Hornsea 4

Ørsted

Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

Volume 5, Annex 5.3: Offshore Ornithology Collision Risk Modelling

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Version A

Table of Contents

List of Tables

List of Figures

Acronyms

Acronym	Definition
CRM	Collision Risk Modelling
LAT	Lowest Astronomical Tide
MSL	Mean Sea Level
PCH	Potential Collision Risk Height
RSPB	Royal Society for the Protection of Birds
sCRM	Stochastic Collision Risk Modelling
SD	Standard Deviations
SNCB	Statutory Nature Conservation Bodies

Units

Unit	Definition
m	Metre (distance)
km	Kilometre (distance)
km^2	Kilometre squared (area)
ms^{-1}	Metres per second (speed)
rpm	Revolutions per minute (speed)
°	Degrees (angle)
%	Percentage (proportion)

1 Introduction

1.1 Project background

1.1.1.1 Ørsted Hornsea Project Four Ltd., (the Applicant) is proposing to develop the Hornsea Project Four offshore wind farm (hereafter Hornsea Four). Hornsea Four is located approximately 65 km offshore from coastline of the East Riding of Yorkshire in the Southern North Sea with the array area covering an area of approximately 600 km^2 and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network.

1.1.1.2 APEM Ltd (hereafter APEM) was commissioned by the Applicant to undertake a study of offshore and intertidal ornithology that characterise the area that may be influenced by Hornsea Four. A separate report (**Volume 5, Annex 5.1: Offshore and Intertidal Ornithology Baseline Characterisation Report**) provides the findings from offshore and intertidal ornithology data to determine the receptors that characterise the baseline and are of relevance to the assessment of potential impacts from Hornsea Four at the Preliminary Environmental Information Report (PEIR) stage.

1.2 Collision Risk Modelling

1.2.1.1 There is potential risk to birds from offshore wind farms through collision with wind turbines and associated infrastructure. There is an increase in potential risk of collision with wind turbines if they are located in areas of high bird densities in which there is a high level of flight activity. That high level of flight activity can be associated with locations where food supplies are concentrated or with areas where there is a high turnover of individuals (possibly commuting daily between nesting and feeding areas or passing through the area on seasonal migrations). The potential collision risk can be estimated using collision risk modelling (CRM).

1.2.1.2 CRM has been carried out for Hornsea Four to provide information for five seabird species of interest identified as potentially at risk and of interest for impact assessment through the evidence plan process (at Technical Panel Meeting 3 on 10.04.19); gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull. CRM was undertaken using the Stochastic Collision Risk Model (sCRM), developed by Marine Scotland (McGregor, 2018), for each seabird species, to determine the risk of collision when in flight.

1.2.1.3 Historically, the Band (2012) model in Microsoft Excel format was used for informing collision risk of seabirds in potential offshore wind farm developments. Masden (2015) developed the Band (2012) model through the creation of the package 'BandModel' in the R statistical program (http://www.r-project.org). This was in response to feedback from stakeholder interviews that the Band (2012) model was occasionally difficult to use and error prone. In addition, the Masden (2015) version of the Band (2012) model required uncertainty to be accounted for in the form of Standard Deviations (SD) around input parameters and applied a method of Monte Carlo simulation used by McAdam (2005) to allow for these. Following a review funded by Natural England of the Masden (2015) programme undertaken by MacArthur Green (Trinder, 2017), it was determined that a number of improvements were required before the 'BandModel' R package would be deemed as the agreed method for collision risk modelling for the basis of the assessment of collision mortality rates from proposed offshore wind farm developments.

1.2.1.4 Marine Scotland aimed to improve estimates of CRM models by commissioning an additional working group to address the errors that were present in the Masden (2015) code as well as to develop a 'shinyapp' interface (McGregor, 2018). The 'shinyapp' interface is a user-friendly graphical user interface accessible via a standard web-browser that uses an R code to estimate collision risk. The advantages are that users are not required to use any R code, are not required to install or maintain R and updates to the model are made directly to the server, so are immediately programmed to users (Donovan, 2018). The work funded by Marine Scotland is the most up-to-date development of the CRM originally created by Band (2012) and addressed the uncertainty in developments and other key input parameters as progressed initially by Masden (2015). Through the evidence plan process (at Technical Panel Meeting 3 on 10.04.19) it was agreed with Natural England and the Royal Society for the Protection of Birds (RSPB) that this newly developed sCRM would be the method used to determine collision risk for Hornsea Four.

2 Methodology

2.1 Guidance and Models

2.1.1.1 The guidance document outlined by Marine Scotland (Donovan, 2018) has been followed for the modelling and assessment of impacts predicted for Hornsea Four.

2.1.1.2 The parameters used in the Band CRM are presented in **Sections 2.1** to **2.5**. Five species were used for the CRM: gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull. Fulmar was excluded because there were no individuals recorded at the height with highest potential risk, using the site-specific boat flight height data (HiDef BioConsult, 2018a), and therefore it was not possible to run through the sCRM shinyapp.

2.1.1.3 Within this report the shinyapp outputs / results for three different Band Options are presented, as described in the following sections.

2.1.2 Basic Band CRM Option 1 with site-specific flight heights

2.1.2.1 The Basic Band model applies a uniform distribution of bird flights between the lowest and the highest levels of the rotors. The percentage of bird flights passing between the lowest and the highest levels of the rotors (i.e. the proportion of birds at potential collision height (PCH)) is determined from the observations of bird flight heights made from the boat-based site-specific surveys. This Option has been considered for all five seabird species.

2.1.3 Basic Band CRM Option 2 with generic flight heights

2.1.3.1 The Basic Band model applies a uniform distribution of bird flights between the lowest and the highest levels of the rotors. The PCH was determined from the results of the SOSS-02 project (Cook *et al.,* 2012) that analysed the flight height measurements taken from boat surveys conducted around the UK. The project was updated following Johnston *et al.*, (2014), and the revised published spreadsheet[1] is used to determine the 'generic' percentage of flights at PCH for each species based on the proposed project's wind turbine parameters. This Option has been considered for all five seabird species.

2.1.4 Extended Band CRM Option 3 with generic flight heights

2.1.4.1 The Extended Band model accounts for the skewed vertical distribution of bird flight heights between the lowest and the highest levels of the rotors. Most seabird species are observed flying more frequently at the lower level of the rotor swept height (i.e. closer to the sea surface) than at heights equivalent to the rotor hub height or at the upper levels of the rotor and the probability of being struck by the moving rotor varies with vertical position. Extended Band Option 3 uses the data spreadsheet[2] that accompanies Johnston *et al.*, (2014) which is the result of a statistical analysis of a large number of boat surveys across multiple study sites. This data is fed into the model in order to allow for the flight distribution to be calculated based upon the windfarm parameters of the proposed project.

2.1.4.2 Option 3 has only been considered for kittiwake, lesser black-backed gull, herring gull, and great black-backed gull as per Statutory Body advice (JNCC *et al.*, 2014 in response to Cook *et al.*, 2014; Bowgen & Cook, 2018).

2.2 CRM Input Parameters

2.2.1.1 This report presents sCRM results based on input parameters supported by recent evidence in the literature (for instance in Bowgen & Cook, 2018 and Skov *et al.*, 2018). More specifically, the input parameters used to define the collision risk within this report rely on alternate nocturnal activity rates for all five species and alternate avoidance rates, which have been applied within the basic and extended models dependent upon the latest species-specific evidence detailed in **Table 2**. For the avoidance of doubt, this evidence-based approach represents the CRM approach for Hornsea Four and the corresponding outputs are those taken forward to the detailed assessment phase in the PEIR (**Volume 5, Chapter 5: Offshore and Intertidal Ornithology**).

2.2.1.2 A second iteration of the sCRM (0) has been provided which incorporates input parameters currently advocated for use by SNCBs. The sCRM was run for each species with these input parameters in agreement with Natural England and the RSPB through the evidence plan process (at Technical Panel Meeting 4 on 11.06.19) in order to provide their more precautionary range of outputs.

[1] Final_Report_SOSS02_FlightHeights2014.xls
[2] Final_Report_SOSS02_FlightHeights2014.xls

2.2.2 Avoidance Rates

2.2.2.1 The species-specific avoidance rates that were applied in the CRM are presented in Table 1. The avoidance rate for use in the gannet sCRM follows the guidance from Cook *et al.*, (2014) and the SNCBs review of avoidance rates to be applied in the Band models (JNCC *et al.*, 2014 in response to Cook *et al.*, 2014). The avoidance rates from Bowgen & Cook (2018) were applied in the sCRM for kittiwake, lesser black-backed gull, herring gull, and great black-backed gull. Bowgen & Cook (2018) presented upper and lower confidence intervals around the avoidance rates and as such a calculation assuming a normal distribution was undertaken to estimate a standard deviation for input to the sCRM (Table 1).

Table 1: Basic and Extended CRM Option associated avoidance rates for Hornsea Four for six species: gannet, kittiwake, lesser black-backed gull, herring gull, and great black-backed gull.

Species	Basic Band Option Avoidance Rates (± SD)	Extended Band Option Avoidance Rate (± SD)
Gannet	0.989 ± 0.002	n/a[1]
Kittiwake	0.994 ± 0.0055	0.970 ± 0.0295
Lesser black-backed gull	0.997 ± 0.00175	0.990 ± 0.00525
Herring gull	0.997 ± 0.00175	0.990 ± 0.00525
Great black-backed gull	0.997 ± 0.00175	0.990 ± 0.00525

[1] A default value of 1 ± 0 was inserted for these species so that all possible fields were completed for the shinyapp to run

2.2.3 Species Biometrics

2.2.3.1 The species-specific biometric input parameters used in the CRM are provided in Table 2.

Table 2: Species biometrics used in the collision risk modelling of the proposed Hornsea Four for five species: gannet, kittiwake, lesser black-backed gull, herring gull, and great black-backed gull.

Species	Body Length (m)[1] ± SD[2]	Wingspan (m)[1] ± SD[2]	Flight Speed (ms^{-1}) ± SD	Nocturnal Activity ± SD	Flight Type
Gannet	0.94 ± 0.0325	1.72 ± 0.0375	14.90 ± 0.00 [3]	0.00 ± 0 [6]	Gliding
Kittiwake	0.39 ± 0.005	1.08 ± 0.04	7.26 ± 0.40 [4]	0.033 ± 0.0045 [4]	Flapping
Lesser black-backed gull	0.58 ± 0.03	1.42 ± 0.0375	13.10 ± 1.90 [5]	0.25 ± 0 [6]	Flapping
Herring gull	0.60 ± 0.0225	1.44 ± 0.03	12.80 ± 1.80 [5]	0.25 ± 0 [6]	Flapping
Great black-backed gull	0.71 ± 0.035	1.58 ± 0.0375	13.70 ± 1.20 [5]	0.25 ± 0 [6]	Flapping

[1]Robinson (2005); [2]Marine Scotland (2018); [3]Pennycuick (1997); [4]Masden (2015); [5]Alerstam *et al.*, (2007); [6]Garthe & Hüppop (2004).

2.2.3.2 The body length and wingspan of the five key seabirds included in the collision risk modelling were derived from Robinson (2005). Automatic inputs for the SD of these parameters were retained from Marine Scotland (2018).

2.2.3.3 Flight speeds and associated standard deviations for lesser black-backed gull, herring gull, and great black-backed gull were derived from Alerstam *et al.,* (2007). The flight speed for gannet was derived from Pennycuick (1997). The flight speed for kittiwake is reduced in comparison to the previously used estimate of 13.1 m/s from Alerstam *et al.*, (2007) based on recent literature (Masden, 2015; Skov *et al.*, 2018).

2.2.3.4 The nocturnal activity rate for gannet, lesser black-backed gulls, herring gull, and great black-backed gulls was based on a 1 to 5 scoring index for each species in Garthe and Hüppop (2004) or King *et al.,* (2009), with the spreadsheet converting these factors into nocturnal activity as follows; 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, 5 = 100%. It is considered that these literature sources for nocturnal activity rates are overly precautionary (gannet: 2, kittiwake: 3, and large gulls: 3) and have been superseded by more recent studies (MacArthur Green, APEM & Royal HaskoningDHV, 2015; Skov *et al.*, 2018; Masden, 2015). They were considered precautionary for the East Anglia THREE application based on a review of information from data loggers deployed on kittiwakes, gannets, and lesser black-backed gulls (MacArthur Green, 2015). The results indicated that the nocturnal activity of these species was less than what was assumed to be the case in Garthe & Huppop (2004). MacArthur Green (2015) argued that the simplistic categorical factors in Garthe & Huppop (2004) were not intended to represent a scale of 0 to 100%. Similarly, Masden (2015) presented information from data loggers for the nocturnal activity of kittiwake in the species example provided for the sCRM. Skov *et al.* (2018) provided information that indicated nocturnal flight activity recorded from thermal videos constituted a negligible proportion of total flight activity (<3%), but sample size was a limitation and therefore concluded this information should be interpreted as anecdotal. As such the nocturnal activity rates used for the sCRM presented in this report follow more recent evidence, which are collated and presented in **Table 2**.

2.2.4 Proportion at Potential Collision Height

2.2.4.1 The proportion of individuals flying at PCH for use in Band Option 1 for each species were obtained from the site-specific boat based derived flight heights (**Table 3**), which provides a generic PCH per species which is in this model. It was not possible to calculate a SD around the PCH for the site-specific data due to the nature of boat-based flight height estimates being within flight height band categories.

2.2.4.2 To determine the proportion of birds at potential collision risk height (based on 35 m against Lowest Astronomical Tide (LAT)) for all five species, it was necessary to convert the lower rotor swept value against Mean Sea Level (MSL), a requirement for the sCRM, which was calculated to be 32.57 m. To calculate PCH, the number of records across the year and from the flight height category "32.5 – 37.5 m" were summed and divided by the total recorded for each species.

Table 3: Proportion (%) at PCH used in the Band CRM Option 1 of the proposed Hornsea Four development.

Species	Boat-based site-specific PCH
Gannet	0.034 ± 0
Kittiwake	0.005 ± 0
Lesser black-backed gull	0.088 ± 0
Herring gull	0.1215 ± 0

Species	Boat-based site-specific PCH
Great black-backed gull	0.1721 ± 0

2.2.5 Density of Birds in Flight

2.2.5.1 Design-based abundance and density estimates +/- SD were determined for Hornsea Four using data collected from the 24-month programme of digital aerial video surveys (carried out between April 2016 and March 2018, inclusive), which are presented in (Volume 2, Chapter 5, Annex 1). For the five species of key seabirds, the CRM is based on the mean density of flying birds per month (Table 4). The SD was calculated using two flying density estimates for each month from the two different years of survey data and per species (Table 4).

Table 4: Monthly values for the mean density +/- SD of flying birds used in the CRM of the proposed Hornsea Four development for five species: gannet, kittiwake, lesser black-backed gull (LBB gull), herring gull (H gull), and great black-backed gull (GBB gull).

Month	Gannet	Kittiwake	LBB Gull	H Gull	GBB Gull
January	0.12 ± 0.16	0.23 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.14 ± 0.04
February	0.03 ± 0.04	0.35 ± 0.43	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.00
March	0.14 ± 0.11	0.34 ± 0.13	0.00 ± 0.00	0.01 ± 0.01	0.04 ±0.01
April	0.06 ± 0.01	1.34 ± 1.47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
May	0.15 ± 0.16	2.20 ± 0.25	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.01
June	0.50 ± 0.54	1.41 ± 0.75	0.03 ± 0.04	0.03 ± 0.04	0.02 ± 0.02
July	0.55 ± 0.09	0.96 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	0.46 ± 0.34	2.51 ± 0.86	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
September	0.18 ± 0.02	0.58 ± 0.78	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00
October	0.20 ± 0.14	0.13 ± 0.09	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
November	0.48 ± 0.05	0.26 ± 0.32	0.00 ± 0.00	0.00 ± 0.00	0.10 ± 0.07
December	0.29 ± 0.32	0.95 ± 0.62	0.00 ± 0.00	0.02 ± 0.02	0.13 ± 0.01

2.2.6 Turbine Parameters

2.2.6.1 Input parameters for the wind turbine specifications used within the CRM are shown in Table 5 and Table 6.

Table 5: Wind turbine specification for the proposed Hornsea Four development.

Input Parameter (units in brackets)	Value	Source
No. of Blades	3	Provided by Hornsea Four.
Rotor Radius (m)	152.5	Provided by Hornsea Four.
Air Gap (m)	30.29	Air gap measured against Highest Astronomical Tide (HAT); 35 m air gap provided by Hornsea Four based on Lowest Astronomical Tide [LAT], tidal offset of 4.71 m used for conversion as supplied by Hornsea Four).
Max. Blade Width (m)	6	Provided by Hornsea Four.
Tidal Offset (m)	2.28	To correct for flight heights calculated against Mean Sea Level (MSL; site-specific data assumed to be measured against MSL) and air gap in relation to HAT. Difference

Input Parameter (units in brackets)	Value	Source
		between HAT and MSL as provided by Hornsea Four (4.71 m and 2.43 m respectively).
Wind Farm Width (km)	53.063643	See Figure 1
Latitude (degrees)	54.092594	Latitude of the centroid of Hornsea Four, Figure 1. Latitude informs daylight hours in the Band Model calculation. Longitude is not a requirement of the Band CRM input.
Rotation speed (rpm)	6.5 ± 0.2	Provided by Hornsea Four.
Large Array Correction	Yes	Standard procedure.
Pitch (°)	4.6 ± 1.0	Provided by Hornsea Four.
Wind speed (ms^{-1})	11.2 ± 0.5	Provided by Hornsea Four.

2.2.6.2 Wind farm width was calculated using the longest distance across the wind farm which is worst case as this maximises the amount of time a bird could spend in the wind farm (Figure 1). The latitude was calculated from the shapefile provided by Hornsea Four and represents the centroid (Figure 1).

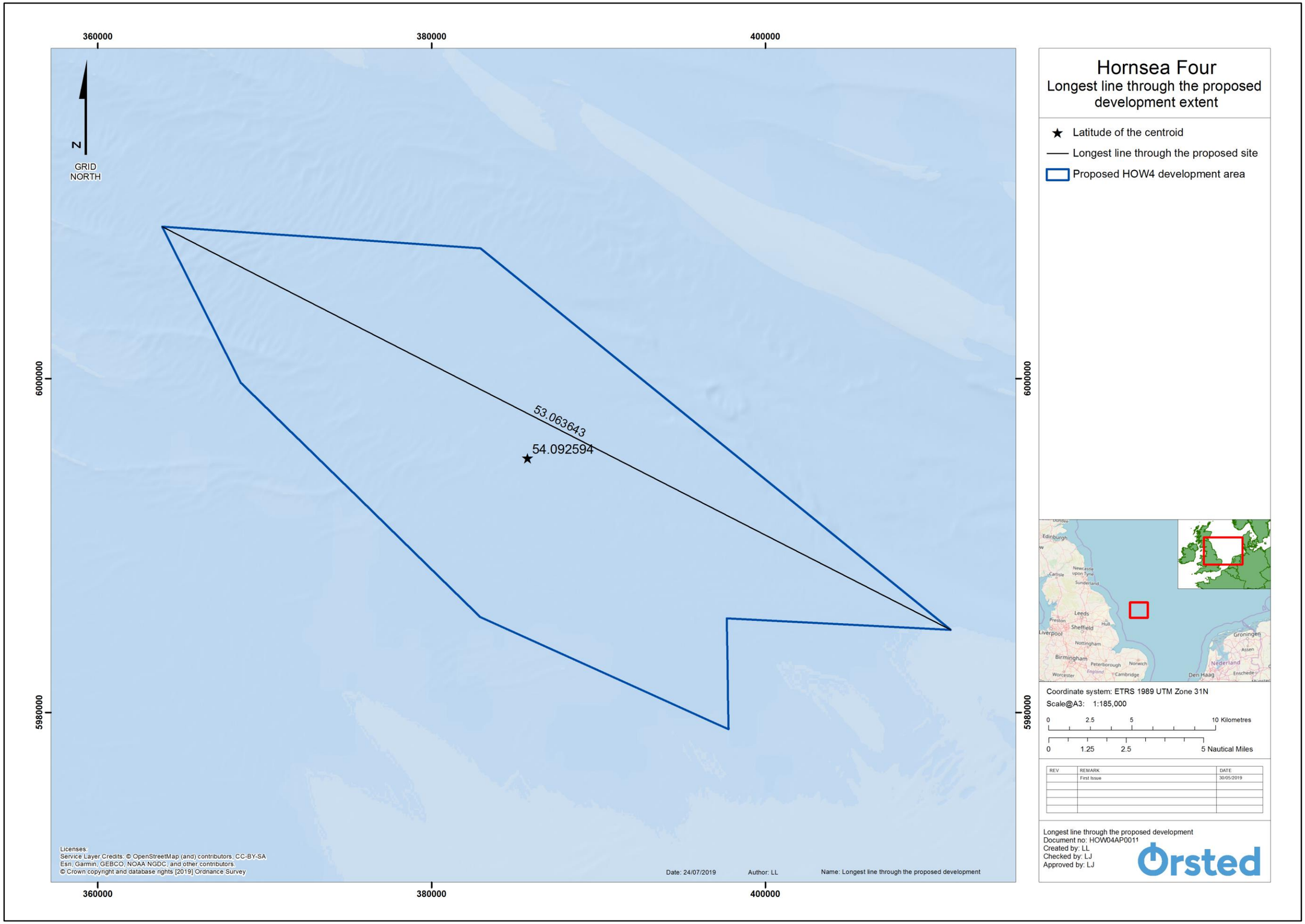

Figure 1: The proposed Hornsea Four development: the line used to estimate the longest distance through the wind farm (not to scale).

Table 6: Theoretical operational time of the proposed Hornsea Four turbines as provided by Hornsea Four.

