Activity Factor[c]	Avoidance rate (%)[d]
Black-legged kittiwake	0.39 (±0.005)	1.08 (±0.0625)	13.1 (±0.40)	0.375 (±0.0637) (25-50%)	0.993 (±0.0003)
Great black-backed gull	0.71 (±0.0375)	1.58 (±0.0375)	13.7 (±1.20)	0.375 (±0.0637) (25-50%)	0.994 (±0.0004)
European herring gull	0.60 (±0.0225)	1.44 (±0.03)	12.8 (±1.80)	0.375 (±0.0637) (25-50%)	0.994 (±0.0004)
Lesser black-backed gull	0.58 (±0.03)	1.42 (±0.0375)	13.1 (±1.90)	0.375 (±0.0637) (25-50%)	0.994 (±0.0004)
Northern fulmar	0.48 (±0.0125)	1.07 (±0.025)	13.0 (±1.98)	0.75 (±0.00) (75%)	0.991 (±0.0004)[c]
Manx shearwater	0.34 (±0.02)	0.82 (±0.0325)	11.46 (± 2.23)	1.0 (± 0.00) (100%)	0.991 (±0.0004)[c]
Northern gannet	0.94 (±0.0325)	1.72 (±0.0375)	14.9 (±0.00)	0.08 (±0.10) (0-25%) (and 4-8%)	0.993 (±0.0003)

Turbine model

1.2.4.6 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 are shown in Table 1.2 and were taken from Table 1.14 in volume 6, chapter 10: Offshore Ornithology report of the PEIR.

Table 1.2: 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 PEIR).

Parameter[a]	Parameter value	Source/Reference
Max. number of wind turbines	107	Volume 6, chapter 10: Offshore ornithology of the PEIR
Number of rotor blades per wind turbine	3	Volume 6, chapter 10: Offshore ornithology of the PEIR
Max. chord width (m)	6.8	Volume 6, chapter 10: Offshore ornithology of the PEIR
Average blade pitch (degrees)	10	Volume 6, chapter 10: Offshore ornithology of the PEIR
Max. rotor radius (m)	125	Volume 6, chapter 10: Offshore ornithology of the PEIR
Average rotation speed (rpm)	6.4	Volume 6, chapter 10: Offshore ornithology of the PEIR
Tidal offset (m) (MSL)	+/- 4	Volume 6, chapter 10: Offshore ornithology of the PEIR
Lower blade tip height above Lowest Astronomical Tide LAT (m)	34	Volume 6, chapter 10: Offshore ornithology of the PEIR
Air gap (MSL) (m)	30	Air gap relative to Mean Sea Level (MSL) allowing for -4m tidal offset between LAT and MSL
Wind farm width (km)	35.64	Calculated in RStudio
Latitude	53.70	Calculated in RStudio
Large array correction	YES	Standard procedure

Flight heights

1.2.4.7 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 Natural England. 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. 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.

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

1.2.5 Seasonality

1.2.5.1 Collision risk is reported for each 'bio-season'. Bio-seasons were defined according to the breeding, non-breeding and migratory periods using seasonal divisions proposed for Biologically Defined Minimum Population Scales (BDMPS) by Furness (2015) as shown in Table 1.3.

1.2.5.2 The estimated collision risks are presented on a monthly basis with no apportioning to colonies (i.e. the total predicted collision rates).

Table 1.3: Seasonal definitions, from Furness (2015).

Species	Pre-Breeding Season/spring migration	Breeding season	Post Breeding Season/autumn migration	Non-breeding/winter season
Black-legged kittiwake	January to April	April to August	August to December	n/a
Great black-backed gull	n/a	Late March to August	n/a	September to March
European herring gull	n/a	March to August	n/a	September to February
Lesser black-backed gull	March to April	April to August	August to October	November to February
Northern gannet	December to March	March to September	September to November	n/a
Northern fulmar	December to March	January to August	September to October	November
Manx shearwater	Late March to May	April to August	August to early October	n/a

1.2.5.3 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.

1.2.5.4 For the breeding season, the assessment was undertaken against an appropriate regional population scale (covering the total colony counts within mean-maximum foraging range plus one standard deviation). Foraging ranges were identified from Woodward *et al.* (2019). Species-specific mean-max (+1S.D.) foraging ranges compiled by Woodward *et al.* (2019) were used to select the relevant colonies (SPA and non-SPA) and calculate appropriate breeding population sizes. The locations of the breeding sites were sourced from data.gov.uk (Seabird Nesting Counts (British Isles)). The latest colony counts were sourced from the Seabird Monitoring Programme (SMP) online database (https://app.bto.org/seabirds/public/index.jsp).

1.2.5.5 Similarly, the assessment was undertaken against an appropriate population scale during the non-breeding season and migratory periods using biological populations (BDMPS) defined by Furness (2015).

1.2.5.6 The magnitude of the collision risks to each species has been preliminarily assessed against a threshold of 1% increase in the rate of baseline mortality, derived from Horswill and Robinson (2015). Where this threshold is exceeded, the impact will be subject to further consideration such as population modelling. Where the 1% threshold is not exceeded, the impact of the project alone is not considered likely to be significant but will be examined in the context of the assessment of cumulative or in-combination impacts.

1.2.5.7 Population figures and average baseline mortality rates used within the sCRM assessment are presented within Table 1.4.

Table 1.4: Bio-season population sizes and average background mortality rate used within the assessment.

Species	Pre-breeding season/spring migration	Breeding season	Post-breeding Season/autumn migration	Non-breeding/ winter season	Average mortality rate
Black-legged kittiwake	January to April (691,526)	April to August (393,449)	August to December (911,586)	n/a	0.157
Great black-backed gull	n/a	Late March to August (10,480)	n/a	September to March (17,742)	0.096
European herring gull	n/a	March to August (100,561)	n/a	September to February (173,299)	0.172
Lesser black-backed gull	March to April (163,304)	April to August (96,971)	August to October (163,304)	November to February (41,159)	0.124
Northern gannet	December to March (661,888)	March to September (448,235)	September to November (545,954)	n/a	0.187
Northern fulmar	December to March (828,194)	January to August (393,701)	September to October (828,194)	November (556,367)	0.181
Manx shearwater	March to May (1,580,895)	April to August (1,974,500)	August to early October (1,580,895)	n/a	0.131

1.3 Results

1.3.1 Black-legged kittiwake

1.3.1.1 The monthly expected number of collisions for black-legged kittiwake are presented in Figure 1.2 and Table 1.5. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.6.

1.3.1.2 Black-legged kittiwake had monthly densities of flying birds of up to 0.99 per km^2. The annual number of expected collisions is 37, ranging from 23 to 55. The corresponding increase in annual baseline mortality ranges from 0.023% to 0.055%, which is well below the 1% threshold.