Month	Wind Availability (%)	Mean Downtime ± SD (%)
January	92.15	4 ± 2
February	92.58	4 ± 2
March	92.42	4 ± 2
April	91.46	4 ± 2
May	91.25	4 ± 2
June	90.04	4 ± 2
July	89.87	4 ± 2
August	90.49	4 ± 2
September	91.75	4 ± 2
October	92.61	4 ± 2
November	92.60	4 ± 2
December	92.45	4 ± 2

3 Results

3.1 Introduction

3.1.1.1 This section provides the standard outputs from the CRM for each of the five seabird species. To interpret the boxplots: the 'box' is the interquartile range which represents the middle half of the data, with the middle bold line representing the median. The 'whiskers' are the largest and smallest non-outliers. The range of the entire data includes the outliers represented by circles. The density plots provide a visual representation of the distribution of data, the peak of the density plot displays where values are concentrated over the interval.

3.2 Gannet

3.2.1.1 **Table 7** presents the annual gannet collision rates for Option 1 and Option 2. **Figure 2** presents the gannet annual collision probability density for Option 1 and Option 2. Monthly collision rates for Option 1 and Option 2 are presented in **Figure 3** and **Figure 4** respectively.

3.2.1.2 **Appendix B** details the monthly CRM, bird parameter and turbine parameter outputs for gannet.

Table 7: Gannet overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	50.232	12.922	0.257	49.184	28.688	40.812	58.391	78.15
Option 2	51.112	29.887	0.585	45.196	11.603	26.7	69.678	120.713

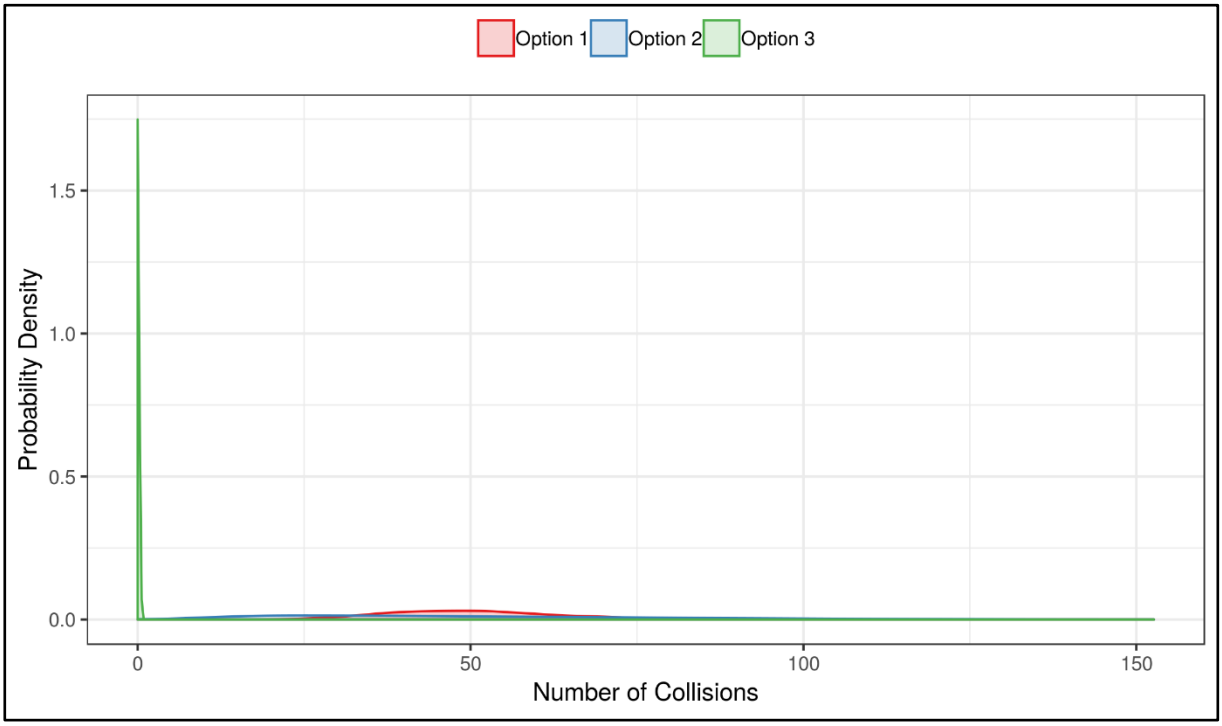

Figure 2: Gannet overall collisions probability density.

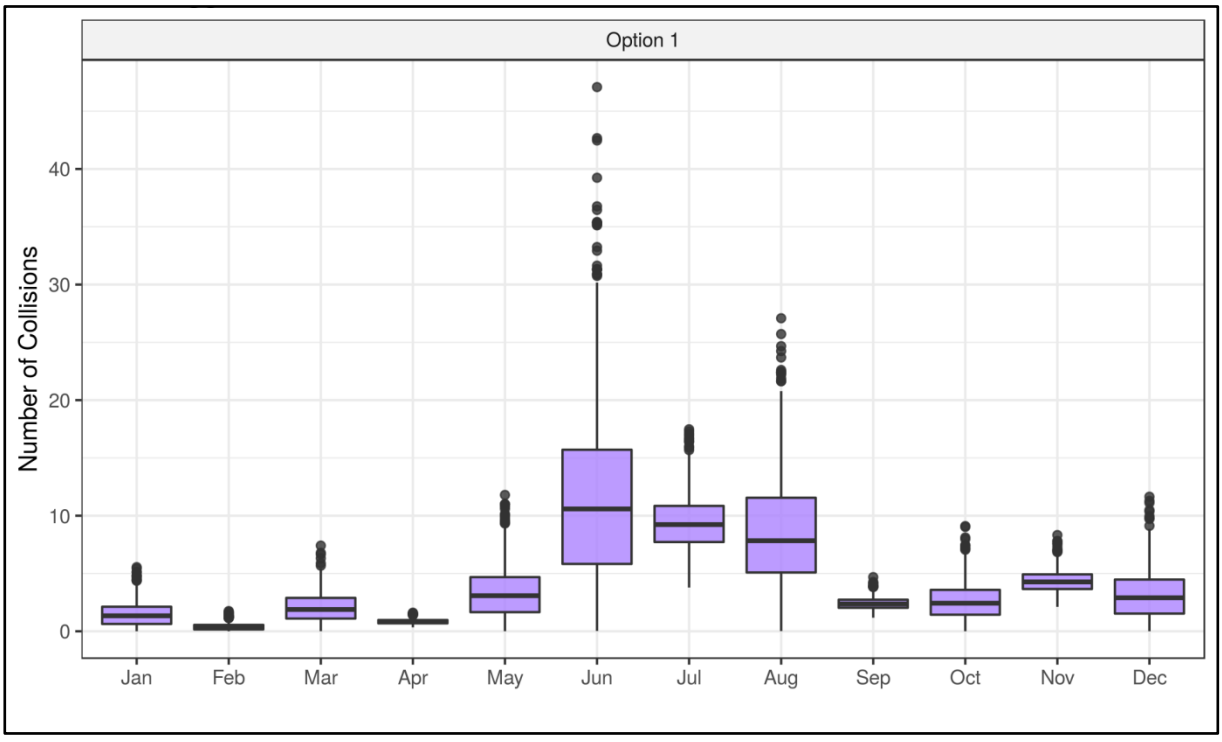

Figure 3: Gannet monthly collisions Option 1.

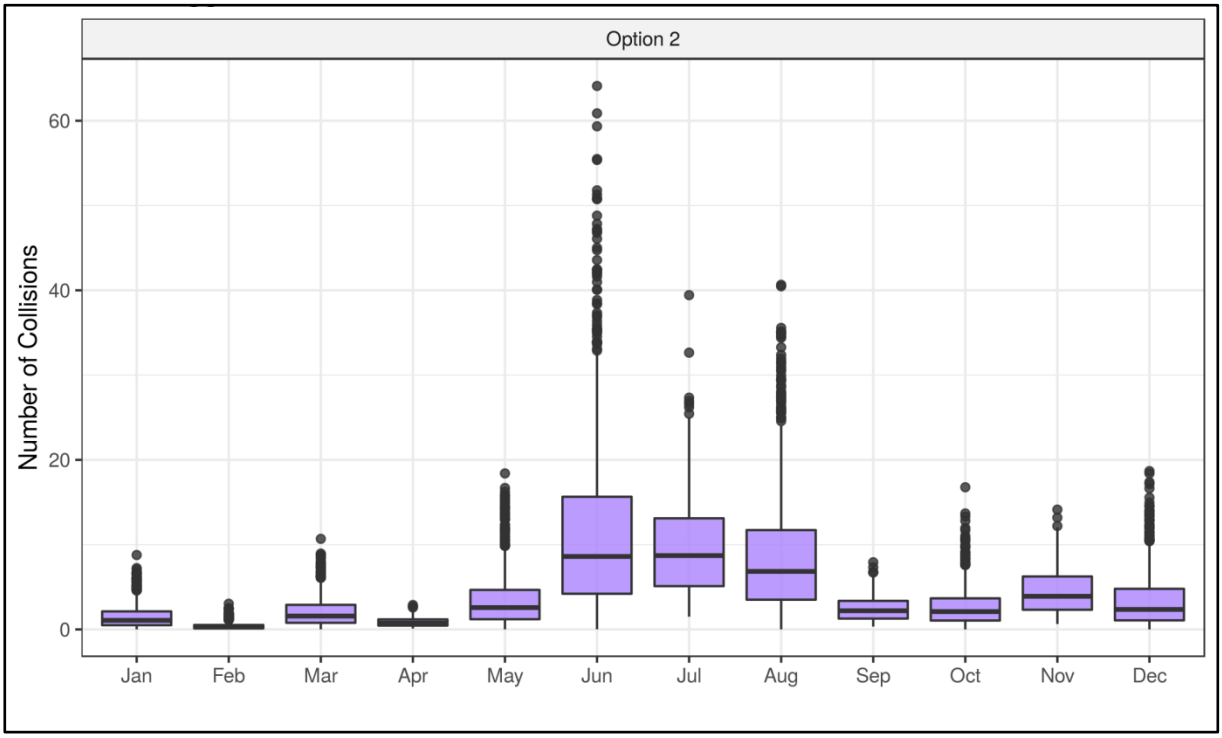

Figure 4: Gannet monthly collisions Option 2.

3.3 Kittiwake

3.3.1.1 Table 8 presents the annual kittiwake collision rates for Option 1 and Option 2. Figure 5 presents the kittiwake annual collision probability density for Option 1, Option 2 and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in Figure 6, Figure 7, and Figure 8 respectively.

3.3.1.2 Appendix C details the monthly CRM, bird parameter and turbine parameter outputs for kittiwake.

Table 8: Kittiwake overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	6.874	6.2	0.902	5.242	0.313	2.355	9.35	22.051
Option 2	56.019	52.213	0.932	40.663	2.387	18.67	75.97	193.243
Option 3	49.503	53.619	1.083	32.182	1.454	12.699	67.292	196.911

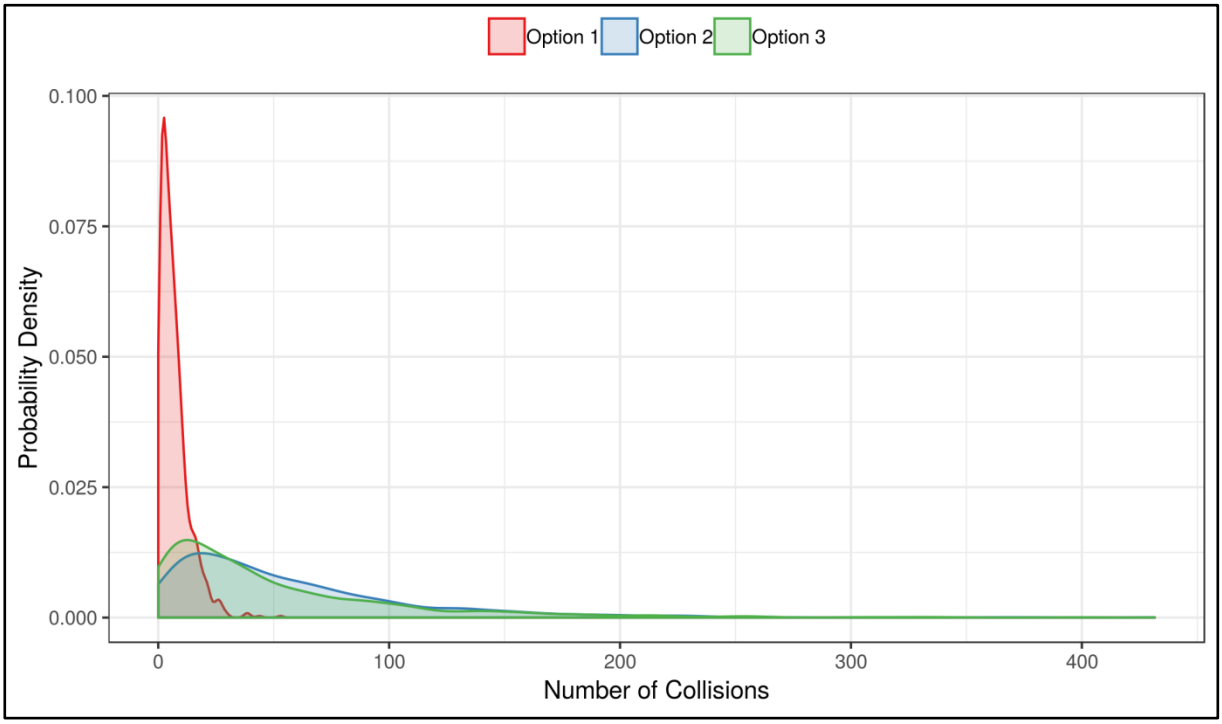

Figure 5: Kittiwake overall collisions probability density.

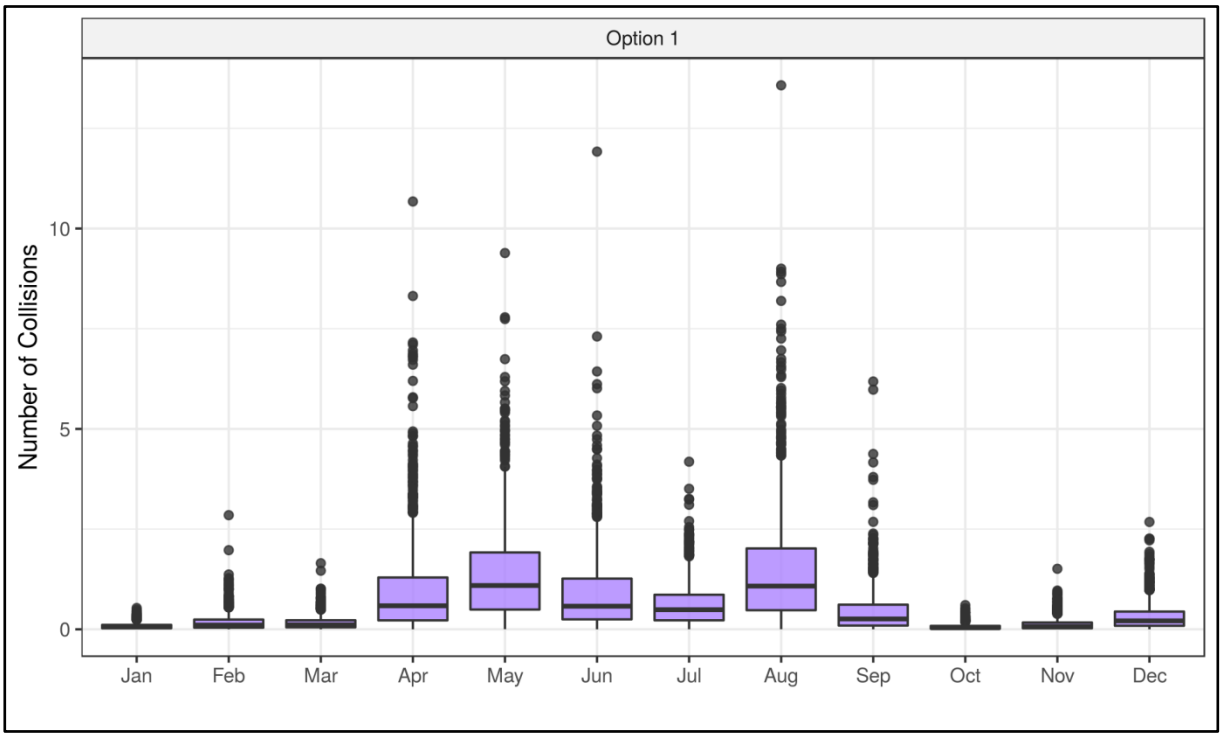

Figure 6: Kittiwake monthly collisions Option 1.

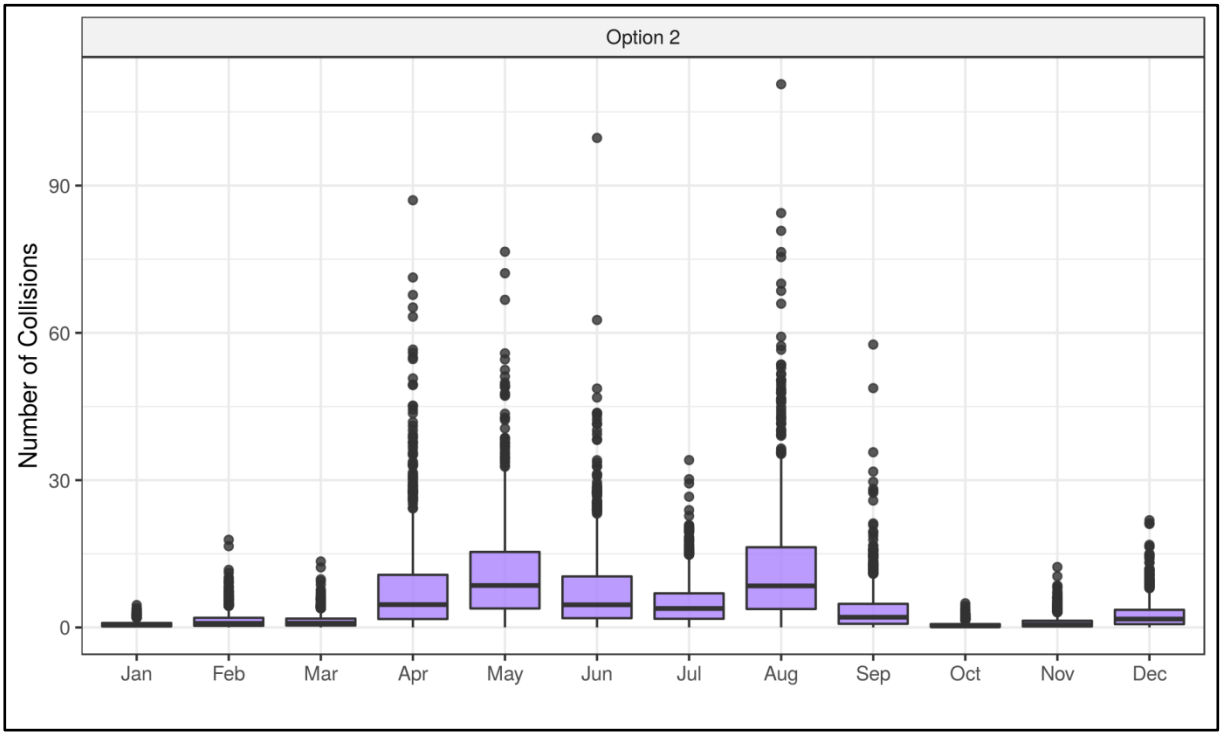

Figure 7: Kittiwake monthly collisions Option 2.

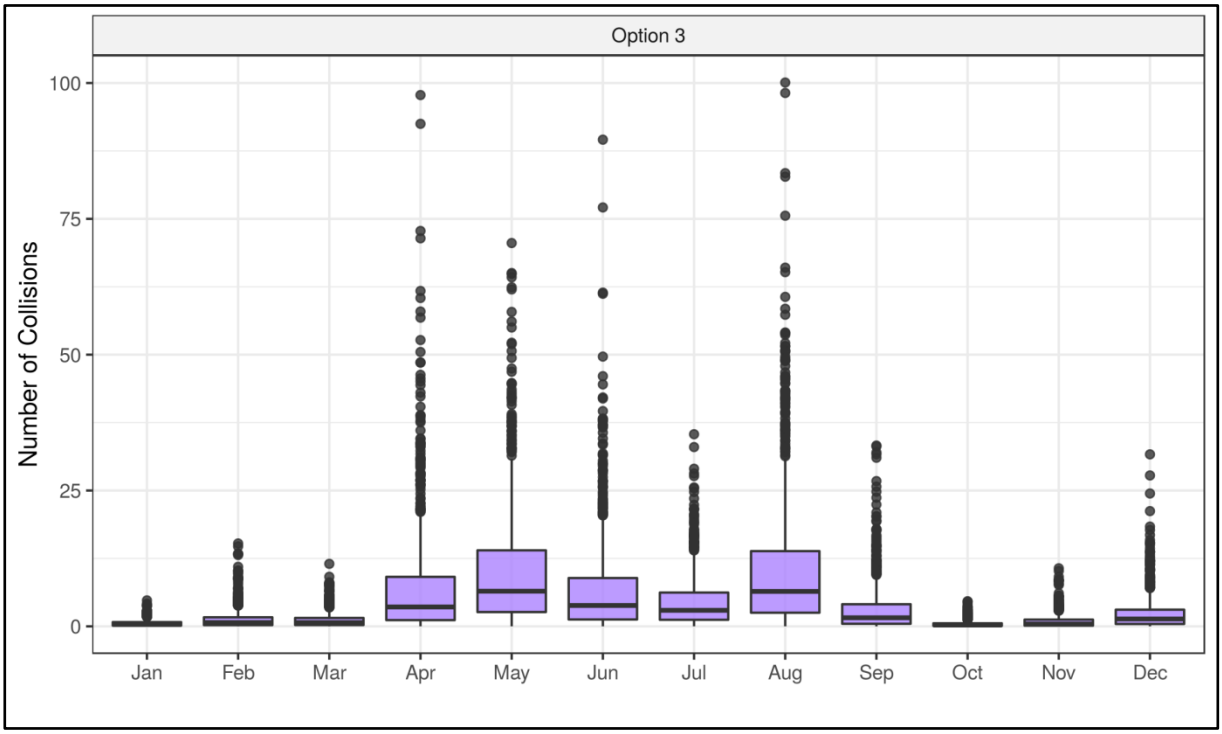

Figure 8: Kittiwake monthly collisions Option 3.

3.4 Lesser black-backed gull

3.4.1.1 Table 9 presents the annual lesser black-backed gull collision rates for Option 1 and Option 2. Figure 9 presents the lesser black-backed gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in Figure 10, Figure 11 and Figure 12 respectively.

3.4.1.2 Appendix D details the monthly CRM, bird parameter and turbine parameter outputs for lesser black-backed gull.

Table 9: Lesser black-backed gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	0.713	0.566	0.793	0.579	0.096	0.327	0.939	2.15
Option 2	1.052	0.96	0.913	0.768	0.122	0.413	1.337	3.7
Option 3	0.881	0.902	1.024	0.599	0.105	0.337	1.079	3.375

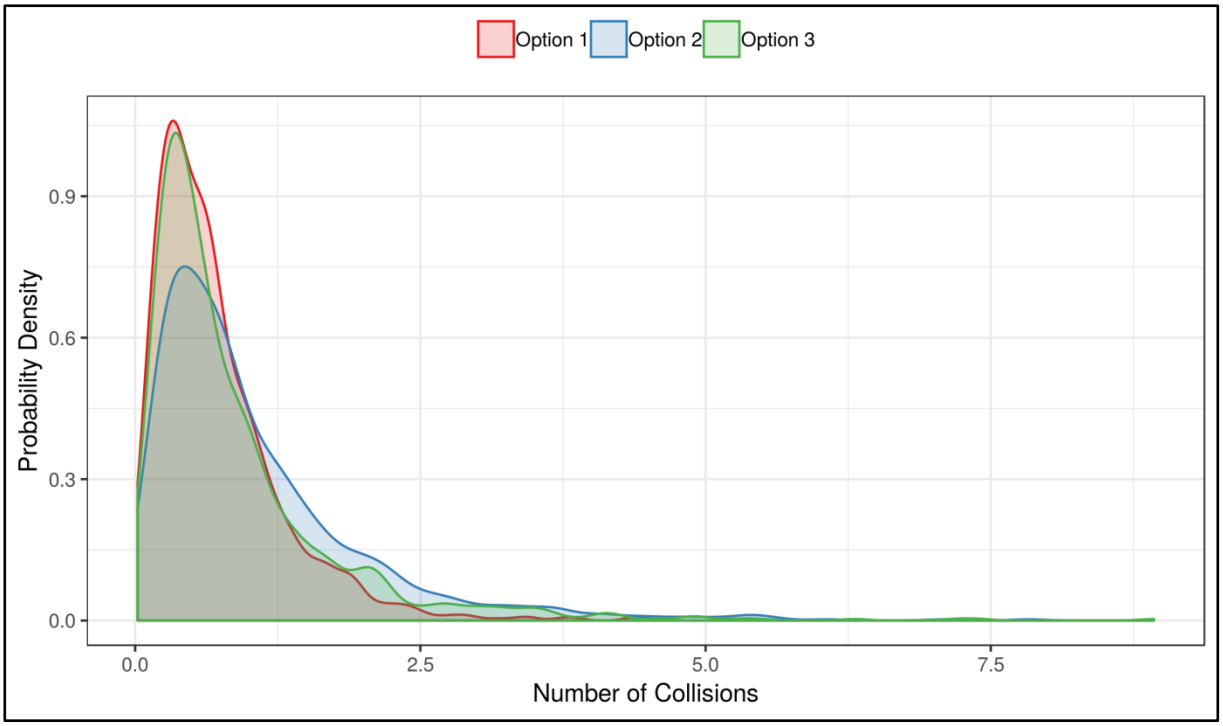

Figure 9: Lesser black-backed gull overall collisions probability density.

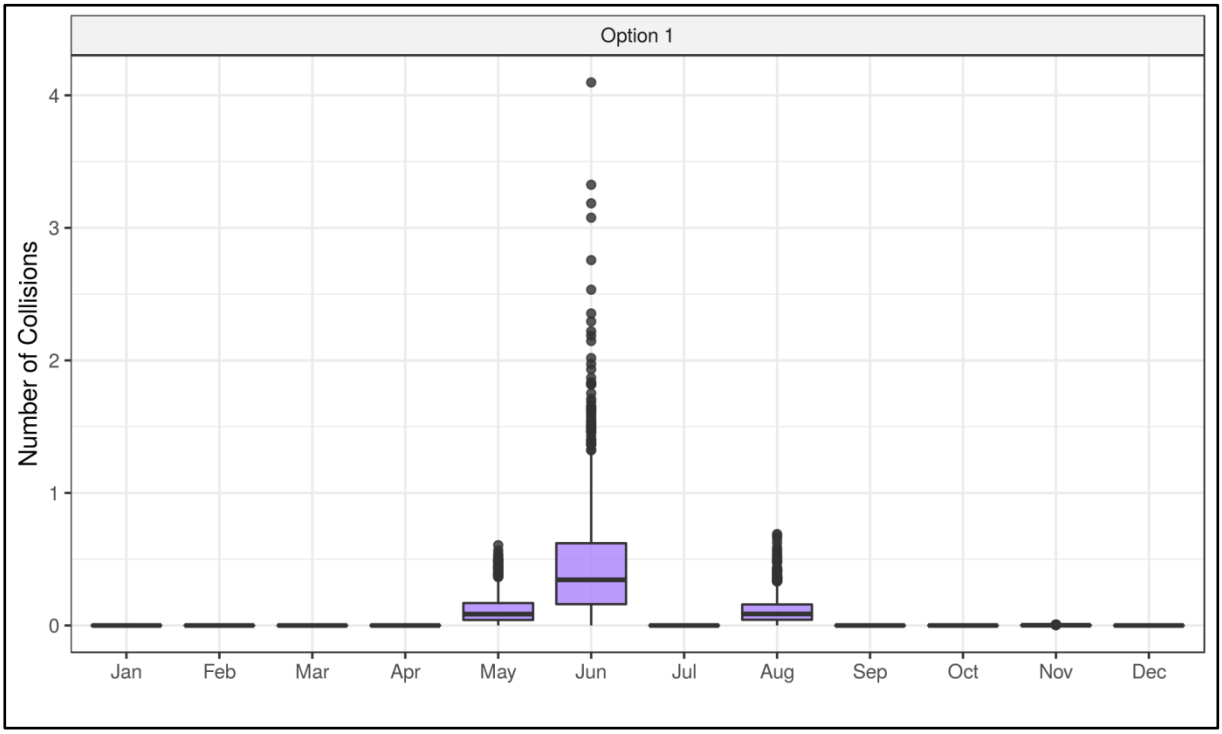

Figure 10: Lesser black-backed gull monthly collisions Option 1.

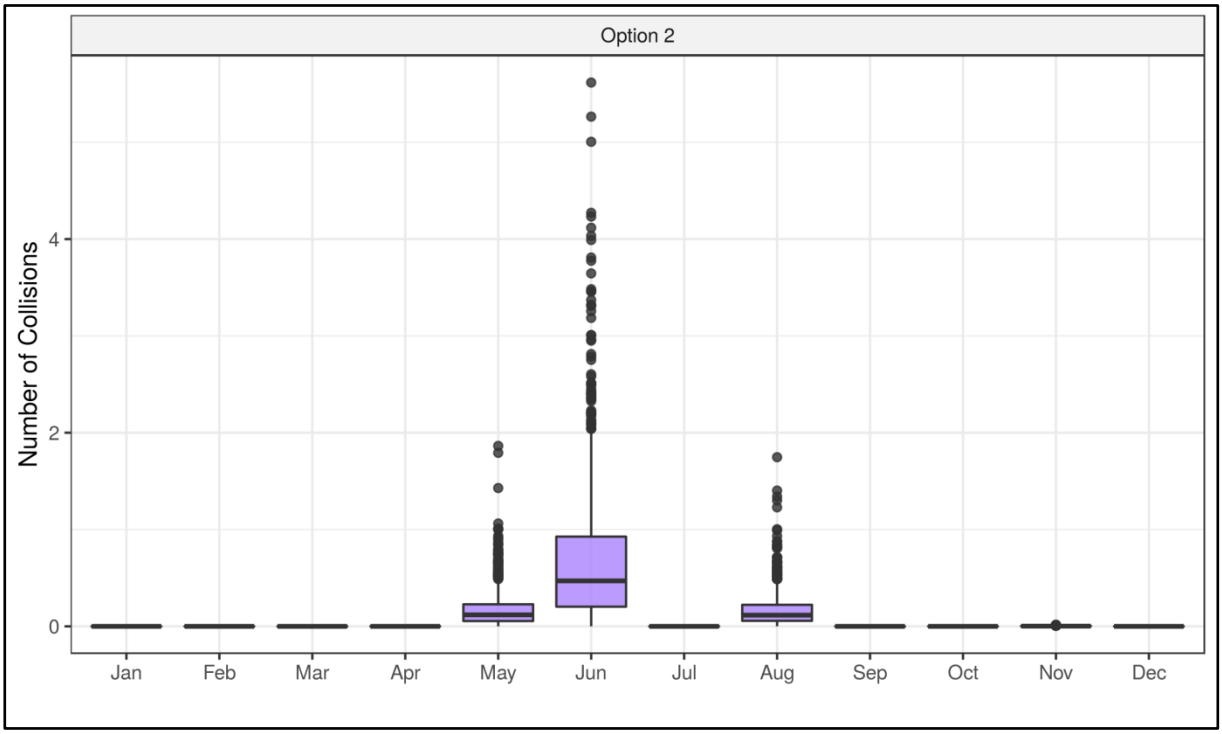

Figure 11: Lesser black-backed gull monthly collisions Option 2.

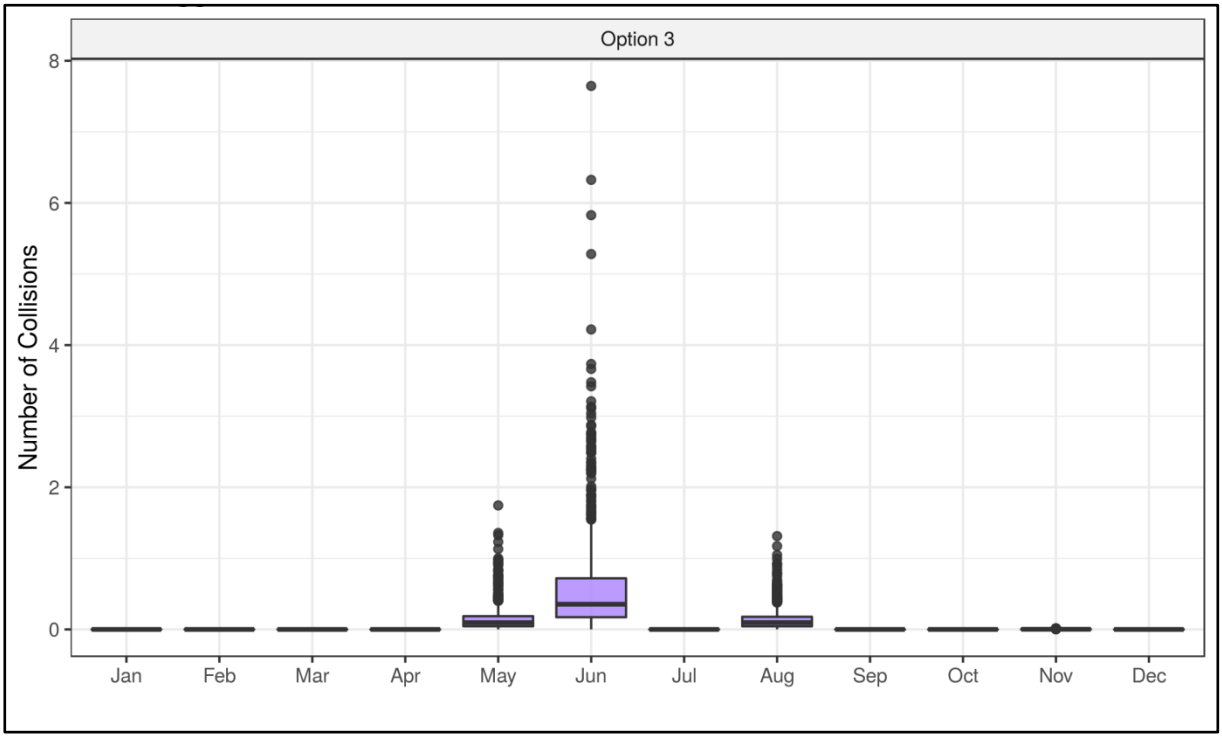

Figure 12: Lesser black-backed gull monthly collisions Option 3.

3.5 Herring gull

3.5.1.1 Table 10 presents the annual herring gull collision rates for Option 1, Option 2, and Option 3. Figure 13 presents the herring gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in Figure 14, Figure 15, and Figure 16 respectively.

3.5.1.2 Appendix E details the monthly CRM, bird parameter and turbine parameter outputs for herring gull.

Table 10: Herring gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	1.11	0.806	0.726	0.937	0.175	0.514	1.473	3.149
Option 2	1.355	1.031	0.761	1.087	0.203	0.613	1.803	3.982
Option 3	1.166	0.905	0.776	0.916	0.216	0.563	1.489	3.736

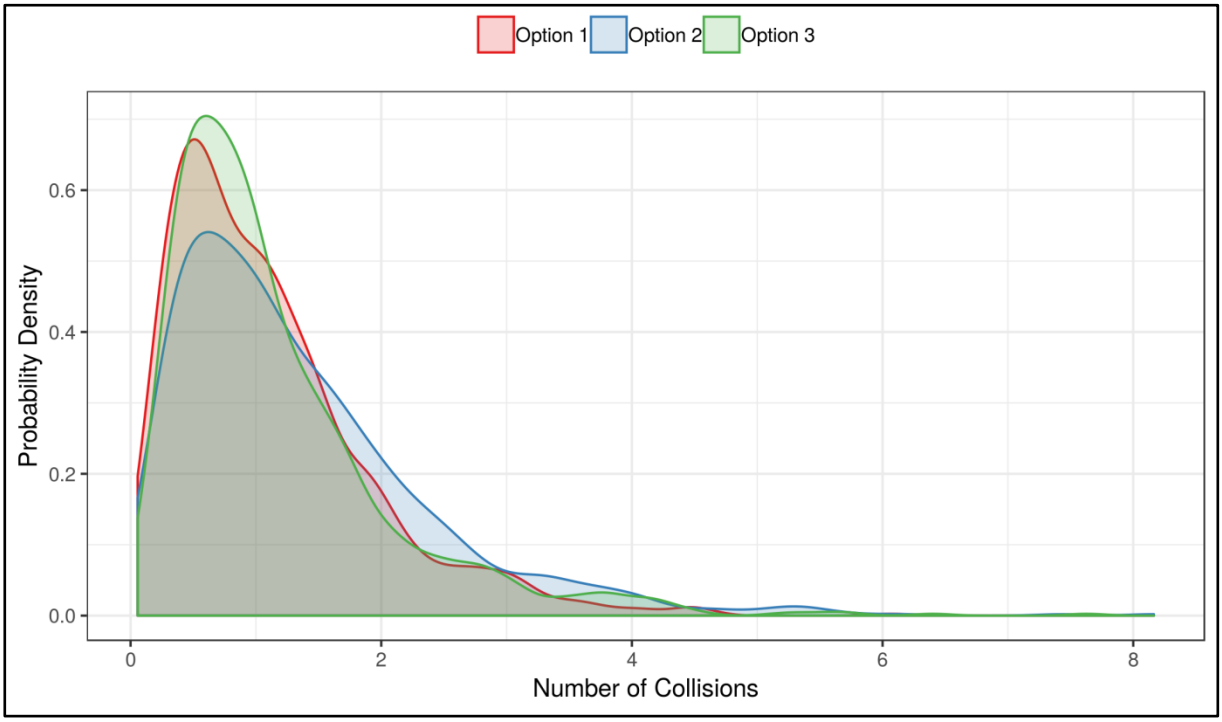

Figure 13: Herring gull overall collisions probability density.

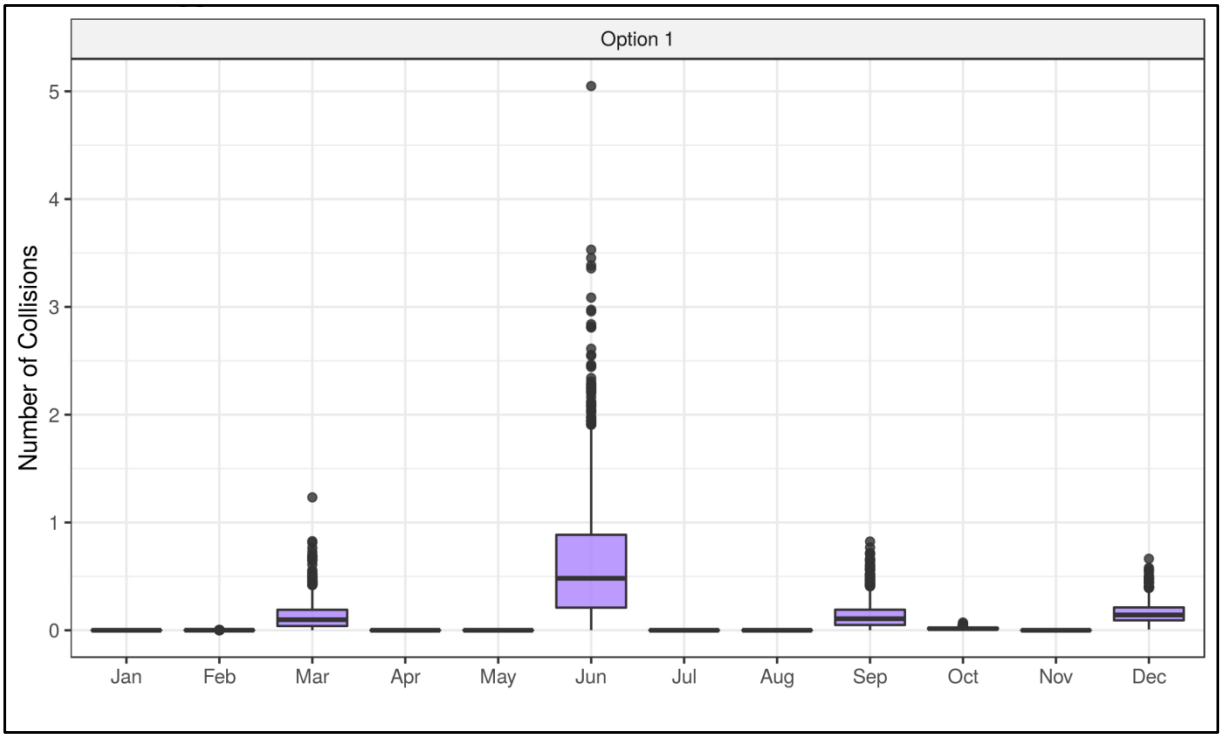

Figure 14: Herring gull monthly collisions Option 1.

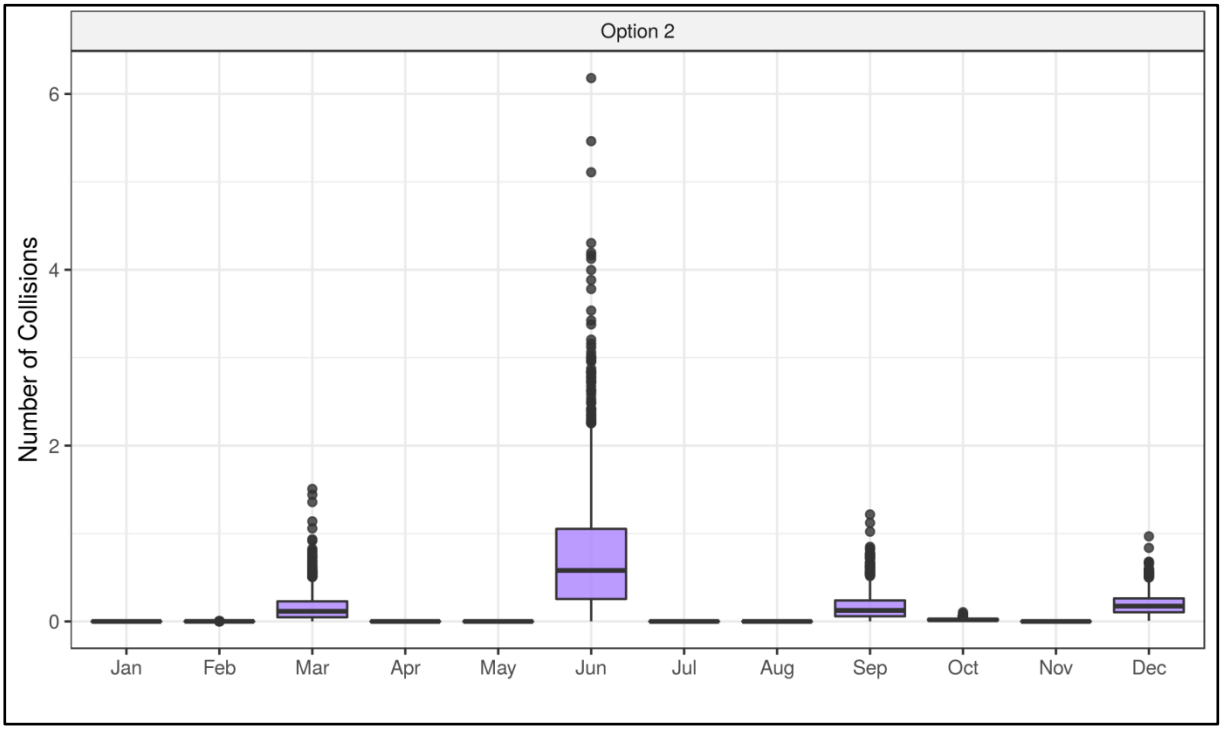

Figure 15: Herring gull monthly collisions Option 2.