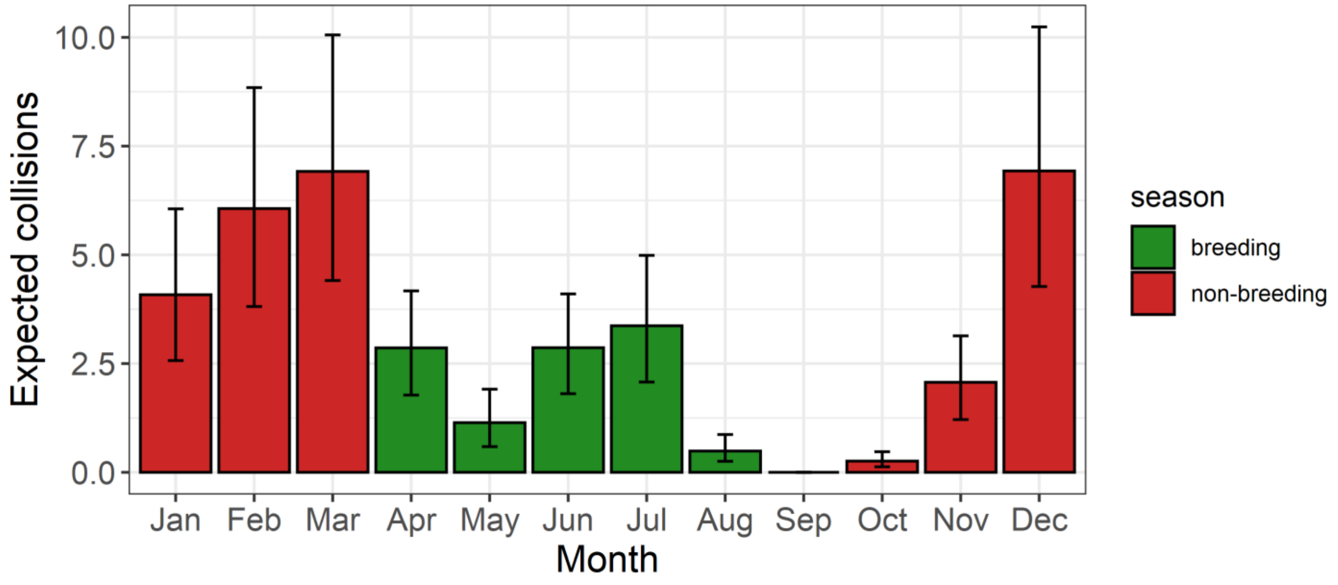

Figure 1.2: Black-legged kittiwake expected collisions across months.

Table 1.5: Black-legged kittiwake expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.57	4.08	2.57	6.06
February	0.88	6.06	3.81	8.85
March	0.83	6.92	4.41	10.06
April	0.33	2.86	1.78	4.17
May	0.12	1.14	0.59	1.91
June	0.30	2.87	1.81	4.10
July	0.34	3.37	2.08	4.99
August	0.05	0.49	0.25	0.87
September	0.00	0.00	0.00	0.00
October	0.03	0.26	0.13	0.47
November	0.29	2.07	1.21	3.14
December	0.99	6.93	4.27	10.24
TOTAL	0.39	37.05	22.91	54.86

Table 1.6: Black-legged kittiwake expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional baseline population	Baseline mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Pre-breeding	691,526	108,570	12.6 to 29.1	0.0116 to 0.0268
Breeding	393,307	61,771	4.6 to 11.4	0.0074 to 0.0184
Post-breeding	911,586	143,119	5.7 to 14.3	0.0040 to 0.0100
Annual	911,586	143,119	22.9 to 54.9	0.0230 to 0.0552

1.3.2 Great black-backed gull

1.3.2.1 The monthly expected number of collisions for great black-backed gull are presented in Figure 1.3 and Table 1.7. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.8.

1.3.2.2 Great black-backed gull had monthly densities of flying birds of up to 0.07 per km^2. The annual number of expected collisions is seven, ranging from three to 15. The corresponding increase in annual baseline mortality ranges from 0.18% to 0.87%, which is below the 1% threshold.

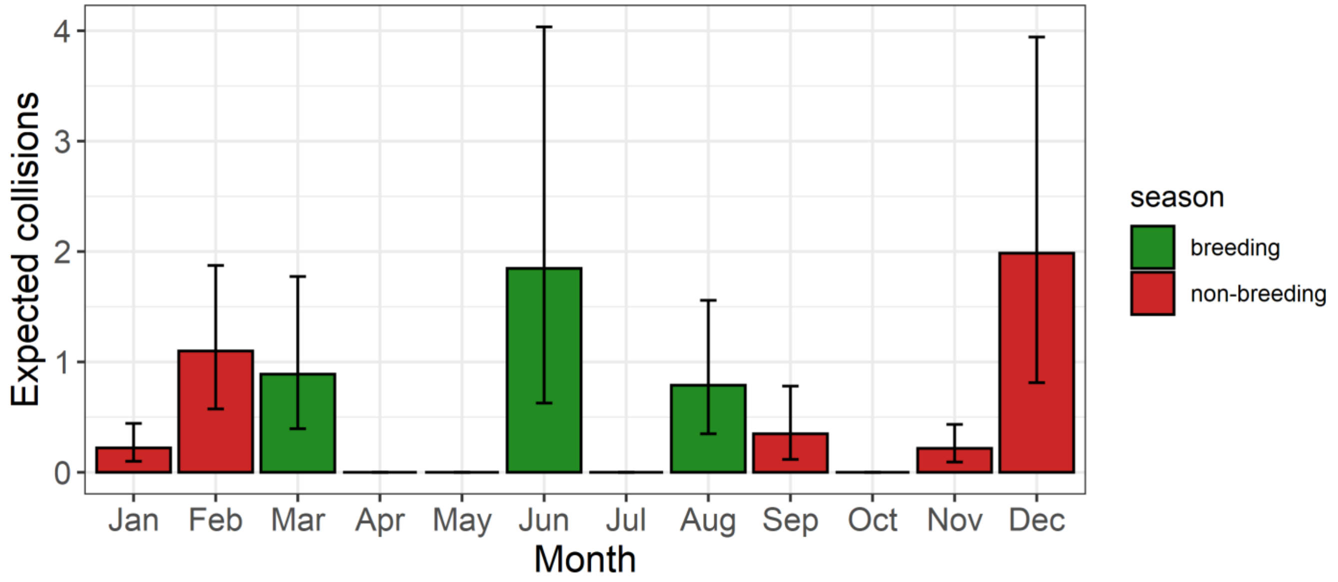

Figure 1.3: Great black-backed gull expected collisions across months.

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

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.01	0.22	0.10	0.44
February	0.04	1.10	0.57	1.87
March	0.03	0.89	0.40	1.77
April	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00
June	0.05	1.85	0.63	4.04
July	0.00	0.00	0.00	0.00
August	0.02	0.79	0.35	1.56
September	0.01	0.35	0.12	0.78
October	0.00	0.00	0.00	0.00
November	0.01	0.22	0.09	0.43
December	0.07	1.99	0.81	3.94
TOTAL	**0.02**	**7.41**	**3.07**	**14.83**

Table 1.8: Great black-backed gull expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Breeding	10,480	1,006	1.2 to 6.5	0.1193 to 0.6461
Non-breeding	17,742	1,703	1.9 to 8.4	0.1112 to 0.4910
Annual	17,742	1,703	3.1 to 14.8	0.1801 to 0.8715

1.3.3 European herring gull

1.3.3.1 The monthly expected number of collisions for European herring gull are presented in Figure 1.4 and Table 1.9. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.10.

1.3.3.2 European herring gull had monthly densities of flying birds of up to 0.03 per km^2. The annual number of expected collisions is two, ranging from one to five. The corresponding increase in annual baseline mortality range is 0.002% to 0.016%, which is well below the 1% threshold.

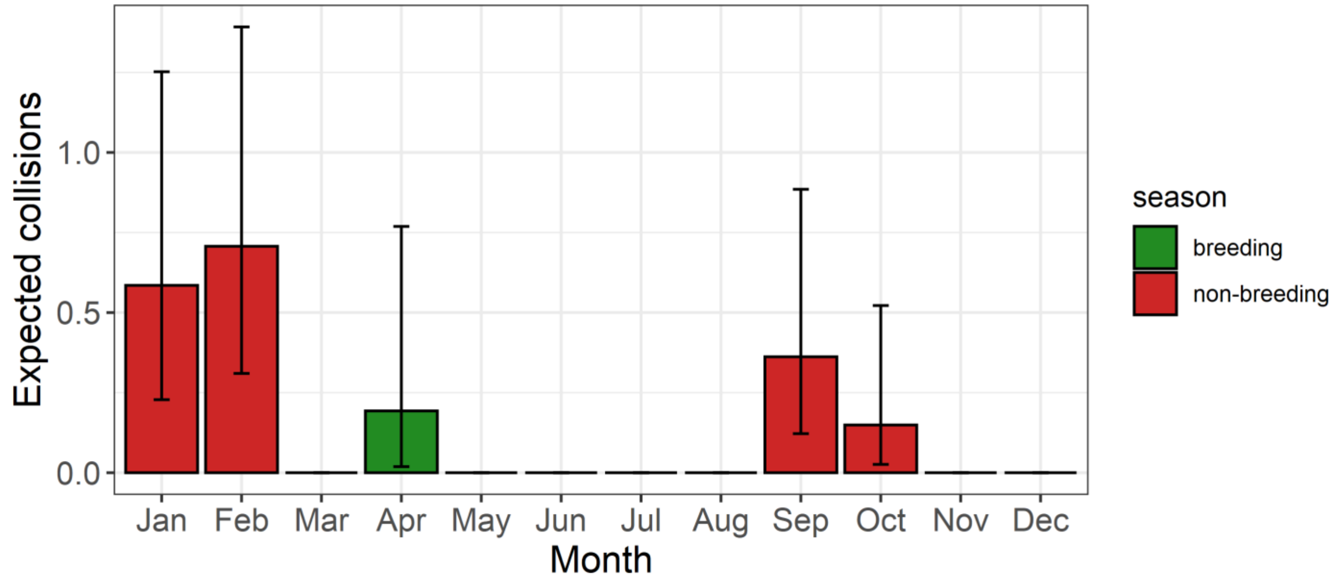

Figure 1.4: European herring gull expected collisions across months.

Table 1.9: Herring gull expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.03	0.59	0.23	1.25
February	0.03	0.71	0.31	1.39
March	0.00	0.00	0.00	0.00
April	0.01	0.19	0.02	0.77
May	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00
September	0.01	0.36	0.12	0.89
October	0.01	0.15	0.03	0.52
November	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00
TOTAL	**0.01**	**2.00**	**0.71**	**4.82**

Table 1.10: European herring gull expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Breeding	99,462	17,296	0.0 to 0.8	0.0001 to 0.0046
Non-breeding	173,299	29,807	0.7 to 4.1	0.0023 to 0.0136
Annual	173,299	29,807	0.7 to 4.8	0.0024 to 0.0162

1.3.4 Lesser black-backed gull

1.3.4.1 The monthly expected number of collisions for lesser black-backed gull are presented in Figure 1.5 and Table 1.11. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.12.

1.3.4.2 Lesser black-backed gull had monthly densities of flying birds of up to 0.03 per km^2. The annual number of expected collisions is two, ranging from one to four. The corresponding increase in annual baseline mortality range is 0.003% to 0.022%, which is well below the 1% threshold.

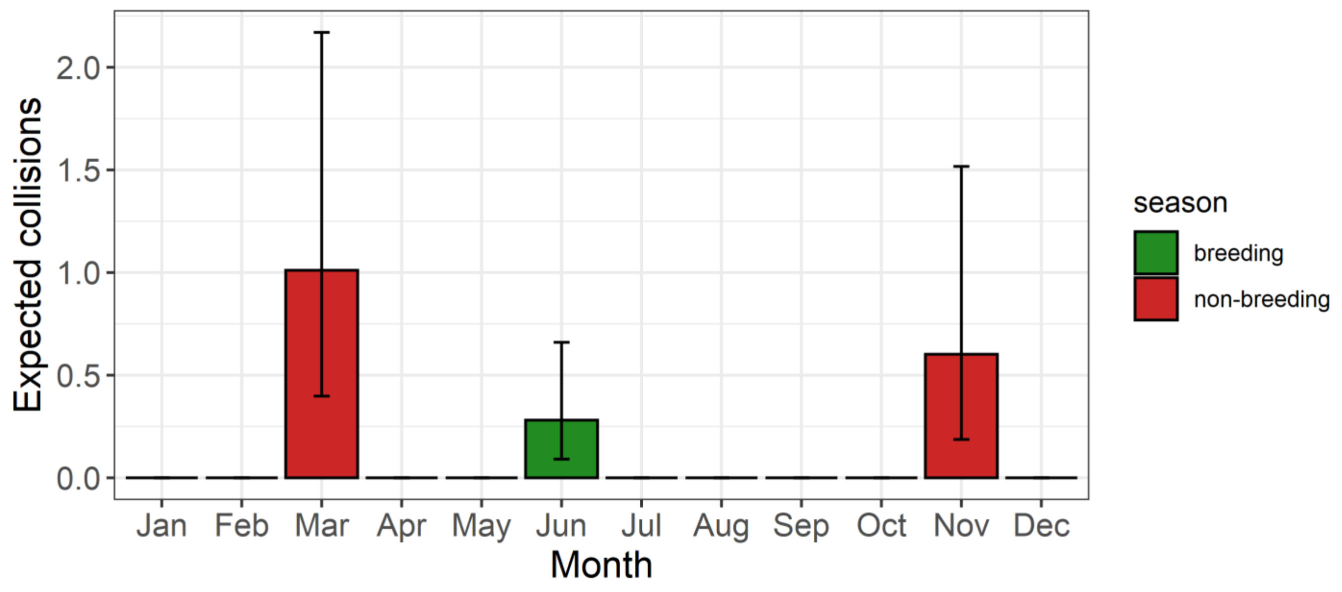

Figure 1.5: Lesser black-backed gull expected collisions across months.