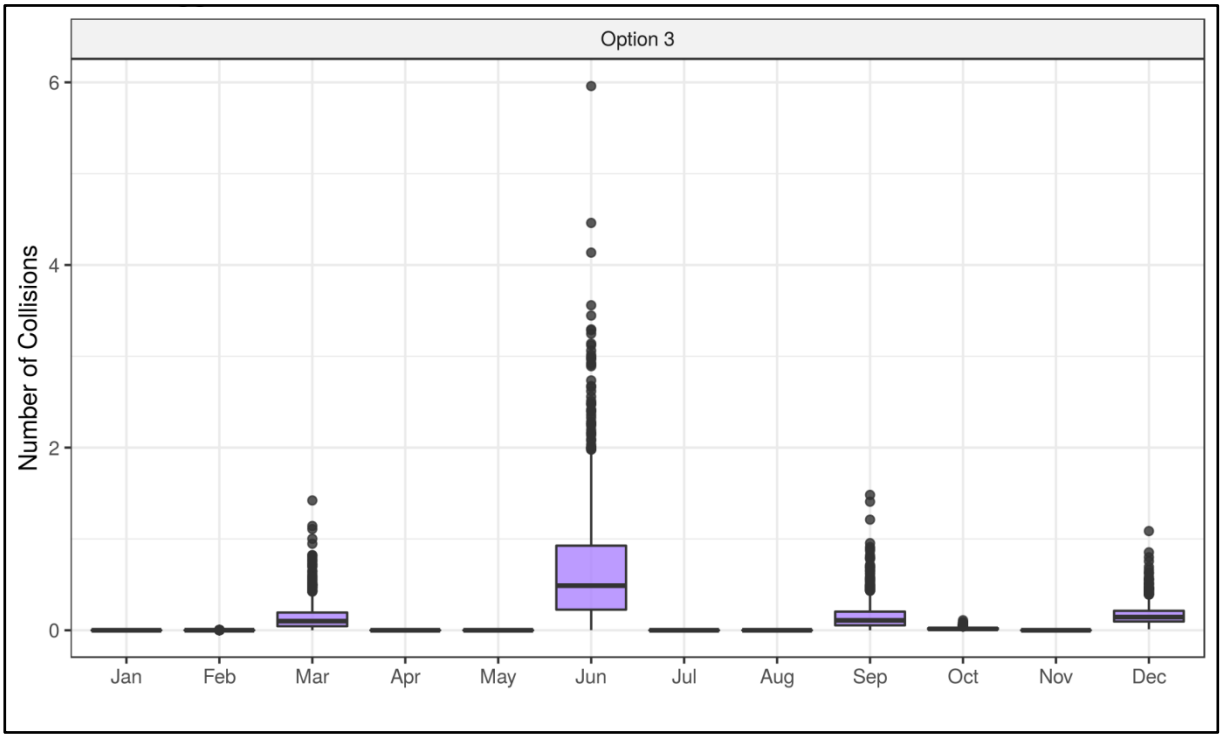

Figure 16: Herring gull monthly collisions Option 3.

3.6 Great black-backed gull

3.6.1.1 Table 11 presents the annual Great black-backed gull collision rates for Option 1, Option 2, and Option 3. Figure 17 presents the Great black-backed gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in Figure 18, Figure 19, and Figure 20 respectively.

3.6.1.2 Appendix F details the monthly CRM, bird parameter and turbine parameter outputs for great black-backed gull.

Table 11: Great black-backed gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	7.708	4.71	0.611	6.614	1.535	4.107	10.389	18.793
Option 2	7.718	4.963	0.643	6.71	1.389	3.995	10.174	19.936
Option 3	7.376	4.591	0.622	6.466	1.553	4.093	9.448	19.283

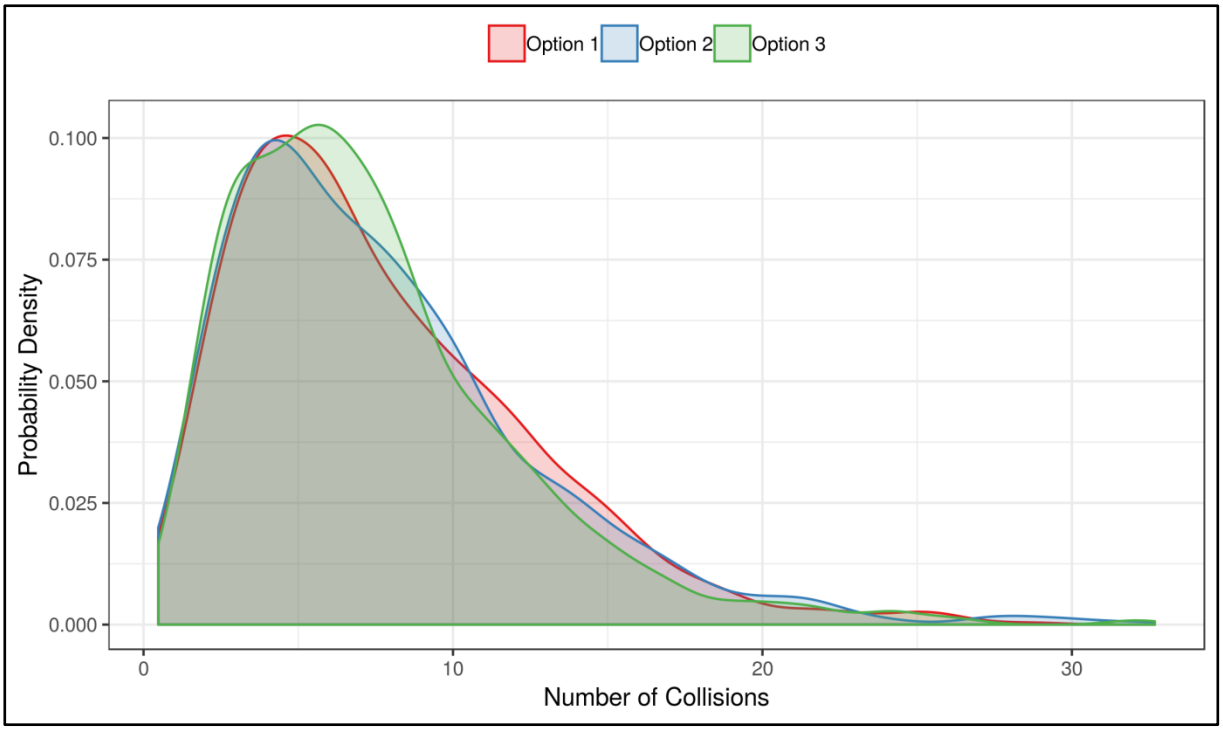

Figure 17: Great black-backed gull overall collisions probability density.

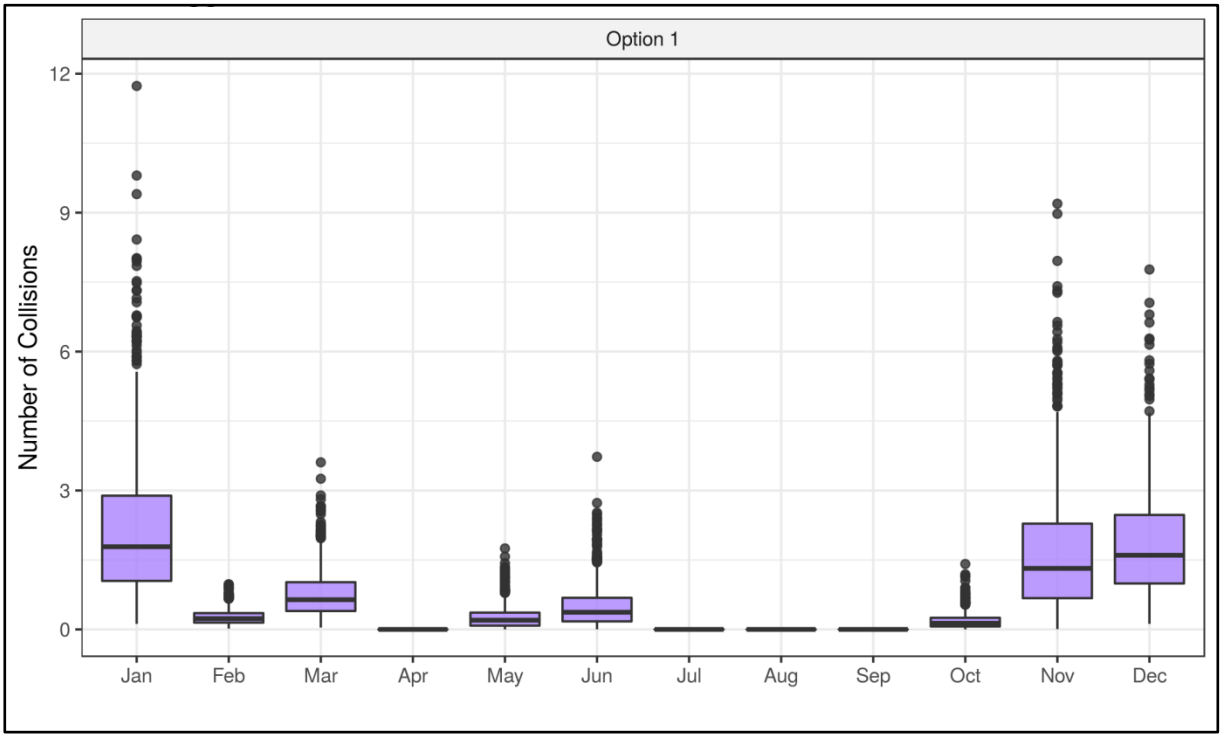

Figure 18: Great black-backed gull monthly collisions Option 1.

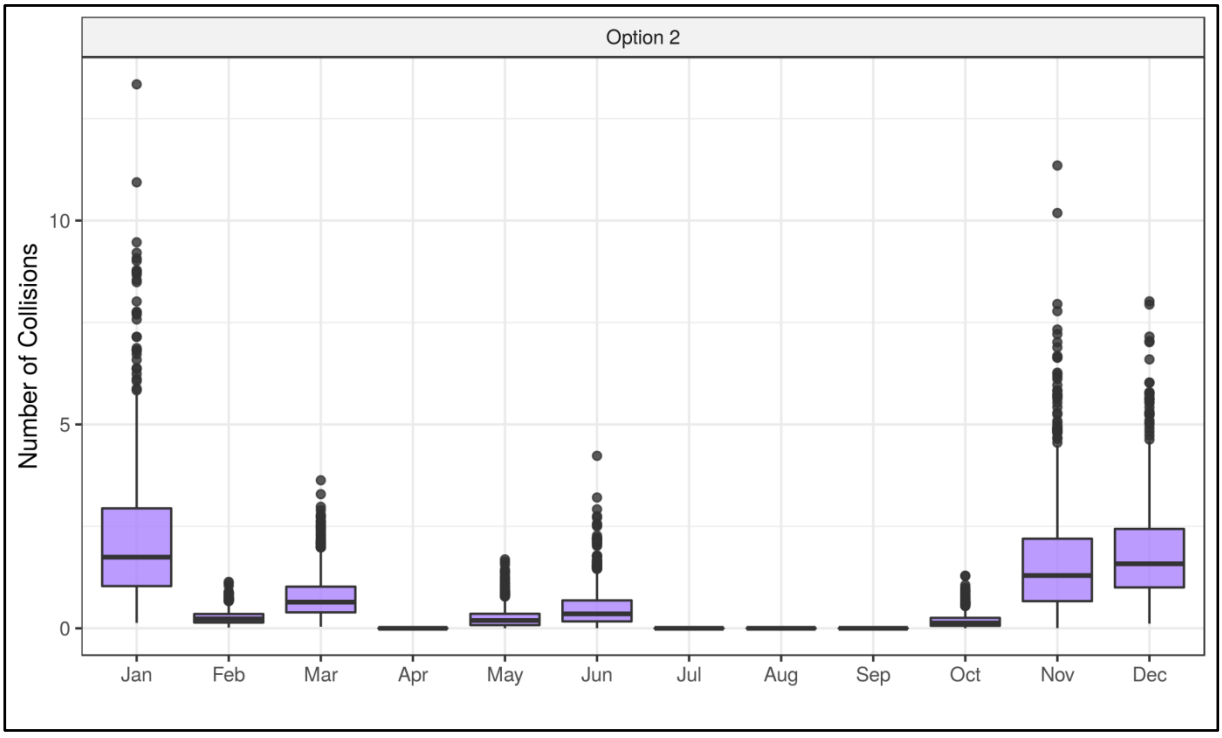

Figure 19: Great black-backed gull monthly collisions Option 2.

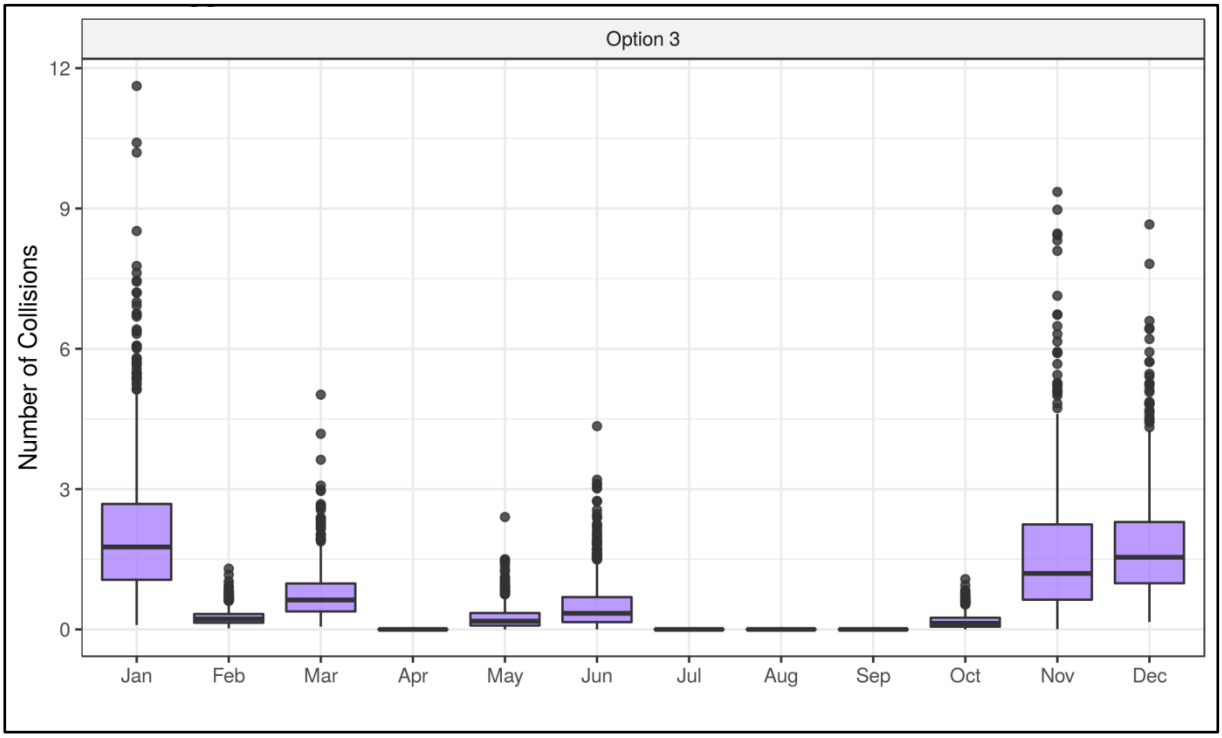

Figure 20: Great black-backed gull monthly collisions Option 3.

4 References

Alerstam, T., Rosén, M., Bäckman, J., Ericson, P.G.P., Hellgren, O. (2007) Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology 5(8): 1656-1662.

Band, W. (2012) Using a collision risk model to assess bird collision risks for offshore windfarms. The Crown Estate Strategic Ornithological Support Services (SOSS) report SOSS-02. http://www.bto.org/science/wetland-and-marine/soss/projects. Original published Sept 2011, extended to deal with flight height distribution data March 2012.

Bowgen, K., Cook, A. (2018) Bird Collision Avoidance: Empirical evidence and impact assessments, *JNCC Report No. 614,* JNCC, Peterborough, ISSN 0963-8091.

Cook, A.S.C.P., Wright, L.J., and Burton, N.H.K. (2012) A review of flight heights and avoidance rates of birds in relation to offshore windfarms. The Crown Estate Strategic Ornithological Support Services (SOSS). http://www.bto.org/science/wetland-and-marine/soss/projects.

Cook, A.S.C.P., Humphries, E.M., Masden, E.A. Burton, N.H.K. (2014) The avoidance rates of collision between birds and offshore turbines. BTO Research Report No 656 to Marine Scotland Science.

Donovan, C. (2018) Stochastic Band CRM – GUI User Manual, Draft V1.0, 31/03/2017.

Garthe, S. & Hüppop, O. (2004) Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41: 724-734.

HiDef BioConsult (2018a) Flight heights for birds around Hornsea Four proposed development derived from boat-based surveys between 2010 and 2013. HiDef BioConsult Scientific Report to Ørsted, 16/03/2018, Issue Draft I, 74pp.

HiDef BioConsult (2018b) Digital video aerial surveys of seabirds and marine mammals at Hornsea Project Four (HOW04): final report for April 2016 to March 2018. HiDef BioConsult Scientific Report to Ørsted, 15/06/2018, Issue Draft I, 369 pp.

JNCC, NE, SNH, NRW, NIEA. (2014) Joint Response from the Statutory Nature Conservation Bodies to the Marine Scotland Science Avoidance Rate Review. [Downloaded from: http://www.snh.gov.uk/docs/A1464185.pdf]

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, E.H.K. (2014) Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology 51: 31-41.

King, S., Maclean, I., Norman, T. and Prior, A. (2009). Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Wind Farm Developers. COWRIE Ltd, London.

MacArthur Green, APEM & Royal Haskoning DHV. (2015) East Anglia THREE: Appendix 13.1 Offshore Ornithology Evidence Plan Volume 3 – Document Reference: 6.3.13(1).

Masden, E. (2015) Developing an avian collision risk model to incorporate variability and uncertainty. Scottish Marine and Freshwater Science Vol 6 No 14. Edinburgh: Scottish Government, 43pp. DOI: 10.7489/1659-1.
McAdam, B.J. (2005) A Monte-Carlo Model for Bird / Wind Turbine Collisions. MSc Ecology. University of Aberdeen.

McGregor, R.M., King, S., Donovan, C.R., Caneco, B., Webb, A. (2018) A Stochastic Collision Risk Model for Seabirds in Flight. HiDef BioConsult Scientific Report to Marine Scotland, 06/04/2018, Issue I, 59 pp.

King, S., Maclean, I.M.D., Norman, T. & Prior, A. (2009) Developing guidance on ornithological cumulative impact assessment for offshore wind developers. COWRIE.

Pennycuick, C.J. (1997) Actual and 'optimum' flight speeds: field data reassessed. The Journal of Experimental Biology 200: 2355-2361.
R-project.org., 2013. The R Project for Statistical Computing. [Online]. Available at: http://www.r-project.org.

Robinson, R.A. (2005) BirdFacts: profiles of birds occurring in Britain & Ireland (BTO Research Report 407). BTO, Thetford (http://www.bto.org/birdfacts).

Skov, H., Heinanen, S., Norman, T., Ward, R.M., Mendex-Roldan, S. & Ellis, I. (2018) ORJIP Bird Collision and Avoidance Study. Final report – April 2018. The Carbon Trust. United Kingdom. 247pp.

Trinder, M. (2017). Offshore wind farms and birds: incorporating uncertainty in collision risk models: a test of Masden (2015). Natural England Commissioned Reports, Number 237, York.

Highways Agency (2008) Design Manual for Roads and Bridges. London, DFT

PINS (2012) Advice note six: Preparation and submission of application documents. Bristol, PINS.

Appendix A - SNCB Parameters CRM Outputs

1 Introduction to Second sCRM Iteration

1.1.1.1 This Appendix presents sCRM results based on the input parameters currently advocated for use by SNCBs. This iteration of the sCRM was run for each species with these input parameters in agreement with Natural England and the RSPB through the evidence plan process (at Technical Panel Meeting 4 on 11.06.19) in order to provide their more precautionary range of outputs.

1.1.1.2 Results from the first iteration of the sCRM (termed: evidence-based approach) has been provided as the main body of this report which incorporates more recent evidence from the literature that is considered within the impact assessments concerned with collision risk. The outputs presented use a reduced nocturnal activity rate for all five species in addition to an increase in avoidance rates in the basic and extended avoidance rates for kittiwake, lesser black-backed gull, herring gull, and great black-backed gull (Masden, 2015; Bowden & Cook, 2018; Skov *et al.*, 2018). In recognition of the evidence led approach to CRM (**Volume 2, Chapter 5: Offshore and Intertidal Ornithology**) the results presented in this Appendix should therefore be considered overly precautionary.

2 Methodology of Second sCRM Iteration

2.1.1.1 The input parameters that have been altered to inform the first (evidence based) and second (SNCB) iterations of the sCRM are presented in **Table A 1**. All other input parameters remained the same.

Table A 1: Summary of the input parameters for the first (evidence-based) and second (SNCB) iteration of the sCRM for Hornsea Four for six species: gannet, kittiwake, lesser black-backed gull (LBB Gull), herring gull (H Gull), and great black-backed gull (GBB Gull).

Input Parameter	Gannet	Kittiwake	LBB Gull	H Gull	GBB Gull
Basic Avoidance Rate: First Iteration	0.989 ± 0.002	0.994 ± 0.0055	0.997 ± 0.00175	0.997 ± 0.00175	0.997 ± 0.00175
Basic Avoidance Rate: Second Iteration	0.989 ± 0.002	0.989 ± 0.002	0.995 ± 0.001	0.995 ± 0.001	0.995 ± 0.001
Extended Avoidance Rate: First Iteration	n/a[1]	0.970 ± 0.0295	0.990 ± 0.00525	0.990 ± 0.00525	0.990 ± 0.00525
Extended Avoidance Rate: Second Iteration	n/a[1]	n/a[1]	0.989 ± 0.002	0.990 ± 0.002	0.989 ± 0.002
Nocturnal Activity: First Iteration	0.00 ± 0 [6]	0.033 ± 0.0045 [4]	0.25 ± 0 [6]	0.25 ± 0 [6]	0.25 ± 0 [6]
Nocturnal Activity: Second Iteration	0.25 ± 0	0.50 ± 0	0.50 ± 0	0.50 ± 0	0.50 ± 0
Flight Speed: First Iteration	14.90 ± 0.00 [3]	7.26 ± 0.40 [4]	13.10 ± 1.90 [5]	12.80 ± 1.80 [5]	13.70 ± 1.20 [5]
Flight Speed: Second Iteration	14.90 ± 0.00 [3]	13.10 ± 0.40 [4]	13.10 ± 1.90 [4]	12.80 ± 1.80 [4]	13.70 ± 1.20 [4]

3 Results of Second sCRM Iteration

3.1 Introduction

3.1.1.1 This section provides the standard outputs from the evidence based second iteration of the sCRM for each of the five seabird species. To interpret the boxplots: the 'box' is the interquartile range which represents the middle half of the data, with the middle bold line representing the median. The 'whiskers' are the largest and smallest non-outliers. The range of the entire data includes the outliers represented by circles. The density plots provide a visual representation of the distribution of data, the peak of the density plot displays where values are concentrated over the interval.