Table 1.11: Lesser black-backed gull expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00
March	0.04	1.01	0.40	2.17
April	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00
June	0.01	0.28	0.09	0.66
July	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00
November	0.03	0.60	0.19	1.52
December	0.00	0.00	0.00	0.00
TOTAL	**0.01**	**1.89**	**0.68**	**4.35**

Table 1.12: Lesser black-backed gull expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Pre-breeding	163,304	20,250	0.4 to 2.2	0.0020 to 0.0107
Breeding	96,971	12,024	0.1 to 0.7	0.0008 to 0.0058
Post-breeding	163,304	20,250	0.0 to 0.0	0.0000 to 0.0000
Non-breeding	41,159	5,104	0.2 to 1.5	0.0005 to 0.0037
Annual	163,304	20,250	0.7 to 4.3	0.0033 to 0.0215

1.3.5 Northern gannet

1.3.5.1 The monthly expected number of collisions for northern gannet are presented in Figure 1.6 and Table 1.14. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.14.

1.3.5.2 Northern gannet had monthly densities of flying birds of up to 0.06 per km^2. The annual number of expected collisions is two, ranging from one to five. The corresponding increase in annual baseline mortality range is 0.0005% to 0.0043%, which is well below the 1% threshold.

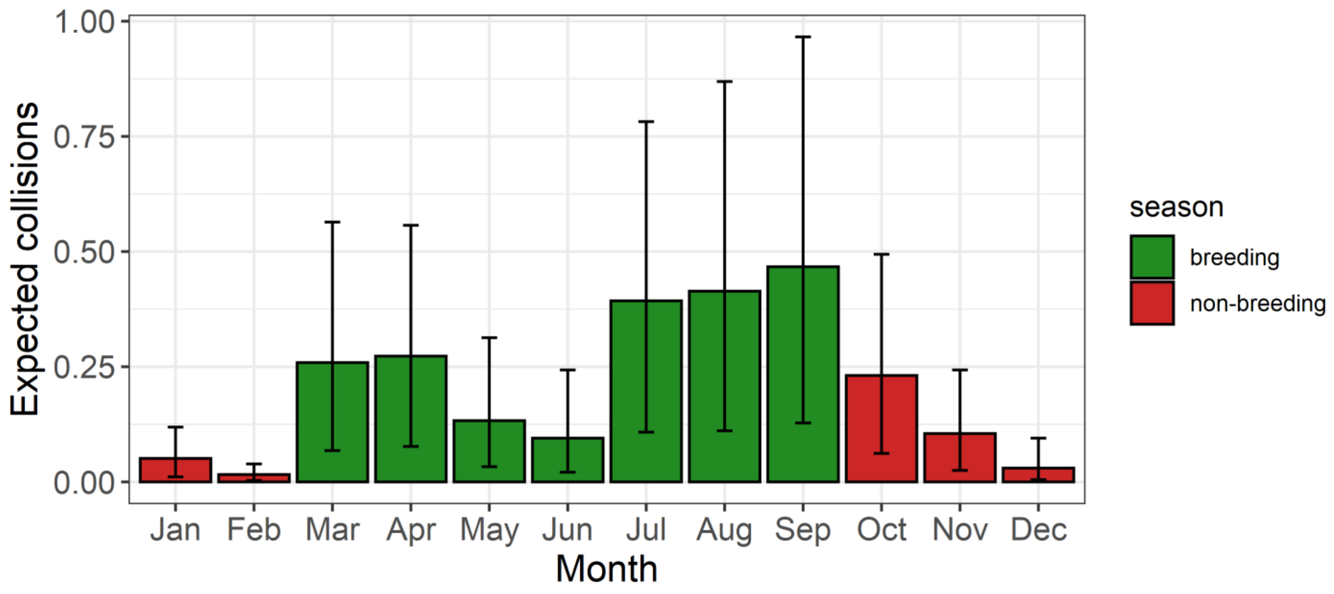

Figure 1.6: Northern gannet expected collisions across months.

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

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.01	0.05	0.01	0.12
February	0.00	0.02	0.00	0.04
March	0.03	0.26	0.07	0.56
April	0.03	0.27	0.08	0.56
May	0.01	0.13	0.03	0.31
June	0.01	0.10	0.02	0.24
July	0.04	0.39	0.11	0.78
August	0.04	0.41	0.11	0.87
September	0.06	0.47	0.13	0.97
October	0.03	0.23	0.06	0.49
November	0.02	0.11	0.03	0.24
December	0.01	0.03	0.01	0.10
TOTAL	0.02	2.47	0.66	5.28

Table 1.14: Northern gannet expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Pre-breeding	661,888	123,773	0.1 to 0.5	0.0000 to 0.0004
Breeding	448,235	83,820	0.4 to 3.5	0.0005 to 0.0042
Post-breeding	545,954	102,093	0.2 to 1.2	0.0001 to 0.0012
Annual (BDPMS)	661,888	123,773	0.7 to 5.3	0.0005 to 0.0043

1.3.6 Northern fulmar

1.3.6.1 The monthly expected number of collisions for northern fulmar are presented in Figure 1.7 and Table 1.15. The corresponding increase in baseline mortality across bio-seasons is presented in Table 1.16.

1.3.6.2 Northern fulmar had monthly densities of flying birds of up to 0.10 per km^2. The annual number of expected collisions is 0, ranging from 0 to 2. The corresponding increase in annual baseline mortality range is 0.000% to 0.001%, which is well below the 1% threshold.