3.2 Gannet

3.2.1.1 Table A 2 presents the annual gannet collision rates for Option 1 and Option 2. Figure A 1 presents the gannet annual collision probability density for Option 1 and Option 2. Monthly collision rates for Option 1 and Option 2 are presented in Figure A 2 and Figure A 3 respectively.

3.2.1.2 Appendix B details the monthly CRM, bird parameter and turbine parameter outputs for gannet.

Table A 2: Gannet overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	60.138	15.284	0.254	58.374	34.414	49.034	69.509	92.775
Option 2	61.287	34.697	0.566	55.398	14.555	33.635	83.26	141.566

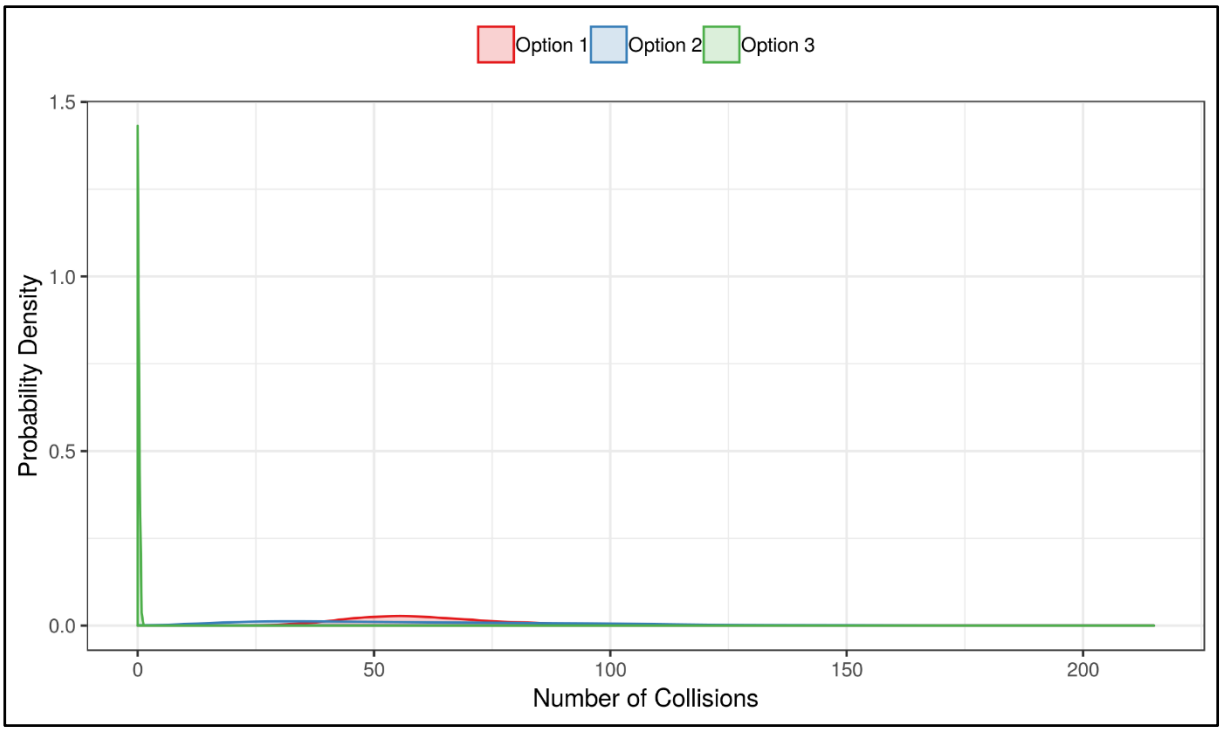

Figure A 1: Gannet overall collisions probability density.

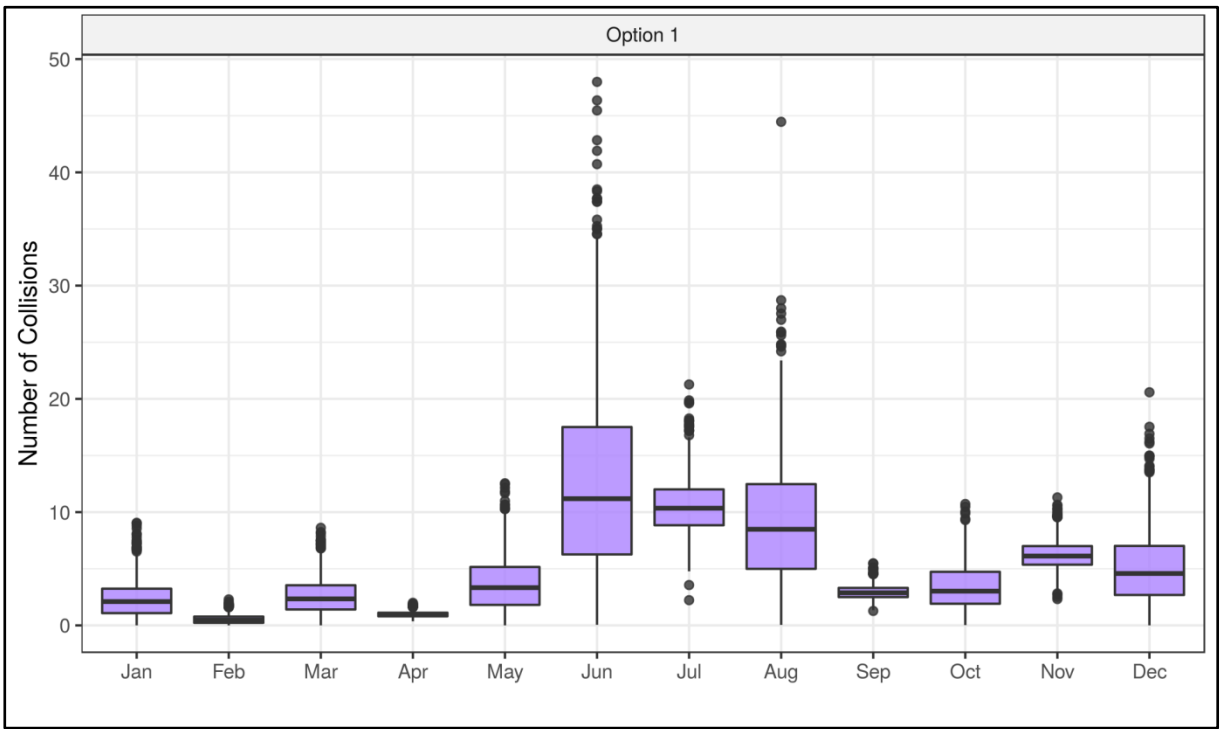

Figure A 2: Gannet monthly collisions Option 1.

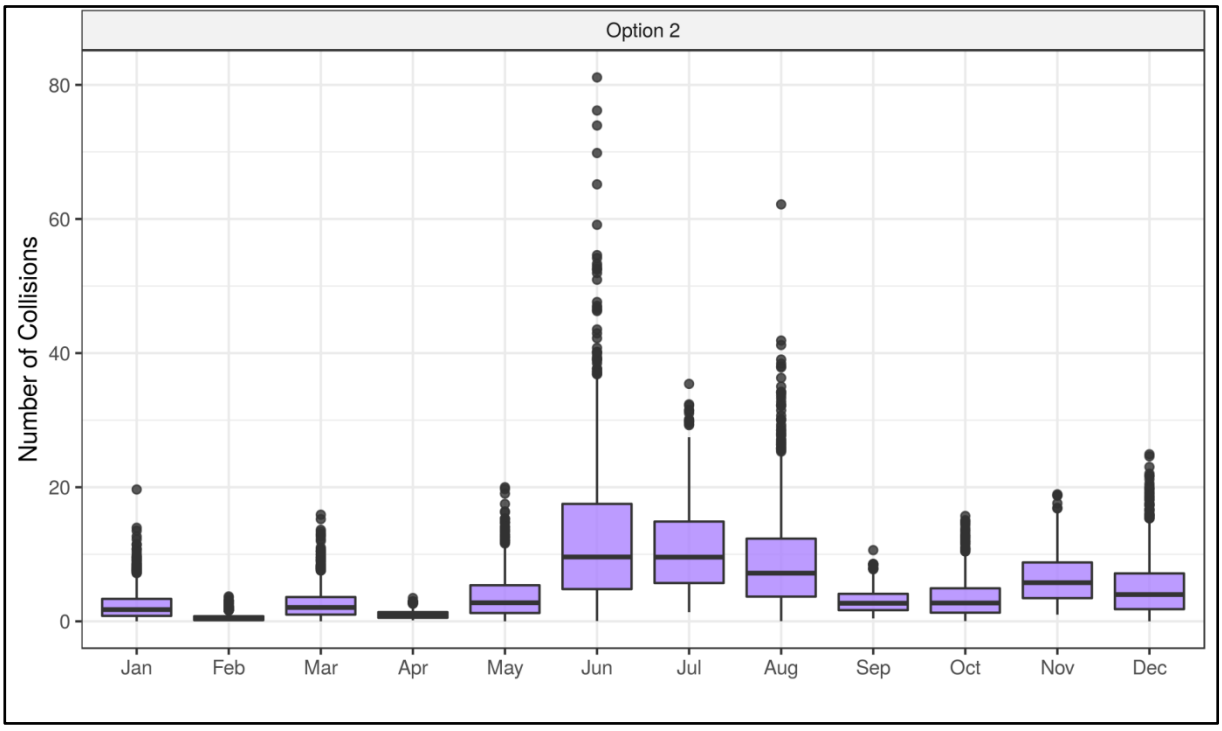

Figure A 3: Gannet monthly collisions Option 2.

Table A 3: Monthly gannet collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	2.339	1.61	0.688	2.104	0.167	1.083	3.242	6.167
Feb	0.548	0.405	0.738	0.458	0.028	0.229	0.78	1.543
Mar	2.602	1.642	0.631	2.342	0.166	1.407	3.545	6.581
Apr	0.978	0.243	0.249	0.959	0.568	0.804	1.12	1.52
May	3.663	2.441	0.667	3.335	0.209	1.813	5.158	9.265
Jun	12.666	8.454	0.667	11.188	0.595	6.267	17.513	32.697
Jul	10.545	2.574	0.244	10.347	6.077	8.844	12.01	16.234
Aug	9.142	5.466	0.598	8.488	0.837	4.994	12.474	21.129
Sep	2.936	0.635	0.216	2.883	1.826	2.501	3.31	4.317
Oct	3.383	1.986	0.587	3.026	0.253	1.913	4.733	7.766
Nov	6.241	1.297	0.208	6.124	3.89	5.363	7.003	9.097
Dec	5.096	3.264	0.641	4.584	0.294	2.688	7.018	12.189

Table A 4: Monthly gannet collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	2.407	2.237	0.929	1.752	0.121	0.815	3.349	8.144
Feb	0.558	0.536	0.961	0.404	0.025	0.177	0.765	1.902
Mar	2.708	2.397	0.885	2.068	0.113	1.005	3.621	9.096
Apr	1.007	0.588	0.583	0.881	0.239	0.532	1.373	2.321
May	3.747	3.341	0.892	2.769	0.139	1.24	5.381	12.889
Jun	12.683	11.144	0.879	9.596	0.505	4.808	17.513	39.896
Jul	10.857	6.313	0.581	9.571	2.444	5.711	14.88	25.293
Aug	9.24	7.588	0.821	7.185	0.559	3.688	12.333	28.526
Sep	3.013	1.684	0.559	2.7	0.702	1.67	4.102	6.749
Oct	3.491	2.862	0.82	2.736	0.246	1.289	4.929	10.825
Nov	6.414	3.576	0.557	5.764	1.535	3.46	8.784	14.097
Dec	5.16	4.422	0.857	3.997	0.217	1.815	7.147	16.721

Table A 5: Gannet sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.989	0.002	0.9892	0.0026
AvoidanceExtended	1	0	1	0
WingSpan	1.7181	0.0376	1.718	0.0508
BodyLength	0.9358	0.0322	0.9356	0.0454
PCH	0.0344	0	0.0344	0
FlightSpeed	14.9	0	14.9	0
NocturnalActivity	0.25	0	0.25	0

Table A 6: Gannet sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.5013	0.1974	6.5006	0.2778
Pitch_rad	0.0807	0.0175	0.0804	0.0231
JanOp	88.1726	1.9759	88.2355	2.6804
FebOp	88.6265	1.9843	88.6238	2.5298
MarOp	88.3942	1.97	88.3258	2.5764
AprOp	87.387	1.9482	87.3232	2.5983
MayOp	87.2909	1.9791	87.3276	2.7571
JunOp	85.9406	2.0512	85.9691	2.7852
JulOp	85.8209	2.0249	85.8719	2.7892
AugOp	86.4902	1.9807	86.4747	2.6407
SepOp	87.7182	2.0244	87.7828	2.6978
OctOp	88.7005	2.0727	88.7116	2.8795
NovOp	88.547	2.0238	88.4815	2.7208
DecOp	88.3116	2.0616	88.3266	2.865

3.3 Kittiwake

3.3.1.1 **Table A 7** presents the annual kittiwake collision rates for Option 1 and Option 2. **Figure A 4** presents the kittiwake annual collision probability density for Option 1 and Option 2. Monthly collision rates for Option 1 and Option 2 are presented in **Figure A 5** and **Figure A 6** respectively.

3.3.1.2 **Appendix C** details the monthly CRM, bird parameter and turbine parameter outputs for kittiwake.

Table A 7: Kittiwake overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	24.443	5.871	0.24	23.867	14.705	20.082	28.256	37.778
Option 2	197.914	57.355	0.29	191.905	103.577	156.86	234.339	323.883

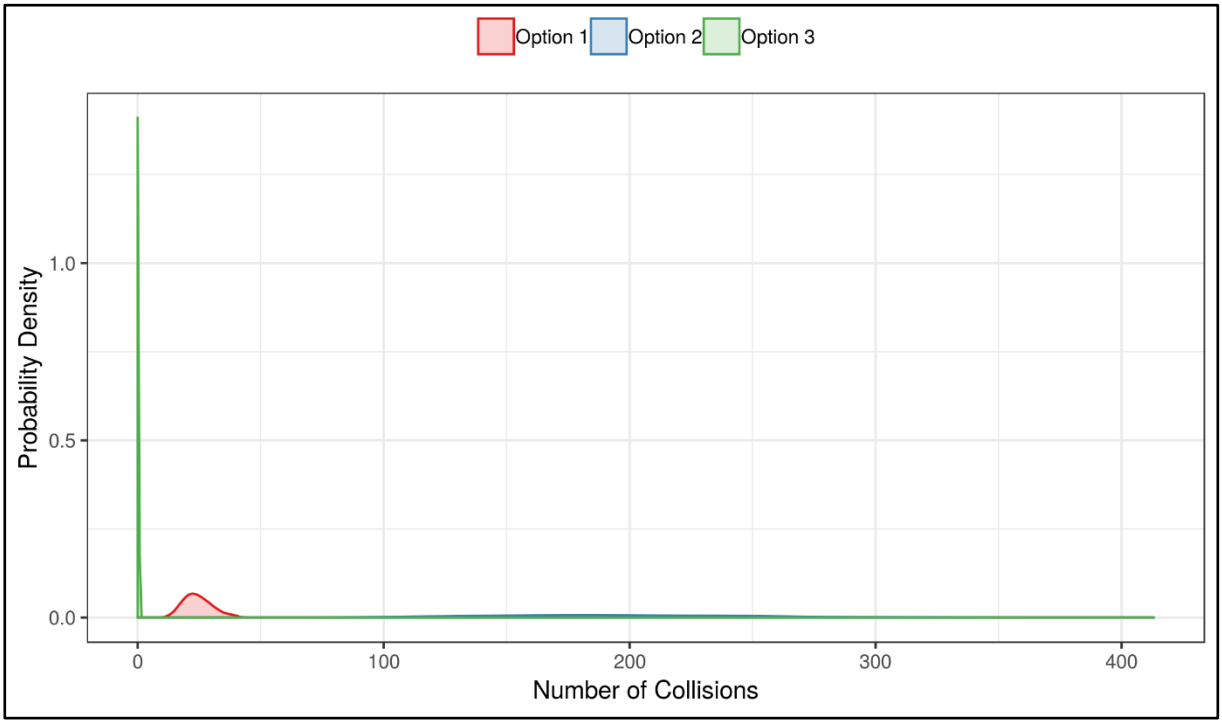

Figure A 4: Kittiwake overall collisions probability density.

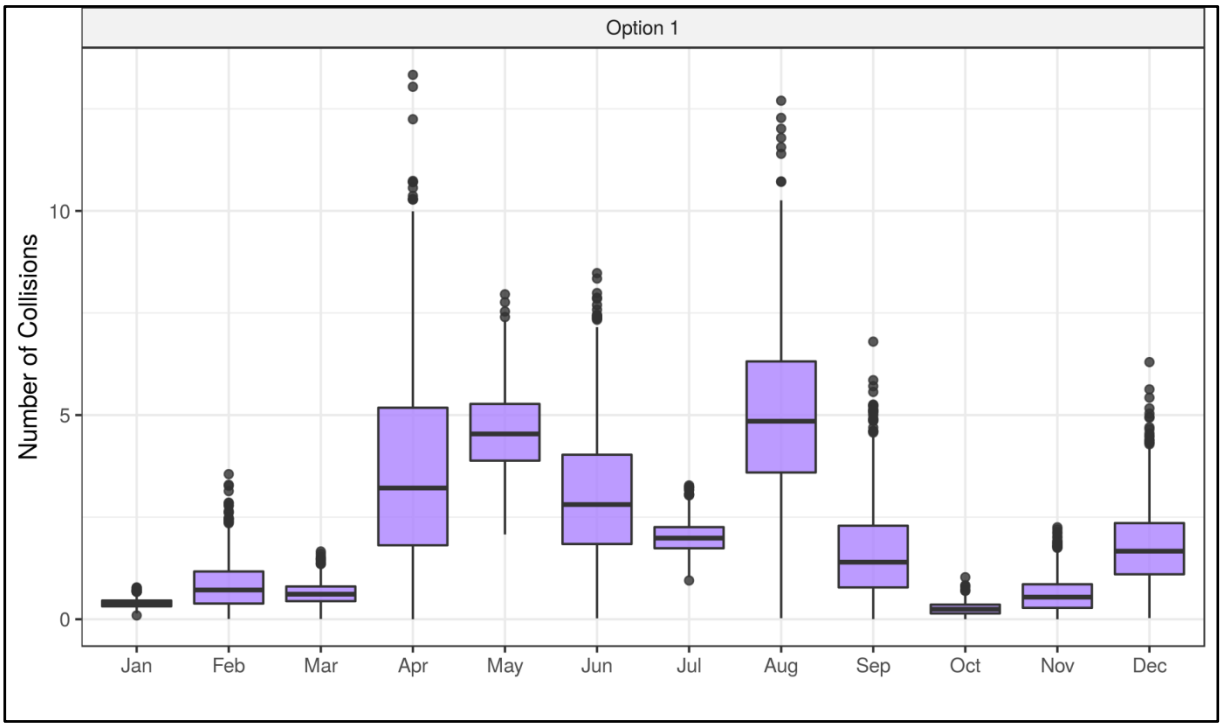

Figure A 5: Kittiwake monthly collisions Option 1.

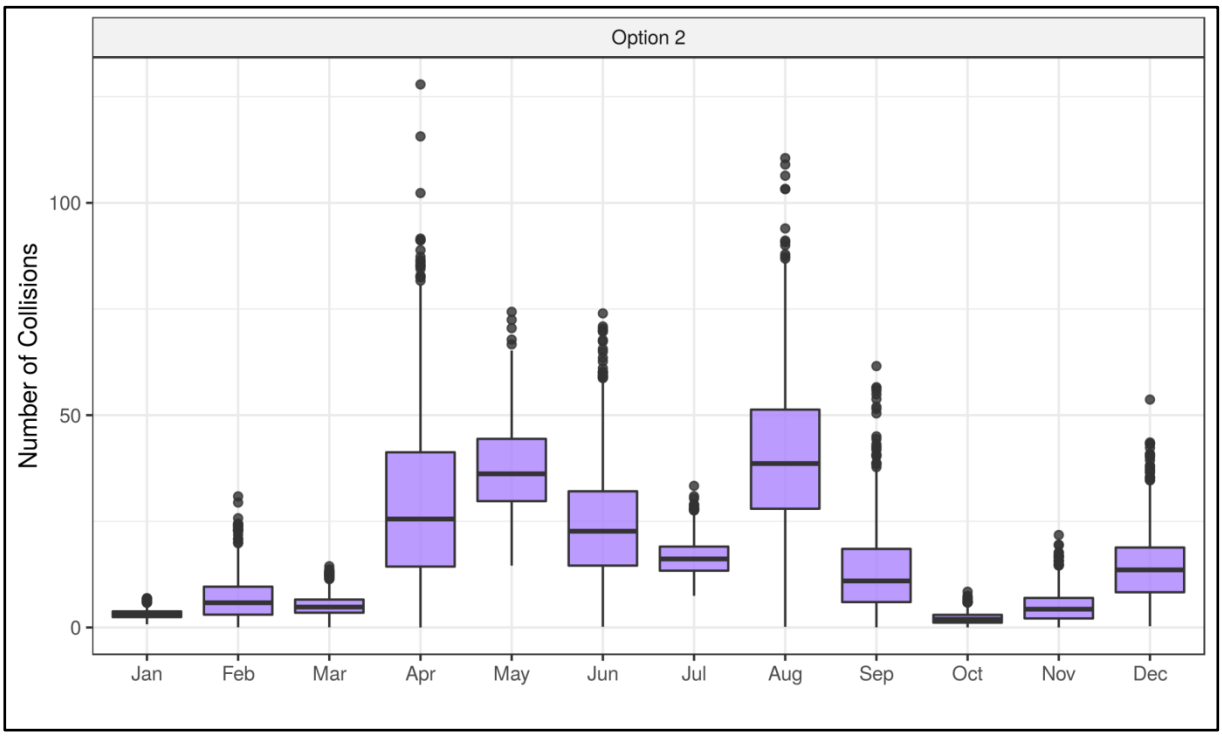

Figure A 6: Kittiwake monthly collisions Option 2.