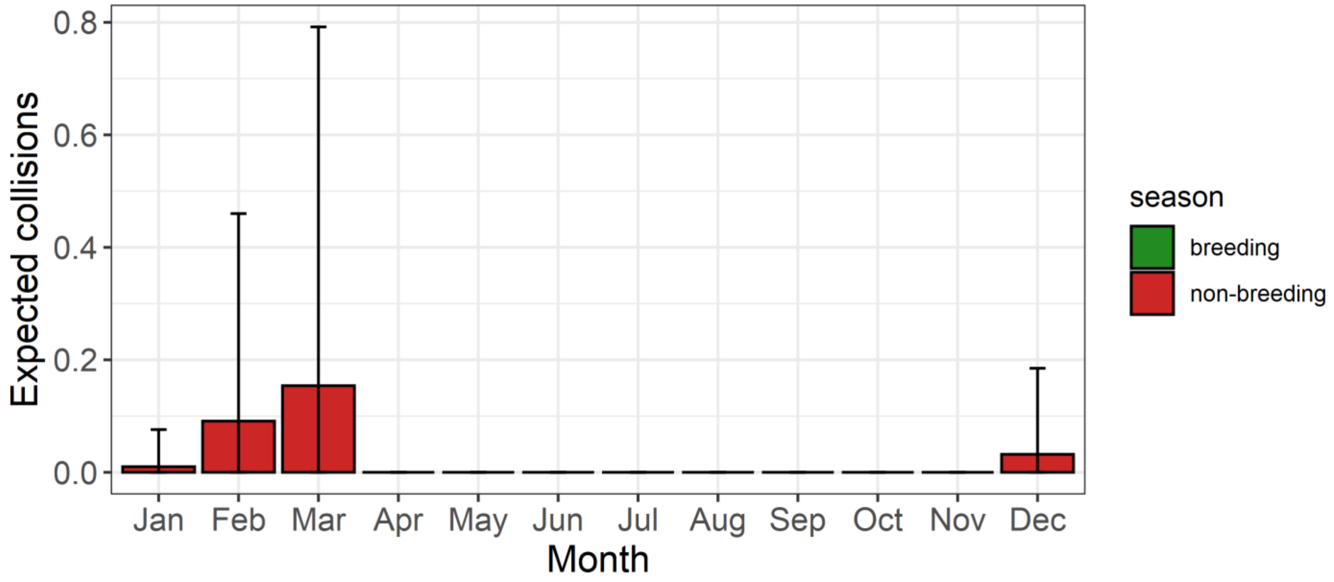

Figure 1.7: Northern fulmar expected collisions across months.

Table 1.15: Northern fulmar expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.00	0.01	0.00	0.08
February	0.06	0.09	0.00	0.46
March	0.10	0.15	0.00	0.79
April	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00
September	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00
December	0.02	0.03	0.00	0.19
TOTAL	0.02	0.28	0.00	1.52

Table 1.16: Northern fulmar expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Pre-breeding	828,194	149,903	0.0 to 1.5	0.0000 to 0.0015
Breeding	393,701	71,260	0.0 to 0.0	0.0000 to 0.0000
Post-breeding	828,194	149,903	0.0 to 0.0	0.0000 to 0.0000
Non-breeding	556,367	100,702	0.0 to 0.0	0.0000 to 0.0000
Annual	828,194	149,903	0.0 to 1.5	0.0000 to 0.0010

1.3.7 Manx shearwater

1.3.7.1 The monthly expected number of collisions for Manx shearwater are presented in Table 1.17. Because collisions are expected to be zero across each month, no figure is presented. The corresponding lack of increase in baseline mortality across bio-seasons is presented in Table 1.18.

1.3.7.2 Manx shearwater had monthly densities of flying birds of up to 1.18 per km^2. As mentioned previously, the annual number of expected collisions is 0 even at the upper range.

Table 1.17: Manx shearwater expected collisions across months including lower (LCI) and upper (UCI) confidence intervals.

Month	Density (birds/km^2)	Expected collisions	LCI	UCI
January	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00
March	0.01	0.00	0.00	0.00
April	0.02	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00
June	1.18	0.00	0.00	0.00
July	0.66	0.00	0.00	0.00
August	0.41	0.00	0.00	0.00
September	0.03	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00

Table 1.18: Manx shearwater expected additional mortality due to collisions with wind turbines across bio-seasons.

Bio-season	Regional Baseline Population	Baseline Mortality	Collision mortality (number of birds)	Increase in baseline mortality (%)
Pre-breeding	1,580,895	207,097	0.0 to 0.0	0.0000 to 0.0000
Breeding	1,974,500	254,336	0.0 to 0.0	0.0000 to 0.0000
Post-breeding	1,580,895	207,097	0.0 to 0.0	0.0000 to 0.0000
Annual (BDPMS)	1,974,500	254,336	0.0 to 0.0	0.0000 to 0.0000

1.4 References

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Appendix A Flight Height Distributions

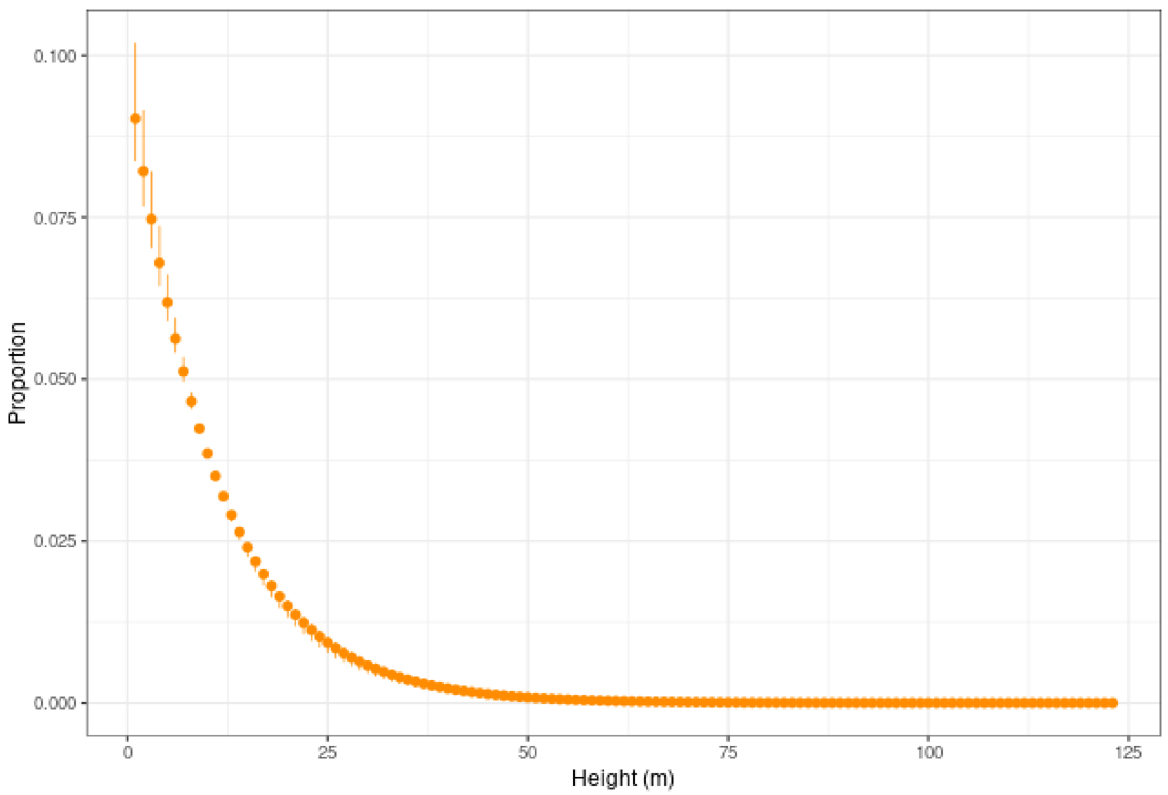

Figure A 1: Proportion of black-legged kittiwake flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