Table A 8: Monthly kittiwake collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0.396	0.108	0.273	0.389	0.216	0.317	0.459	0.637
Feb	0.832	0.58	0.697	0.717	0.048	0.384	1.17	2.166
Mar	0.638	0.274	0.429	0.614	0.173	0.443	0.804	1.251
Apr	3.632	2.365	0.651	3.214	0.254	1.812	5.18	8.927
May	4.608	0.987	0.214	4.539	2.844	3.885	5.274	6.682
Jun	3.007	1.561	0.519	2.81	0.378	1.843	4.029	6.365
Jul	2.021	0.39	0.193	1.988	1.34	1.738	2.256	2.851
Aug	5.029	2.012	0.4	4.85	1.411	3.594	6.315	9.478
Sep	1.621	1.122	0.692	1.398	0.079	0.78	2.29	4.405
Oct	0.266	0.161	0.604	0.246	0.022	0.143	0.358	0.61
Nov	0.611	0.431	0.705	0.542	0.023	0.279	0.857	1.634
Dec	1.781	0.972	0.546	1.667	0.221	1.101	2.355	3.916

Table A 9: Monthly kittiwake collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	3.206	1.027	0.32	3.083	1.539	2.453	3.793	5.569
Feb	6.73	4.844	0.72	5.827	0.384	3.024	9.607	18.505
Mar	5.168	2.397	0.464	4.813	1.394	3.483	6.579	10.622
Apr	29.377	19.913	0.678	25.547	1.841	14.345	41.264	76.652
May	37.352	10.166	0.272	36.189	20.349	29.758	44.424	57.776
Jun	24.359	13.376	0.549	22.677	3.016	14.572	32.076	53.948

Jul	16.38	4.21	0.257	16.145	9.307	13.378	19.05	25.683
Aug	40.662	17.446	0.429	38.611	11.214	27.967	51.311	78.706
Sep	13.221	9.784	0.74	10.965	0.625	5.988	18.51	36.695
Oct	2.15	1.344	0.625	1.948	0.181	1.141	2.979	5.273
Nov	4.946	3.627	0.733	4.312	0.206	2.135	6.957	13.605
Dec	14.363	8.17	0.569	13.567	1.609	8.301	18.834	33.966

Table A 10: Kittiwake sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.989	0.002	0.9892	0.0026
AvoidanceExtended	1	0	1	0
WingSpan	1.0796	0.0402	1.0803	0.0541
BodyLength	0.39	0.0049	0.39	0.0067
PCH	0.005	0	0.005	0
FlightSpeed	13.1018	0.4088	13.1054	0.539
NocturnalActivity	0.5	0	0.5	0

Table A 11: Kittiwake sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.505	0.1997	6.5049	0.2503
Pitch_rad	0.0805	0.0174	0.0802	0.0235
JanOp	88.1624	2.0439	88.1778	2.7582
FebOp	88.6408	2.0015	88.5898	2.7725
MarOp	88.4364	2.0098	88.3863	2.7706
AprOp	87.464	2.0576	87.4427	2.8992
MayOp	87.2808	1.9666	87.2723	2.7144
JunOp	86.0007	2.0365	86.0228	2.7117
JulOp	85.8116	1.9624	85.8438	2.6959
AugOp	86.4388	1.9973	86.3959	2.7526
SepOp	87.6614	2.1013	87.6808	2.9268
OctOp	88.4916	2.0576	88.5291	2.6661
NovOp	88.6373	2.0091	88.608	2.7241
DecOp	88.5147	1.9406	88.5293	2.5451

3.4 Lesser black-backed gull

3.4.1.1 **Table A 12** presents the annual lesser black-backed gull collision rates for Option 1 and Option 2. **Figure A 7** presents the lesser black-backed gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in **Figure A 8**, **Figure A 9** and **Figure A 10** respectively.

3.4.1.2 **Appendix D** details the monthly CRM, bird parameter and turbine parameter outputs for lesser black-backed gull.

Table A 12: Lesser black-backed gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	1.305	0.672	0.515	1.203	0.354	0.807	1.657	2.928
Option 2	1.873	1.174	0.627	1.59	0.425	1.048	2.473	4.815
Option 3	1.021	0.744	0.729	0.839	0.191	0.519	1.294	3.065

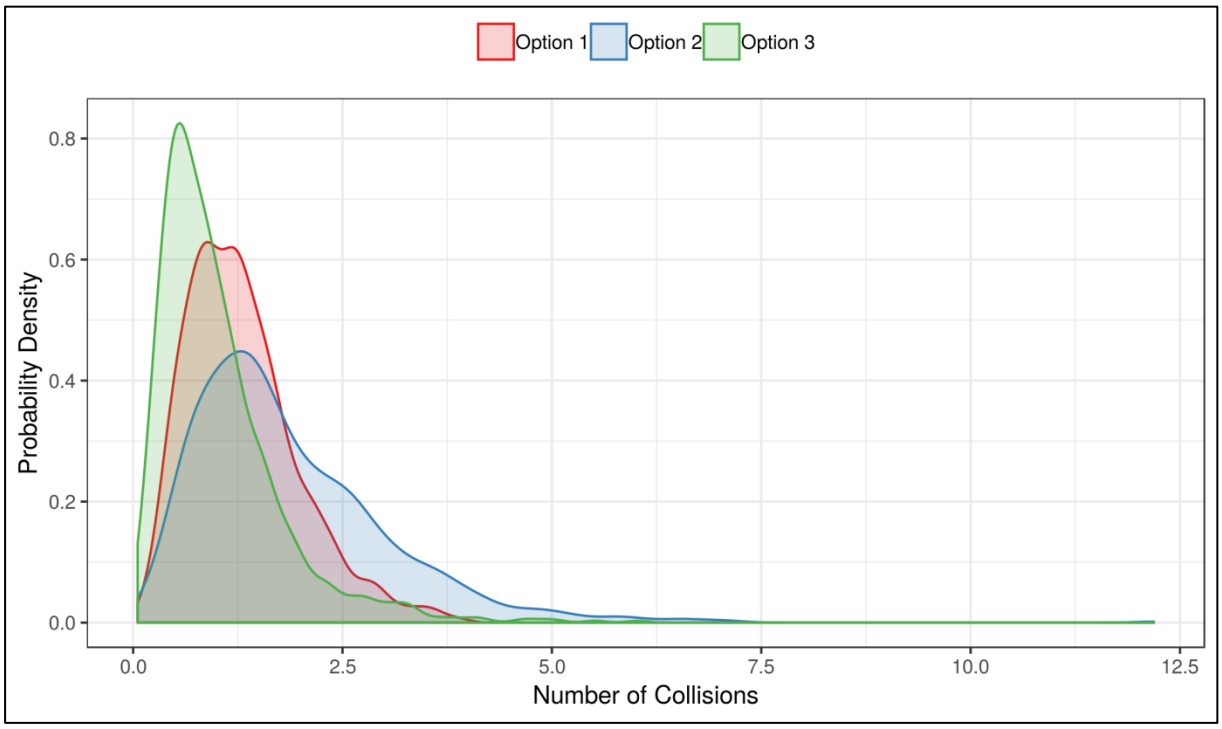

Figure A 7: Lesser black-backed gull overall collisions probability density.

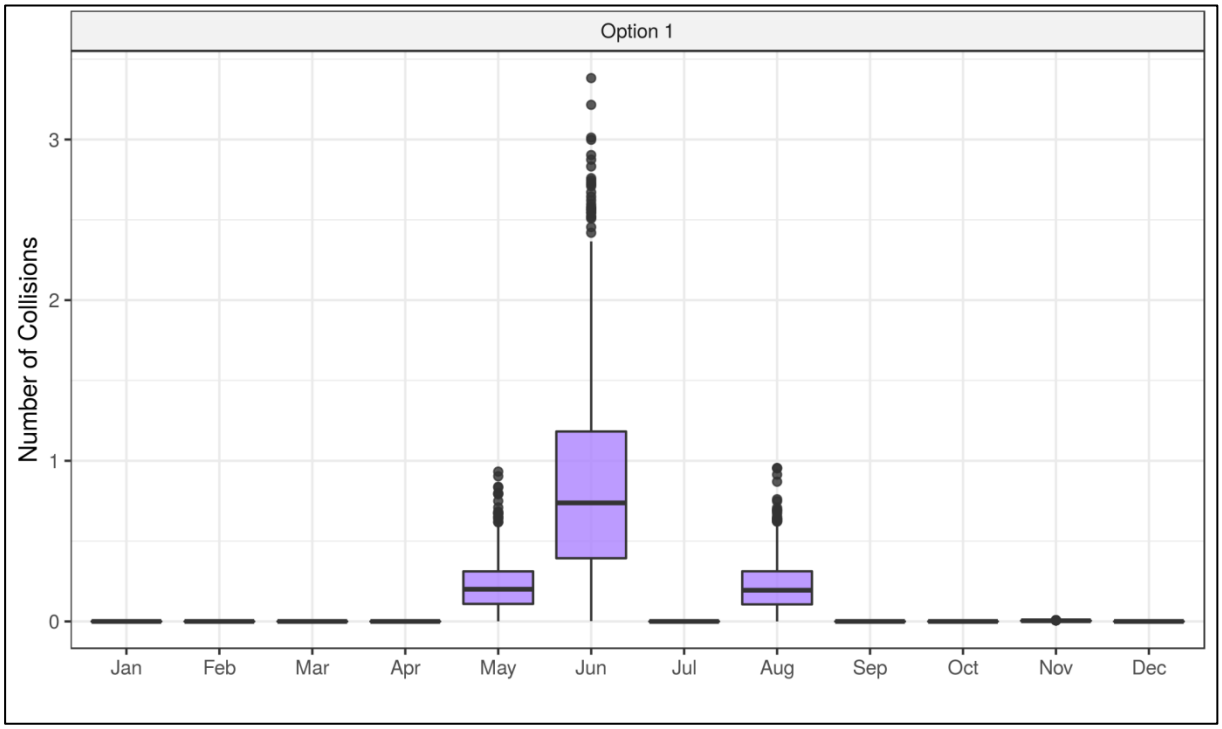

Figure A 8: Lesser black-backed gull monthly collisions Option 1.

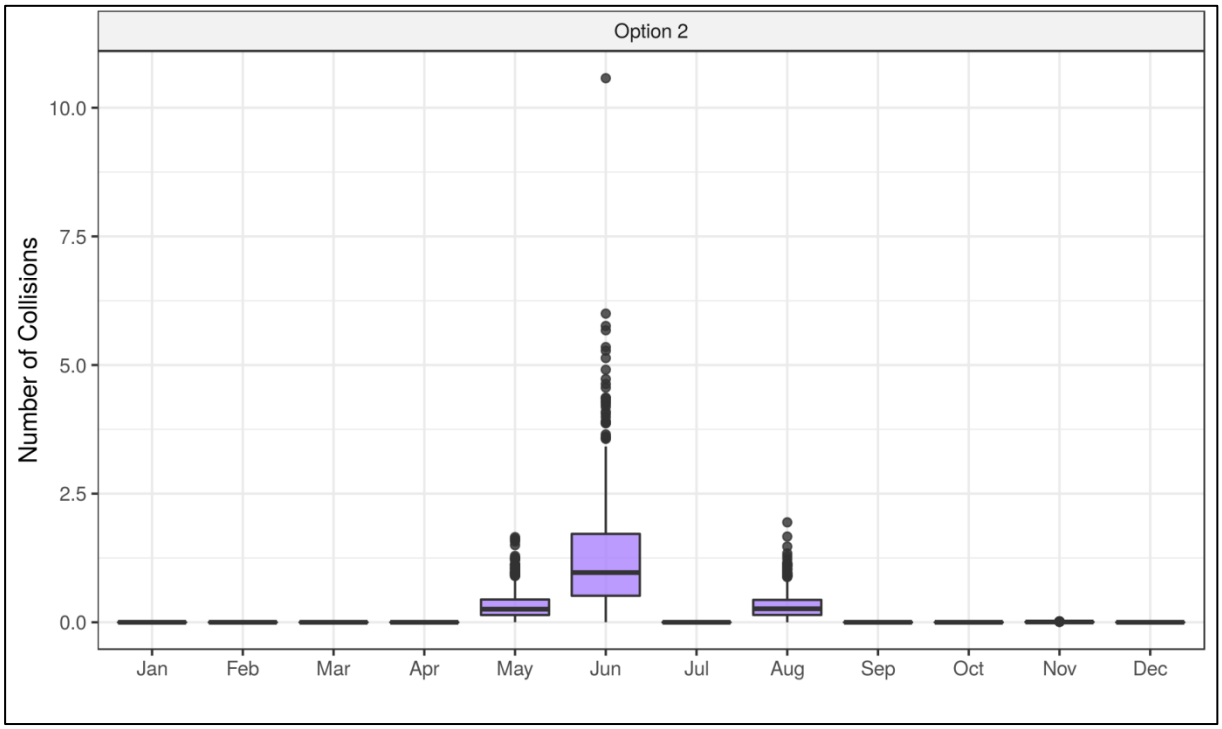

Figure A 9: Lesser black-backed gull monthly collisions Option 2.

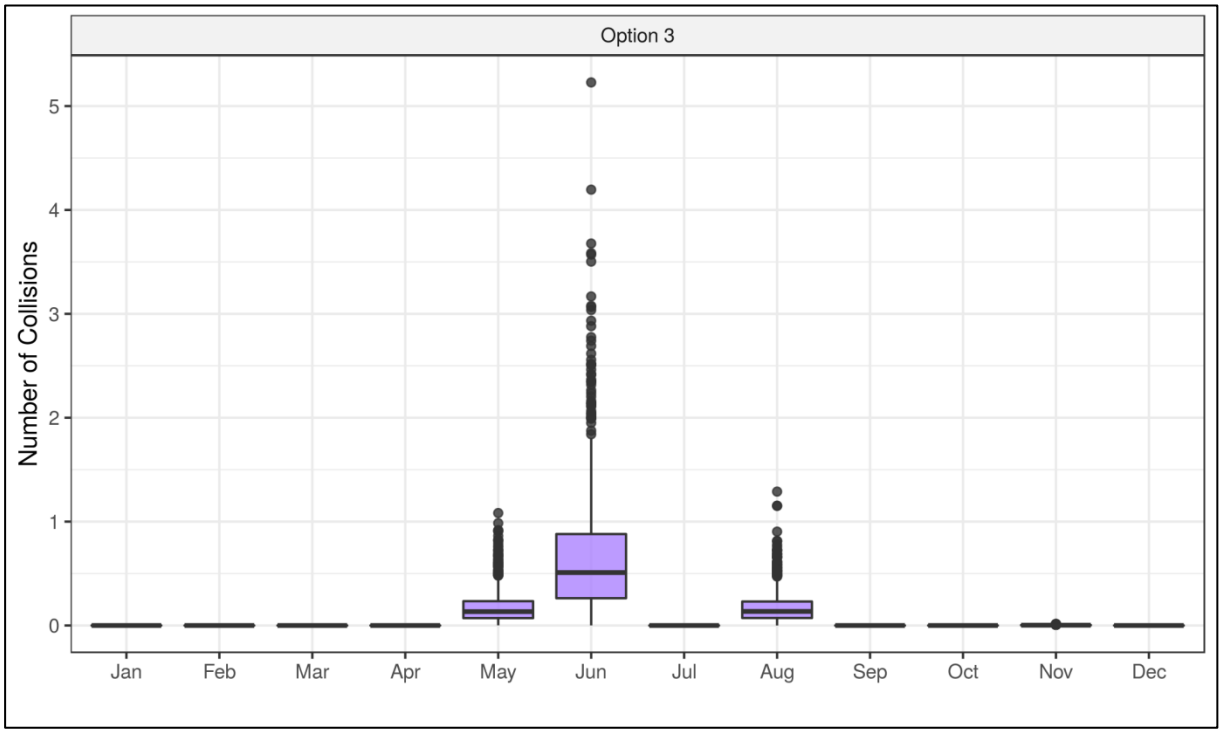

Figure A 10: Lesser black-backed gull monthly collisions Option 3.

Table A 13: Monthly lesser black-backed gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.225	0.154	0.686	0.2	0.013	0.109	0.312	0.578
Jun	0.852	0.608	0.715	0.738	0.038	0.393	1.183	2.456
Jul	0	0	NaN	0	0	0	0	0
Aug	0.225	0.154	0.685	0.194	0.012	0.106	0.312	0.589
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0
Nov	0.004	0.001	0.226	0.004	0.003	0.004	0.005	0.006
Dec	0	0	NaN	0	0	0	0	0

Table A 14: Monthly lesser black-backed gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.322	0.254	0.788	0.255	0.016	0.142	0.443	0.968

Jun	1.221	1.005	0.823	0.966	0.043	0.516	1.718	3.658
Jul	0	0	NaN	0	0	0	0	0
Aug	0.323	0.252	0.78	0.263	0.015	0.142	0.436	0.938
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0
Nov	0.006	0.002	0.401	0.006	0.003	0.004	0.007	0.012
Dec	0	0	NaN	0	0	0	0	0

Table A 15: Monthly lesser black-backed gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.176	0.156	0.885	0.134	0.008	0.071	0.234	0.615
Jun	0.666	0.604	0.907	0.509	0.026	0.263	0.88	2.345
Jul	0	0	NaN	0	0	0	0	0
Aug	0.176	0.154	0.875	0.136	0.008	0.072	0.231	0.587
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0
Nov	0.003	0.002	0.547	0.003	0.001	0.002	0.004	0.008
Dec	0	0	NaN	0	0	0	0	0

Table A 16: Lesser black-backed gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.995	0.001	0.9951	0.0014
AvoidanceExtended	0.9889	0.002	0.989	0.0026
WingSpan	1.4184	0.0378	1.4182	0.0493
BodyLength	0.5791	0.0301	0.5791	0.0439
PCH	0.088	0	0.088	0
FlightSpeed	13.0737	1.8897	13.1407	2.5939
NocturnalActivity	0.5	0	0.5	0

Table A 17: Lesser black-backed gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.5018	0.2009	6.4963	0.2654
Pitch_rad	0.0806	0.0177	0.0812	0.0237
JanOp	88.1639	2.0096	88.1907	2.763
FebOp	88.606	2.0356	88.6532	2.7655

Parameter	Mean	SD	Median	IQR
MarOp	88.4616	1.9484	88.3925	2.6448
AprOp	87.5206	1.9953	87.5908	2.6989
MayOp	87.2911	1.9226	87.2853	2.5515
JunOp	85.9771	1.989	85.9161	2.7795
JulOp	85.7964	2.0956	85.796	2.754
AugOp	86.41	2.0759	86.4963	2.8746
SepOp	87.7825	1.9849	87.6708	2.5893
OctOp	88.6536	2.0463	88.6666	2.715
NovOp	88.6516	1.9286	88.5915	2.5235
DecOp	88.2736	1.9984	88.3221	2.6621

3.5 Herring gull

3.5.1.1 **Table A 18** presents the annual herring gull collision rates for Option 1, Option 2, and Option 3. **Figure A 11** presents the herring gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in **Figure A 12**, **Figure A 13**, and **Figure A 14** respectively.

3.5.1.2 **Appendix E** details the monthly CRM, bird parameter and turbine parameter outputs for herring gull.

Table A 18: Herring gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	2.166	0.977	0.451	1.981	0.743	1.461	2.678	4.584
Option 2	2.664	1.323	0.497	2.411	0.837	1.714	3.288	5.817
Option 3	1.441	0.819	0.568	1.239	0.425	0.865	1.841	3.521

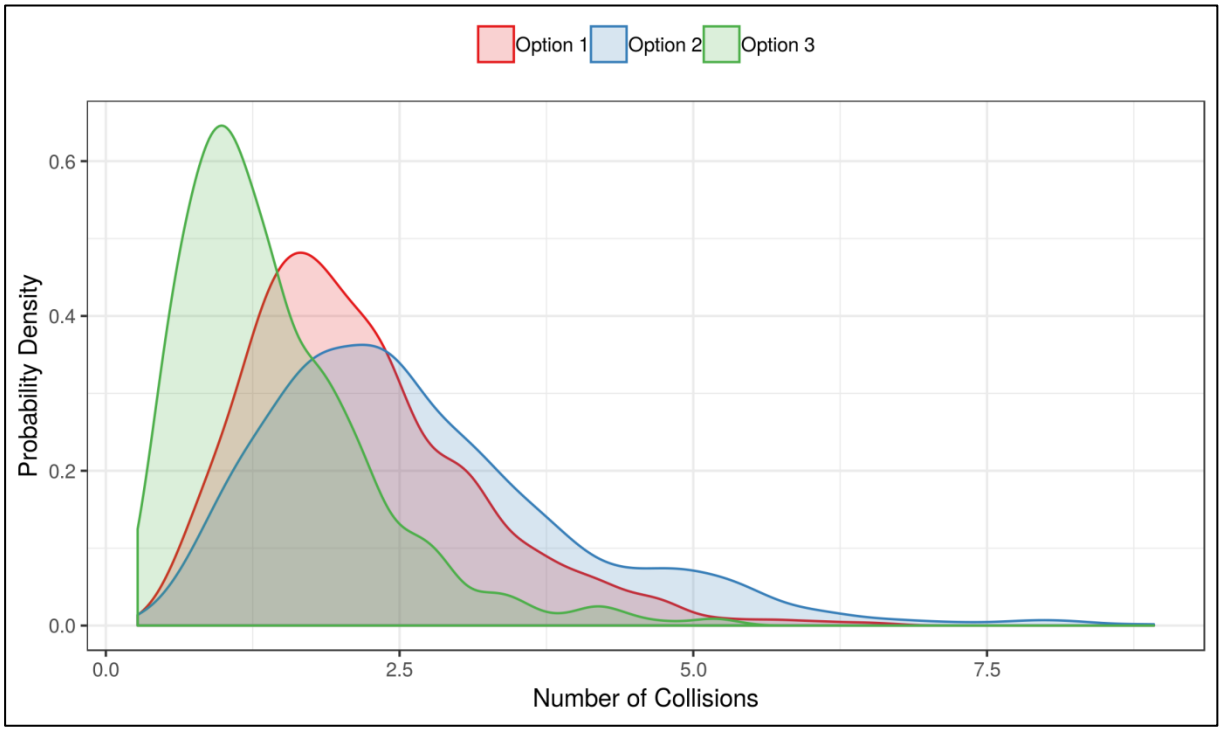

Figure A 11: Herring gull overall collisions probability density.

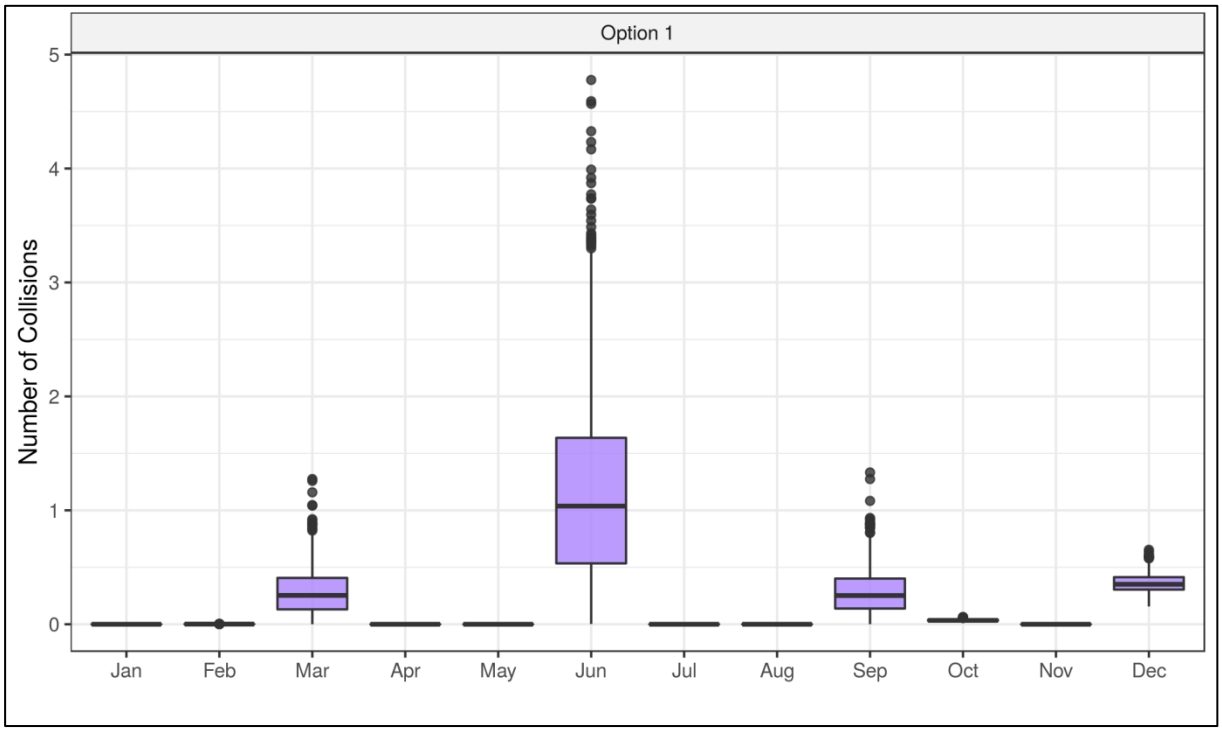

Figure A 12: Herring gull monthly collisions Option 1.

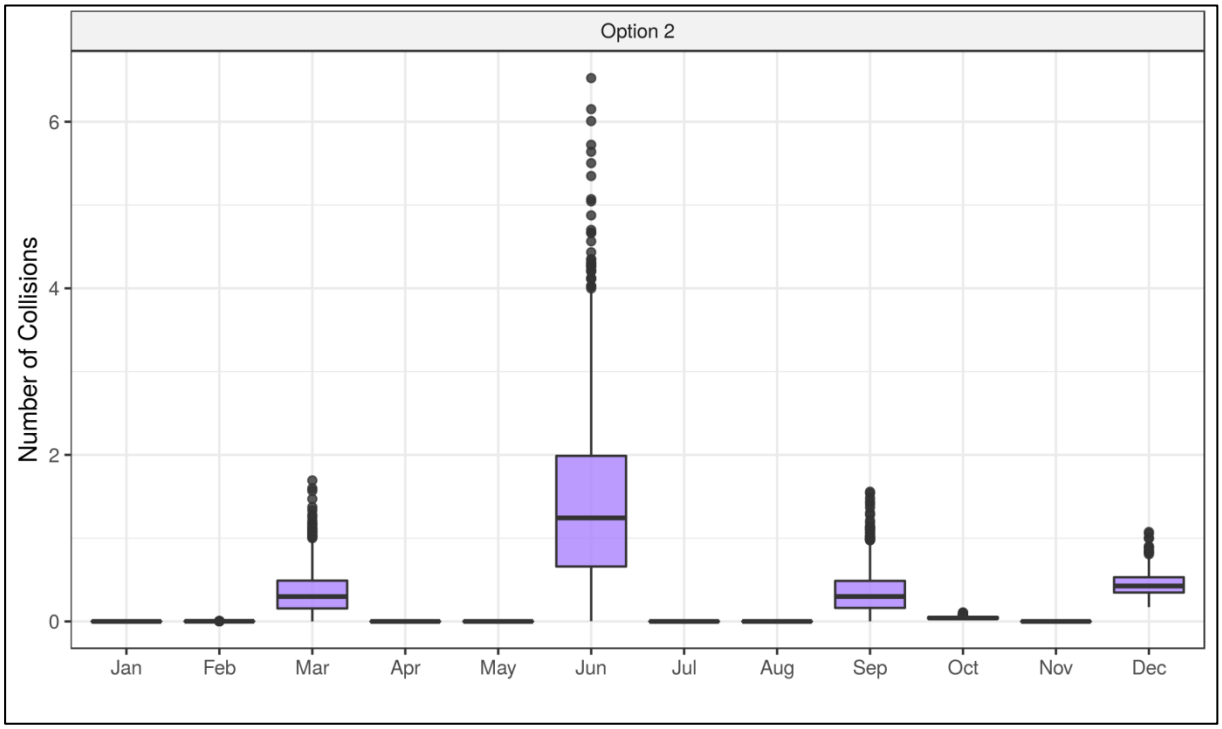

Figure A 13: Herring gull monthly collisions Option 2.

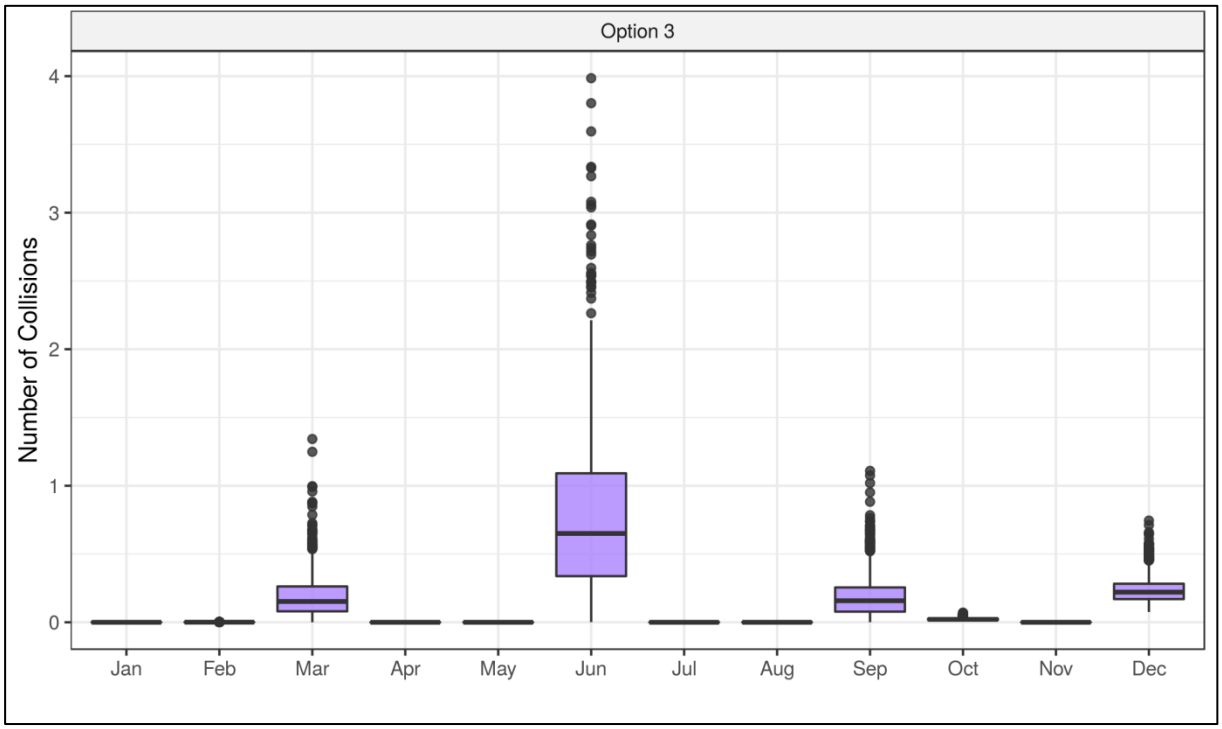

Figure A 14: Herring gull monthly collisions Option 3.

Table A 19: Monthly herring gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.001	0	0.221	0.001	0.001	0.001	0.002	0.002
Mar	0.288	0.203	0.704	0.253	0.015	0.131	0.407	0.77
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	1.194	0.848	0.71	1.037	0.066	0.535	1.636	3.3
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.286	0.197	0.691	0.252	0.022	0.138	0.401	0.718
Oct	0.035	0.008	0.223	0.034	0.021	0.029	0.04	0.052
Nov	0	0	NaN	0	0	0	0	0
Dec	0.361	0.08	0.223	0.351	0.221	0.304	0.413	0.539

Table A 20: Monthly herring gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.002	0.001	0.31	0.002	0.001	0.001	0.002	0.003
Mar	0.355	0.265	0.745	0.299	0.015	0.156	0.49	1.015
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	1.465	1.09	0.744	1.243	0.081	0.659	1.988	4.202
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.353	0.26	0.736	0.299	0.025	0.162	0.487	0.983
Oct	0.043	0.013	0.311	0.041	0.022	0.034	0.051	0.073
Nov	0	0	NaN	0	0	0	0	0
Dec	0.446	0.138	0.31	0.426	0.23	0.347	0.531	0.759

Table A 21: Monthly herring gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.001	0	0.426	0.001	0	0.001	0.001	0.002
Mar	0.196	0.168	0.854	0.152	0.008	0.08	0.263	0.605
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	0.787	0.621	0.788	0.651	0.038	0.338	1.091	2.453
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.191	0.155	0.81	0.158	0.013	0.078	0.255	0.592
Oct	0.023	0.01	0.426	0.021	0.011	0.016	0.027	0.05
Nov	0	0	NaN	0	0	0	0	0

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Dec	0.242	0.103	0.426	0.221	0.112	0.17	0.282	0.523

Table A 22: Herring gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.995	0.001	0.995	0.0013
AvoidanceExtended	0.99	0.0021	0.9901	0.0026
WingSpan	1.4396	0.0309	1.4412	0.042
BodyLength	0.5946	0.0228	0.5943	0.0301
PCH	0.1215	0	0.1215	0
FlightSpeed	12.7754	1.7676	12.7513	2.3841
NocturnalActivity	0.5	0	0.5	0

Table A 23: Herring gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.496	0.2073	6.4868	0.2735
Pitch_rad	0.0798	0.018	0.0802	0.0249
JanOp	88.2808	1.9653	88.3364	2.6755
FebOp	88.5689	2.0309	88.5367	2.7357
MarOp	88.5033	2.015	88.44	2.7165
AprOp	87.3072	1.9756	87.2768	2.7055
MayOp	87.2471	1.9849	87.2969	2.5852
JunOp	85.9762	2.0441	85.9516	2.7367
JulOp	85.8704	2.0632	85.8667	2.7946
AugOp	86.5319	1.9691	86.5509	2.6905
SepOp	87.749	1.9858	87.7579	2.6579
OctOp	88.5744	2.054	88.6361	2.8531
NovOp	88.5595	2.0839	88.4979	2.8389
DecOp	88.5159	1.9783	88.5059	2.7443

3.6 Great black-backed gull

3.6.1.1 Table A 24 presents the annual Great black-backed gull collision rates for Option 1, Option 2, and Option 3. Figure A 15 presents the Great black-backed gull annual collision probability density for Option 1, Option 2, and Option 3. Monthly collision rates for Option 1, Option 2, and Option 3 are presented in Figure A 16, Figure A 17, and Figure A 18 respectively.

3.6.1.2 Appendix F details the monthly CRM, bird parameter and turbine parameter outputs for great black-backed gull.

Table A 24: Great black-backed gull overall collisions.

Option	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Option 1	16.753	4.371	0.261	16.246	9.35	13.779	19.383	26.707
Option 2	16.641	5.199	0.312	16.061	8.525	12.987	19.567	29.882
Option 3	10.525	3.99	0.379	9.787	4.79	7.689	12.483	20.532

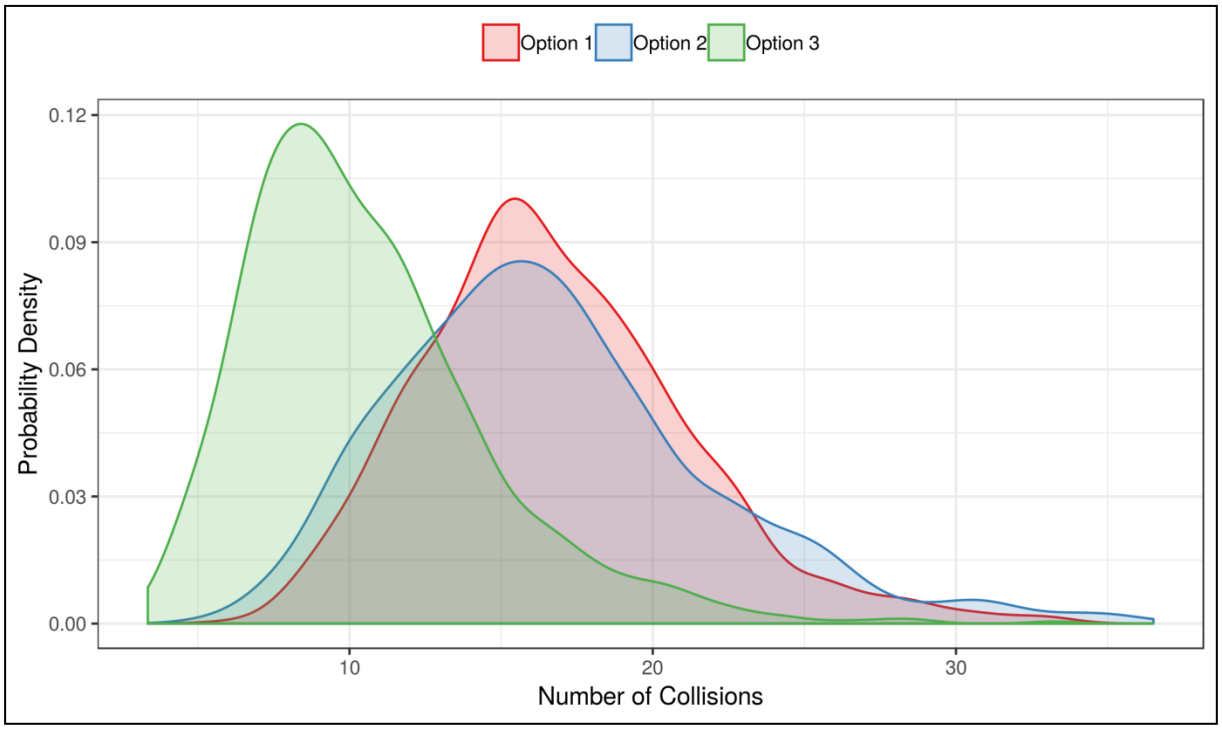

Figure A 15: Great black-backed gull overall collisions probability density.

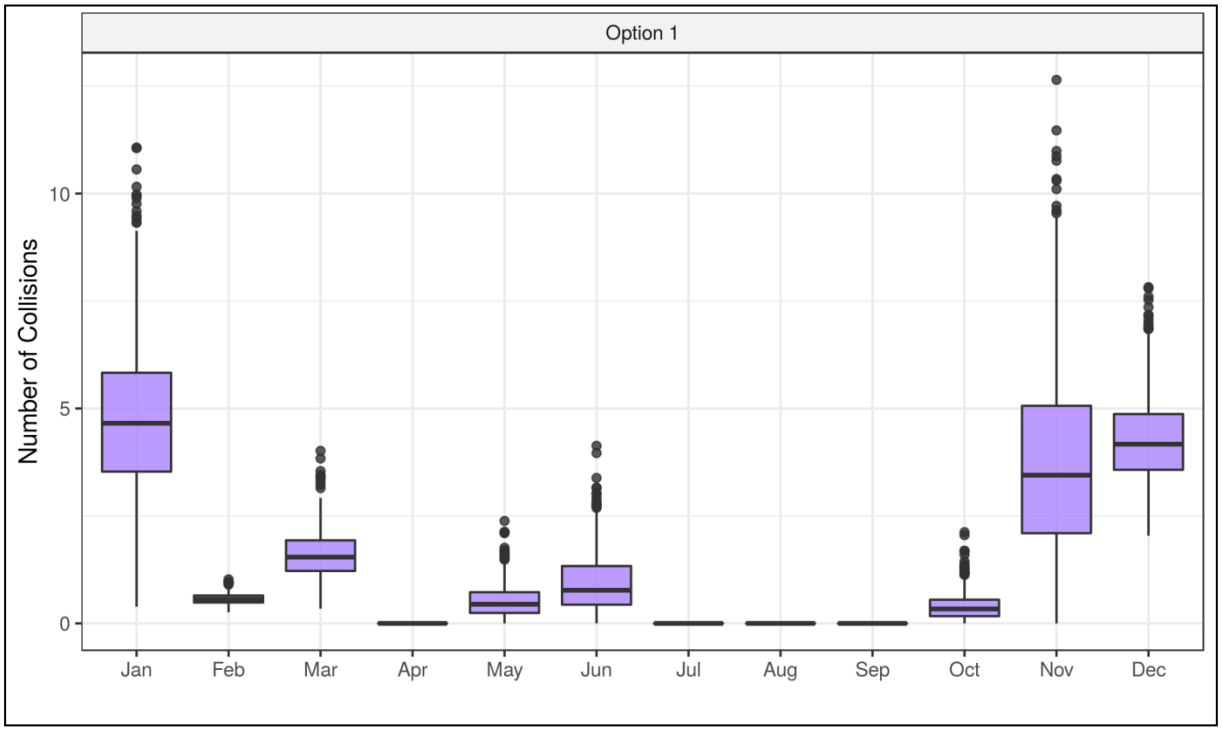

Figure A 16: Great black-backed gull monthly collisions Option 1.

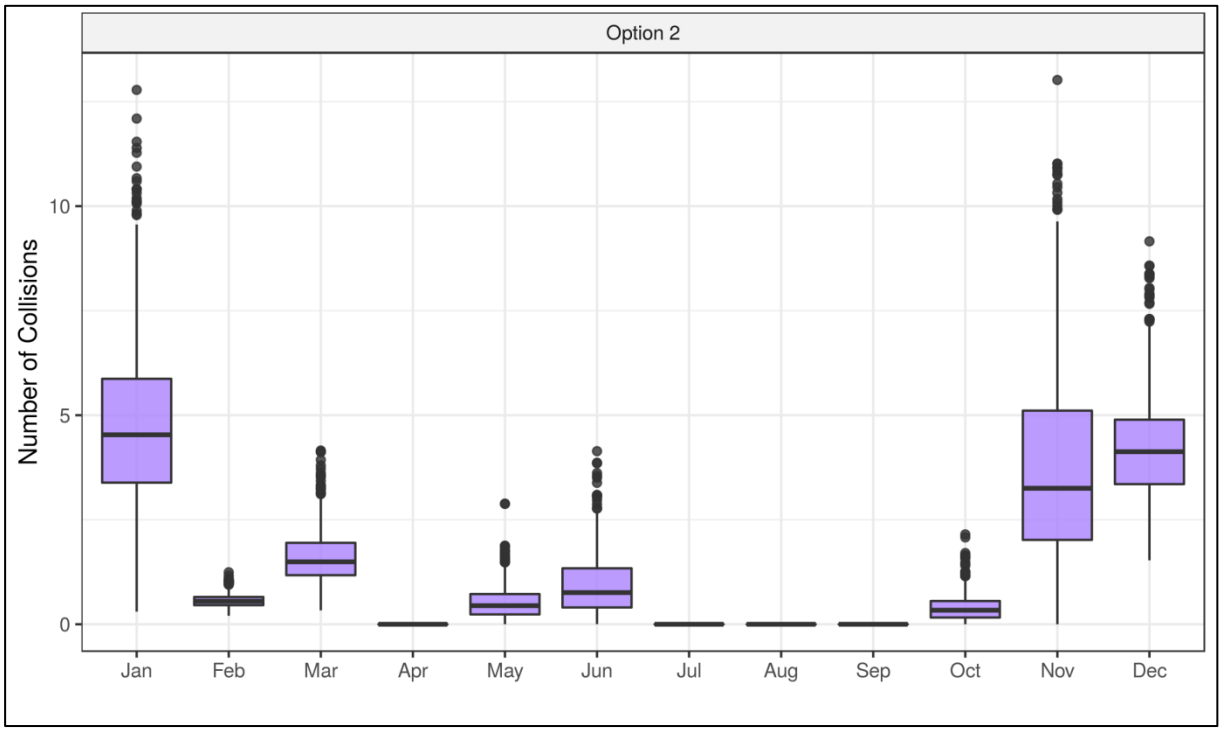

Figure A 17: Great black-backed gull monthly collisions Option 2.