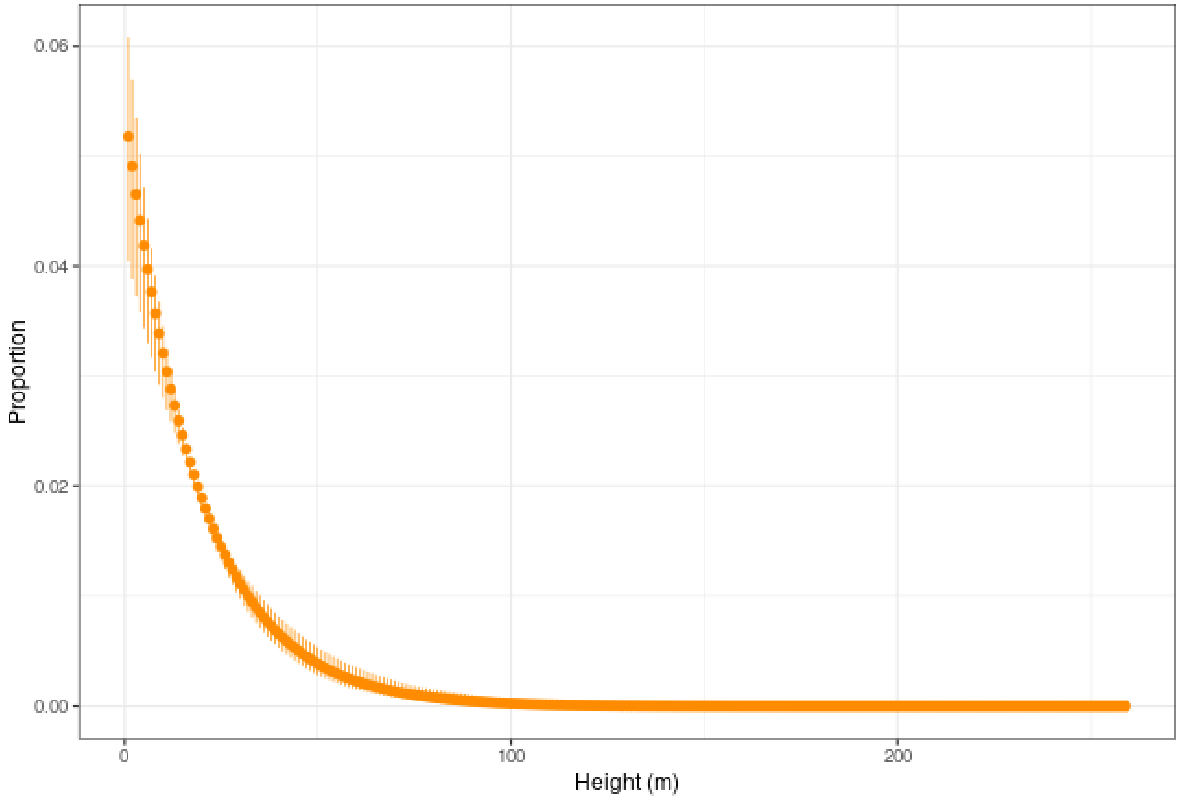

Figure A 2: Proportion of great black-backed gull flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson et al. (2014a, 2014b).

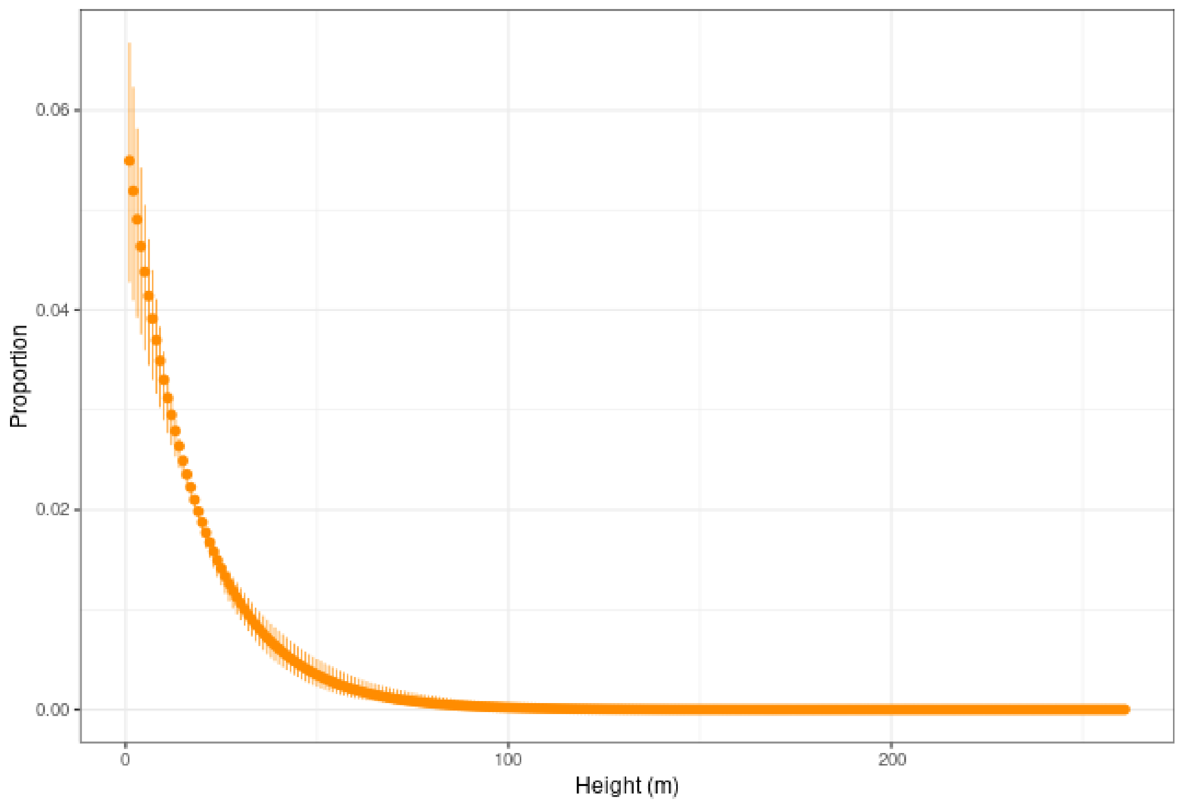

Figure A 3: Proportion of European herring gull flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

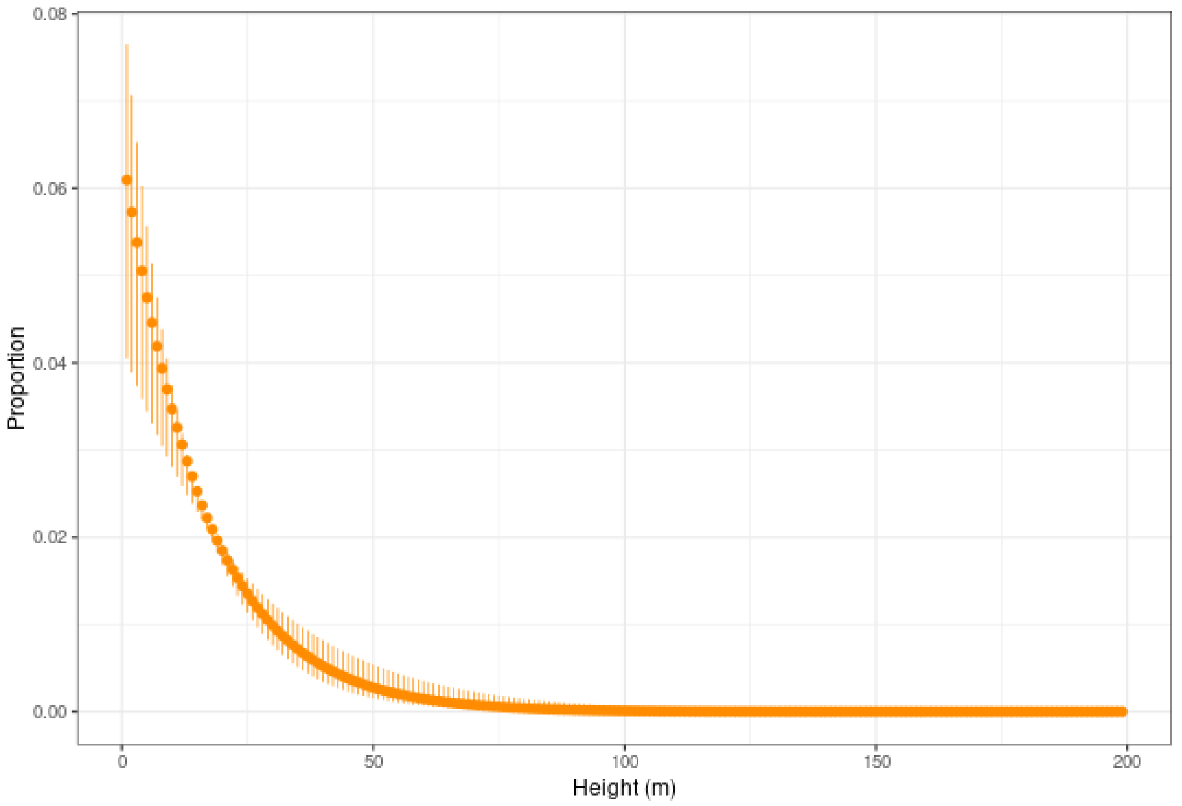

Figure A 4: Proportion of lesser black-backed gull flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

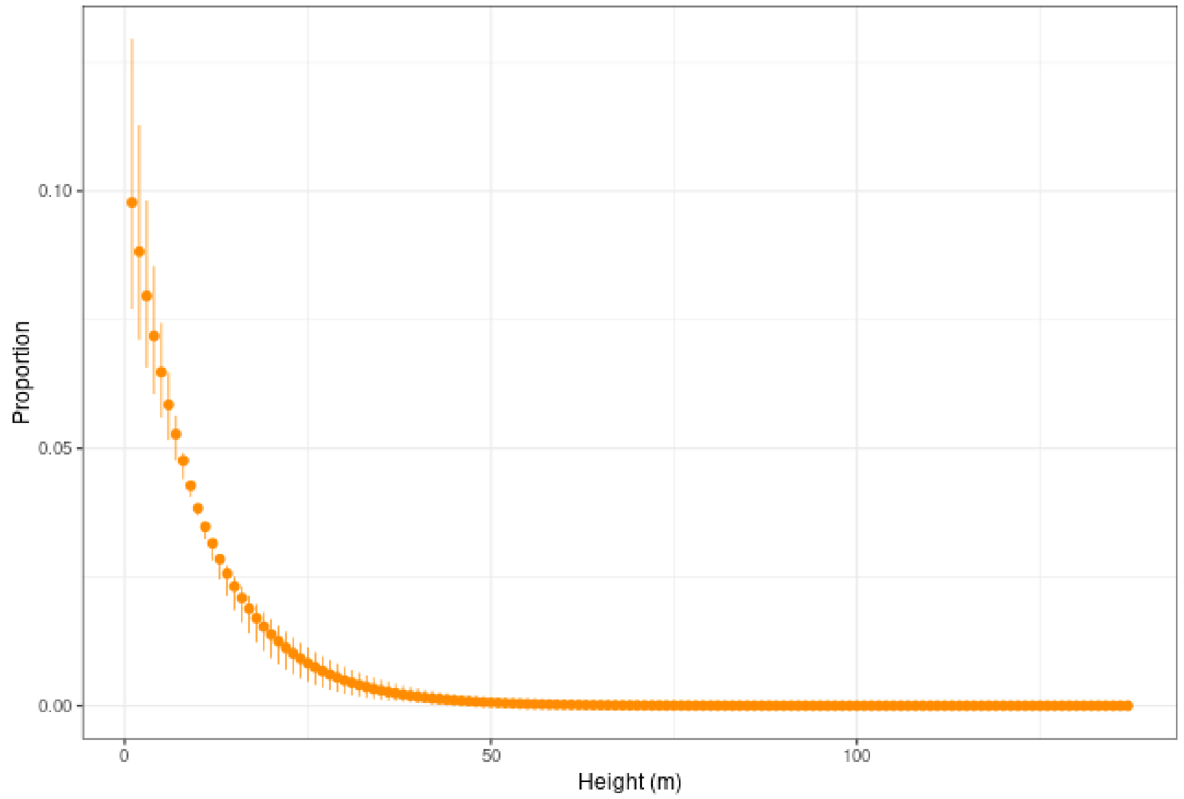

Figure A 5: Proportion of Northern gannet flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

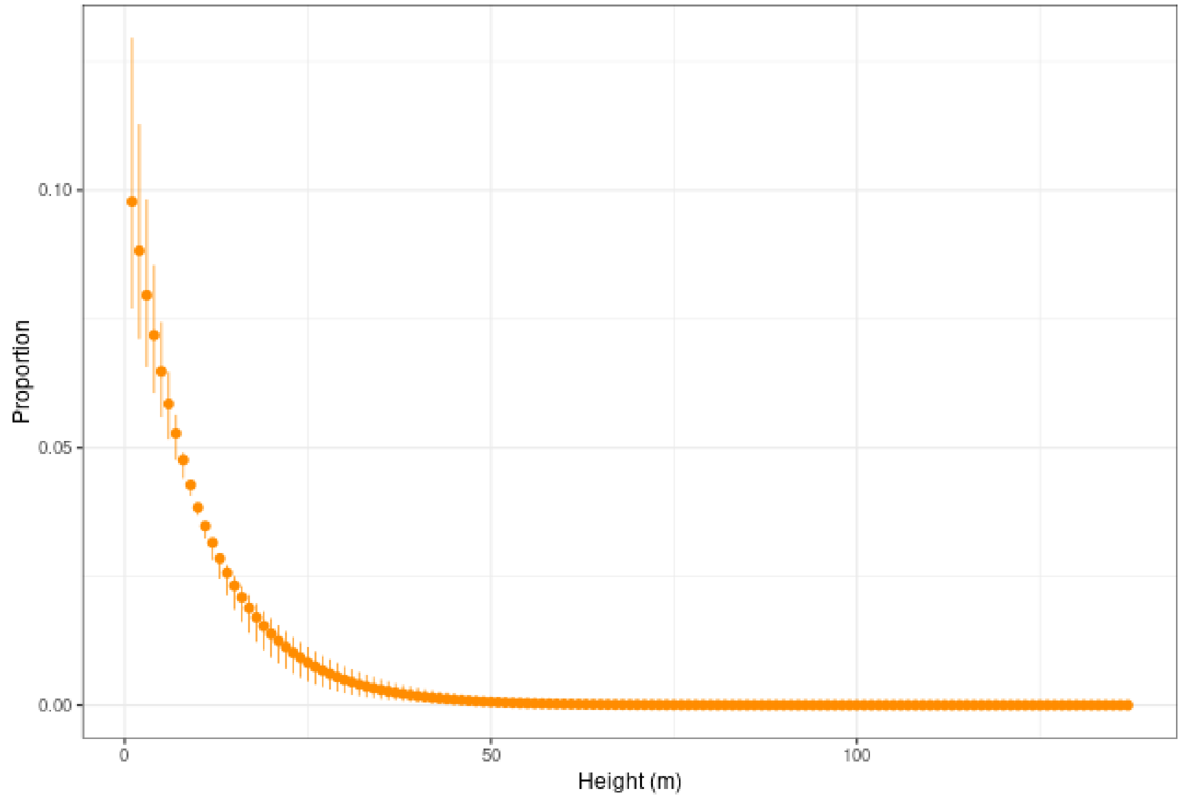

Figure A 6: Proportion of Northern fulmar flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).

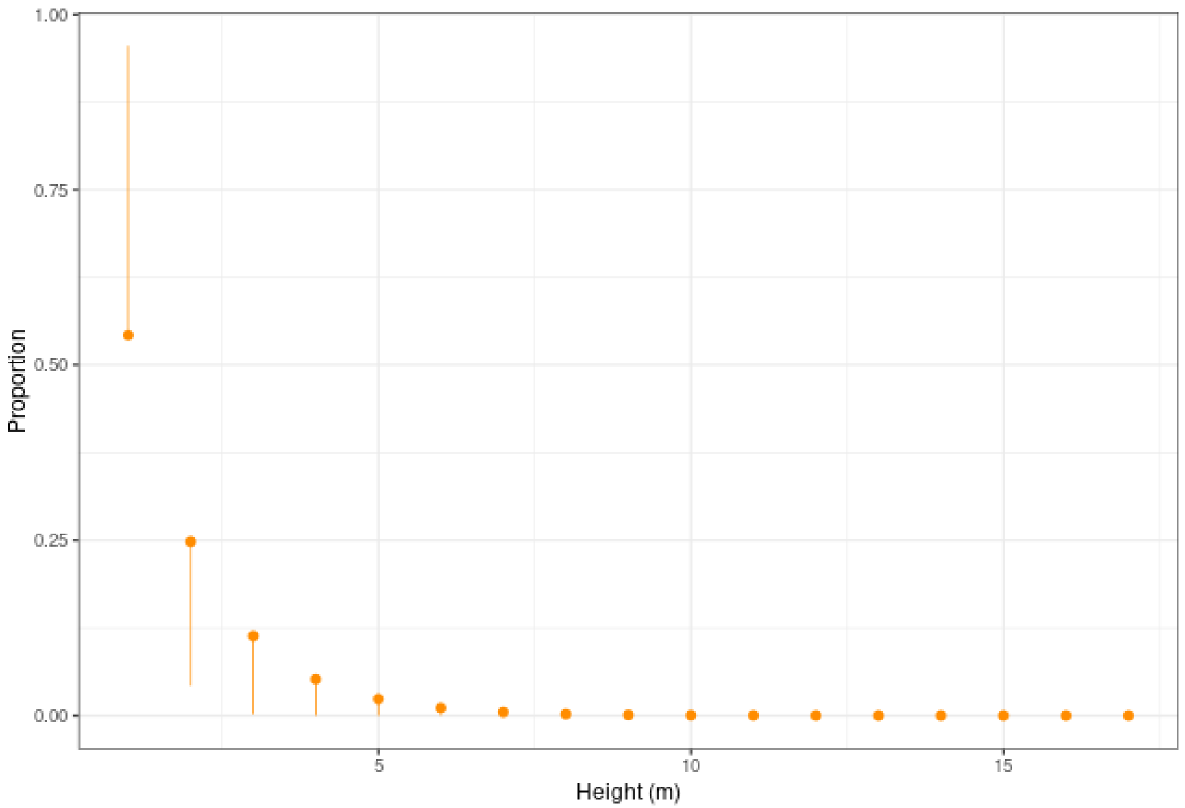

Figure A 7: Proportion of Manx shearwater flying at 1m height intervals (mean and 95% intervals of bootstrap data). Source Johnson *et al.* (2014a, 2014b).