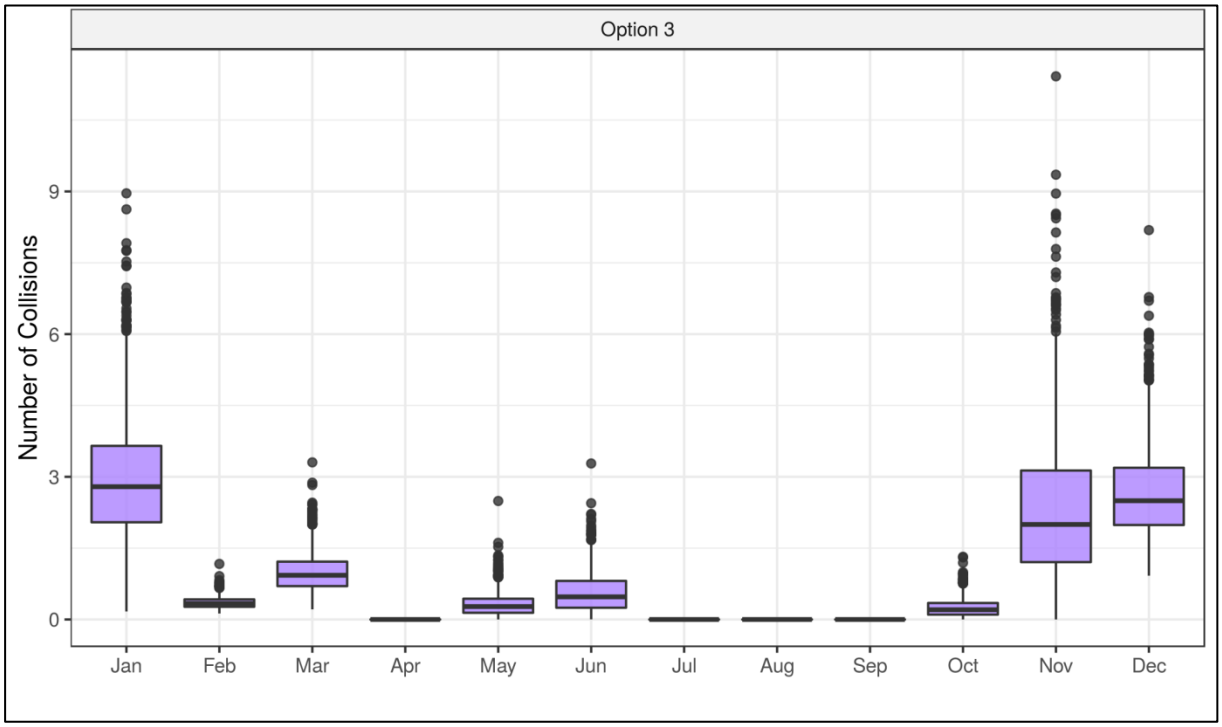

Figure A 18: Great black-backed gull monthly collisions Option 3.

Table A 25: Monthly great black-backed gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	4.777	1.71	0.358	4.656	1.883	3.531	5.83	8.514
Feb	0.568	0.121	0.212	0.56	0.355	0.486	0.649	0.825
Mar	1.602	0.528	0.33	1.543	0.725	1.22	1.932	2.711
Apr	0	0	NaN	0	0	0	0	0
May	0.514	0.361	0.702	0.445	0.026	0.243	0.726	1.374
Jun	0.927	0.655	0.707	0.771	0.054	0.436	1.334	2.425
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.392	0.294	0.751	0.337	0.018	0.169	0.551	1.103
Nov	3.714	2.198	0.592	3.448	0.345	2.099	5.062	8.674
Dec	4.261	0.97	0.228	4.169	2.585	3.574	4.87	6.48

Table A 26: Monthly great black-backed gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	4.751	1.909	0.402	4.532	1.733	3.387	5.871	9.117
Feb	0.565	0.155	0.275	0.551	0.318	0.457	0.653	0.924
Mar	1.59	0.588	0.37	1.493	0.647	1.173	1.947	2.905
Apr	0	0	NaN	0	0	0	0	0
May	0.508	0.37	0.729	0.445	0.03	0.236	0.722	1.402
Jun	0.923	0.677	0.733	0.758	0.058	0.402	1.338	2.42

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.391	0.301	0.772	0.336	0.016	0.161	0.556	1.09
Nov	3.678	2.264	0.615	3.252	0.341	2.018	5.11	8.852
Dec	4.236	1.222	0.288	4.127	2.295	3.351	4.893	7.092

Table A 27: Monthly great black-backed gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	3.002	1.345	0.448	2.792	1.042	2.044	3.65	6.284
Feb	0.358	0.126	0.352	0.336	0.176	0.267	0.422	0.647
Mar	1.005	0.429	0.427	0.929	0.389	0.701	1.216	2.094
Apr	0	0	NaN	0	0	0	0	0
May	0.323	0.254	0.786	0.272	0.014	0.141	0.436	0.921
Jun	0.578	0.435	0.753	0.476	0.037	0.247	0.811	1.598
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.246	0.196	0.795	0.205	0.011	0.102	0.346	0.756
Nov	2.331	1.575	0.676	1.998	0.197	1.206	3.132	6.302
Dec	2.682	0.97	0.362	2.497	1.29	1.987	3.19	5.046

Table A 28: Great black-backed gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.995	0.001	0.9951	0.0014
AvoidanceExtended	0.989	0.0021	0.9891	0.0029
WingSpan	1.5786	0.0377	1.5782	0.0507
BodyLength	0.7095	0.0356	0.7089	0.0485
PCH	0.1721	0	0.1721	0
FlightSpeed	13.7414	1.1658	13.738	1.51
NocturnalActivity	0.5	0	0.5	0

Table A 29: Great black-backed gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.4952	0.195	6.4943	0.2715
Pitch_rad	0.0799	0.0178	0.079	0.0232
JanOp	88.1052	2.005	88.0532	2.7494
FebOp	88.5607	1.9889	88.6345	2.8797

Parameter	Mean	SD	Median	IQR
MarOp	88.3964	1.9697	88.4054	2.7937
AprOp	87.4649	1.9455	87.5537	2.5831
MayOp	87.3029	2.0152	87.2748	2.7006
JunOp	86.0824	2.0298	86.1072	2.686
JulOp	85.8796	1.9215	85.892	2.5704
AugOp	86.3849	2.053	86.3619	2.663
SepOp	87.8291	1.9959	87.8319	2.696
OctOp	88.5541	2.0197	88.5417	2.7234
NovOp	88.5199	2.0045	88.5161	2.5893
DecOp	88.4305	2.0103	88.3856	2.7611

Appendix B - Gannet monthly collision rates

Table B 1: Monthly gannet collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	1.474	1.032	0.7	1.34	0.078	0.634	2.124	3.829
Feb	0.392	0.299	0.762	0.337	0.018	0.157	0.551	1.131
Mar	2.069	1.264	0.611	1.886	0.127	1.102	2.888	4.782
Apr	0.836	0.211	0.252	0.818	0.491	0.687	0.975	1.304
May	3.399	2.236	0.658	3.078	0.155	1.655	4.686	8.796
Jun	11.588	7.502	0.647	10.586	0.992	5.827	15.708	29.038
Jul	9.431	2.353	0.25	9.232	5.357	7.722	10.848	14.523
Aug	8.528	4.816	0.565	7.836	0.894	5.086	11.553	19.432
Sep	2.397	0.515	0.215	2.364	1.471	2.031	2.731	3.467
Oct	2.594	1.526	0.588	2.43	0.225	1.434	3.584	6.001
Nov	4.33	0.937	0.216	4.271	2.758	3.657	4.923	6.374
Dec	3.194	2.123	0.665	2.901	0.209	1.532	4.476	7.889

Table B 2: Monthly gannet collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	1.484	1.365	0.92	1.066	0.06	0.498	2.127	5.133
Feb	0.392	0.393	1.001	0.284	0.012	0.122	0.523	1.499
Mar	2.087	1.764	0.845	1.577	0.088	0.778	2.898	6.668
Apr	0.858	0.509	0.593	0.745	0.183	0.454	1.185	1.993
May	3.473	3.194	0.919	2.577	0.127	1.204	4.664	13.011
Jun	11.691	10.389	0.889	8.604	0.686	4.208	15.647	40.098
Jul	9.624	5.686	0.591	8.709	2.078	5.105	13.105	22.763
Aug	8.615	6.975	0.81	6.842	0.639	3.508	11.716	27.757
Sep	2.442	1.383	0.566	2.204	0.557	1.279	3.366	5.562
Oct	2.666	2.236	0.839	2.103	0.135	1.047	3.668	8.381
Nov	4.427	2.54	0.574	3.906	1.043	2.321	6.245	9.771
Dec	3.352	3.094	0.923	2.357	0.117	1.071	4.79	11.352

Table B 3: Gannet sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.9891	0.0021	0.9891	0.0028
AvoidanceExtended	1	0	1	0
WingSpan	1.7211	0.0375	1.722	0.0486
BodyLength	0.937	0.0316	0.9375	0.0436
PCH	0.0344	0	0.0344	0
FlightSpeed	14.9	0	14.9	0
NocturnalActivity	0	0	0	0

Table B 4: Gannet sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.5102	0.1952	6.5123	0.2677
Pitch_rad	0.0801	0.0171	0.0804	0.0238
JanOp	88.1784	2.079	88.1135	2.6846
FebOp	88.5696	2.0733	88.5225	2.8276
MarOp	88.3943	1.9496	88.411	2.6074
AprOp	87.4171	2.054	87.4364	2.8035
MayOp	87.2354	1.9993	87.2543	2.7266
JunOp	86.0068	1.9616	85.9721	2.6552
JulOp	85.7966	1.9939	85.8386	2.6874
AugOp	86.4095	1.9901	86.4358	2.6643
SepOp	87.8005	2.0585	87.8021	2.7525
OctOp	88.6212	1.9618	88.6964	2.5673
NovOp	88.5238	2.0034	88.5105	2.672
DecOp	88.4657	1.9642	88.4209	2.8082

Appendix C - Kittiwake monthly collision risks

Table C 1: Monthly kittiwake collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0.079	0.072	0.907	0.06	0.004	0.026	0.111	0.267
Feb	0.182	0.228	1.25	0.106	0.002	0.041	0.243	0.748
Mar	0.167	0.173	1.038	0.112	0.006	0.049	0.226	0.617
Apr	0.998	1.202	1.204	0.587	0.014	0.224	1.293	4.222
May	1.4	1.24	0.886	1.093	0.064	0.494	1.918	4.749
Jun	0.934	1.038	1.111	0.576	0.022	0.248	1.265	3.504
Jul	0.628	0.551	0.878	0.49	0.03	0.224	0.863	2.128
Aug	1.5	1.486	0.99	1.079	0.051	0.477	2.019	5.55
Sep	0.454	0.586	1.291	0.259	0.006	0.093	0.615	1.906
Oct	0.064	0.075	1.16	0.039	0.001	0.016	0.086	0.267
Nov	0.131	0.162	1.24	0.071	0.002	0.027	0.17	0.589
Dec	0.335	0.362	1.08	0.211	0.008	0.088	0.443	1.292

Table C 2: Monthly kittiwake collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0.649	0.61	0.94	0.459	0.027	0.217	0.911	2.294
Feb	1.481	1.837	1.24	0.826	0.021	0.337	1.964	6.506
Mar	1.362	1.464	1.075	0.868	0.046	0.396	1.804	5.427
Apr	8.171	10.111	1.237	4.651	0.114	1.718	10.719	36.551
May	11.409	10.477	0.918	8.546	0.506	3.867	15.374	38.373
Jun	7.605	8.635	1.136	4.616	0.181	1.89	10.397	28.287
Jul	5.116	4.627	0.904	3.861	0.232	1.762	6.948	17.449
Aug	12.254	12.532	1.023	8.467	0.356	3.759	16.335	46.711
Sep	3.666	4.834	1.318	2.078	0.044	0.742	4.806	15.142
Oct	0.523	0.615	1.176	0.298	0.009	0.124	0.688	2.259
Nov	1.068	1.37	1.284	0.576	0.015	0.206	1.36	5.097
Dec	2.715	3.001	1.105	1.712	0.065	0.672	3.589	10.87

Table C 3: Monthly kittiwake collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0.576	0.636	1.104	0.367	0.016	0.141	0.785	2.434
Feb	1.338	1.862	1.391	0.702	0.011	0.231	1.664	6.143
Mar	1.219	1.486	1.219	0.697	0.026	0.246	1.543	5.642
Apr	7.255	10.382	1.431	3.568	0.071	1.145	9.108	34.601
May	10.094	10.85	1.075	6.472	0.289	2.631	13.993	40.784
Jun	6.68	8.746	1.309	3.841	0.104	1.266	8.893	30.507
Jul	4.508	4.812	1.067	2.947	0.137	1.209	6.216	17.194
Aug	10.794	12.788	1.185	6.431	0.284	2.509	13.846	46.119
Sep	3.225	4.422	1.371	1.583	0.034	0.473	4.071	14.924

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Oct	0.45	0.596	1.325	0.245	0.006	0.087	0.563	2.167
Nov	0.943	1.341	1.423	0.435	0.009	0.14	1.238	4.608
Dec	2.421	3.202	1.323	1.359	0.041	0.438	3.069	11.623

Table C 4: Kittiwake sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.9939	0.0052	0.9952	0.0064
AvoidanceExtended	0.9702	0.0295	0.9801	0.0342
WingSpan	1.0783	0.0398	1.079	0.0516
BodyLength	0.3903	0.005	0.3901	0.0068
PCH	0.005	0	0.005	0
FlightSpeed	7.2011	1.5226	7.21	2.1364
NocturnalActivity	0.0335	0.0046	0.0333	0.0064

Table C 5: Kittiwake sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.5062	0.2035	6.505	0.2662
Pitch_rad	0.0814	0.0174	0.0811	0.0229
JanOp	88.0345	2.0539	88.0818	2.7297
FebOp	88.6332	1.976	88.6683	2.5916
MarOp	88.511	1.9447	88.4758	2.5512
AprOp	87.421	1.9501	87.3785	2.6379
MayOp	87.2998	2.0731	87.3122	2.7843
JunOp	86.0913	1.9745	86.0713	2.4591
JulOp	85.9389	2.0804	85.9978	2.7809
AugOp	86.3957	2.0395	86.3815	2.8141
SepOp	87.7027	2.0337	87.7562	2.8509
OctOp	88.4821	2.0713	88.4715	2.6966
NovOp	88.5636	2.0148	88.5162	2.6762
DecOp	88.512	1.9803	88.4893	2.7031

Appendix D - Lesser black-backed gull monthly collision rates

Table D 1: Monthly lesser black-backed gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.119	0.106	0.891	0.086	0.004	0.042	0.169	0.409
Jun	0.477	0.462	0.969	0.345	0.017	0.161	0.621	1.634
Jul	0	0	NaN	0	0	0	0	0
Aug	0.115	0.102	0.886	0.087	0.006	0.043	0.159	0.372
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0
Nov	0.002	0.001	0.568	0.002	0	0.001	0.002	0.005
Dec	0	0	NaN	0	0	0	0	0

Table D 2: Monthly lesser black-backed gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.177	0.191	1.083	0.119	0.006	0.055	0.228	0.681
Jun	0.704	0.743	1.056	0.47	0.026	0.203	0.927	2.753
Jul	0	0	NaN	0	0	0	0	0
Aug	0.169	0.177	1.047	0.116	0.008	0.057	0.222	0.621
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0
Nov	0.003	0.002	0.727	0.002	0.001	0.001	0.004	0.008
Dec	0	0	NaN	0	0	0	0	0

Table D 3: Monthly lesser black-backed gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0	0	NaN	0	0	0	0	0
Mar	0	0	NaN	0	0	0	0	0
Apr	0	0	NaN	0	0	0	0	0
May	0.149	0.177	1.191	0.096	0.005	0.045	0.186	0.666
Jun	0.588	0.707	1.201	0.355	0.018	0.172	0.719	2.551
Jul	0	0	NaN	0	0	0	0	0
Aug	0.142	0.153	1.081	0.096	0.008	0.044	0.178	0.576
Sep	0	0	NaN	0	0	0	0	0
Oct	0	0	NaN	0	0	0	0	0

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Nov	0.002	0.002	0.785	0.002	0	0.001	0.003	0.007
Dec	0	0	NaN	0	0	0	0	0

Table D 4: Lesser black-backed gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.9971	0.0016	0.9974	0.002
AvoidanceExtended	0.99	0.0052	0.9907	0.0066
WingSpan	1.4204	0.0362	1.4205	0.047
BodyLength	0.5792	0.0288	0.5795	0.0385
PCH	0.088	0	0.088	0
FlightSpeed	13.1388	1.9295	13.0728	2.5896
NocturnalActivity	0.25	0	0.25	0

Table D 5: Lesser black-backed gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.5004	0.2023	6.5017	0.2714
Pitch_rad	0.0799	0.017	0.0796	0.0219
JanOp	88.0954	2.0121	88.1439	2.7547
FebOp	88.6115	1.9549	88.6108	2.7087
MarOp	88.4137	1.9548	88.3541	2.6377
AprOp	87.4271	2.0328	87.4064	2.7302
MayOp	87.2644	2.018	87.2846	2.8068
JunOp	85.9325	2.0156	85.9358	2.6364
JulOp	85.8326	2.0052	85.8559	2.626
AugOp	86.359	1.98	86.3039	2.6983
SepOp	87.7722	1.9877	87.8138	2.6865
OctOp	88.5635	2.0225	88.5298	2.8257
NovOp	88.4709	2.0046	88.3763	2.6065
DecOp	88.4834	1.9862	88.485	2.6248

Appendix E - Herring gull monthly collision rates

Table E 1: Monthly herring gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.001	0	0.591	0.001	0	0	0.001	0.002
Mar	0.139	0.138	0.996	0.098	0.004	0.039	0.19	0.489
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	0.65	0.602	0.926	0.482	0.027	0.21	0.886	2.245
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.142	0.13	0.919	0.107	0.004	0.049	0.191	0.511
Oct	0.017	0.01	0.59	0.015	0.004	0.01	0.023	0.041
Nov	0	0	NaN	0	0	0	0	0
Dec	0.162	0.096	0.59	0.142	0.034	0.092	0.212	0.397

Table E 2: Monthly herring gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.001	0	0.626	0.001	0	0	0.001	0.002
Mar	0.17	0.177	1.044	0.115	0.005	0.047	0.229	0.609
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	0.791	0.763	0.965	0.58	0.033	0.255	1.053	2.835
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.174	0.165	0.953	0.125	0.005	0.059	0.239	0.63
Oct	0.021	0.013	0.626	0.018	0.004	0.011	0.028	0.055
Nov	0	0	NaN	0	0	0	0	0
Dec	0.199	0.124	0.625	0.174	0.039	0.104	0.262	0.52

Table E 3: Monthly herring gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	0	0	NaN	0	0	0	0	0
Feb	0.001	0	0.653	0.001	0	0	0.001	0.002
Mar	0.145	0.154	1.066	0.1	0.005	0.044	0.194	0.548
Apr	0	0	NaN	0	0	0	0	0
May	0	0	NaN	0	0	0	0	0
Jun	0.68	0.658	0.966	0.489	0.034	0.226	0.926	2.478
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0.151	0.154	1.022	0.108	0.004	0.054	0.205	0.543

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Oct	0.018	0.012	0.651	0.015	0.004	0.01	0.023	0.048
Nov	0	0	NaN	0	0	0	0	0
Dec	0.171	0.111	0.651	0.144	0.042	0.096	0.213	0.453

Table E 4: Herring gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.9969	0.0018	0.9973	0.0024
AvoidanceExtended	0.9902	0.0049	0.9911	0.006
WingSpan	1.4413	0.0298	1.4417	0.0393
BodyLength	0.5955	0.0223	0.5952	0.0298
PCH	0.1215	0	0.1215	0
FlightSpeed	12.7569	1.8611	12.7346	2.6379
NocturnalActivity	0.25	0	0.25	0

Table E 5: Herring gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.4942	0.1985	6.4904	0.2611
Pitch_rad	0.0796	0.0173	0.0791	0.0228
JanOp	88.1377	1.947	88.1269	2.6744
FebOp	88.6211	1.9143	88.6613	2.6711
MarOp	88.3698	2.0484	88.4169	2.7605
AprOp	87.4892	1.9952	87.5472	2.804
MayOp	87.1557	1.957	87.2587	2.7283
JunOp	86.0363	1.9598	86.068	2.6317
JulOp	85.8582	2.0334	85.8631	2.7665
AugOp	86.54	2.0528	86.4455	2.7606
SepOp	87.8036	2.064	87.7809	2.7851
OctOp	88.6734	2.0186	88.6161	2.5915
NovOp	88.6104	2.0406	88.6216	2.819
DecOp	88.5508	1.9443	88.4256	2.704

Appendix F - Great black-backed gull monthly collision rates

Table F 1: Monthly great black-backed gull collision risk estimates for Option 1.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	2.181	1.537	0.705	1.786	0.349	1.048	2.888	6.31
Feb	0.267	0.161	0.605	0.234	0.059	0.146	0.352	0.675
Mar	0.772	0.511	0.662	0.642	0.138	0.398	1.019	2.041
Apr	0	0	NaN	0	0	0	0	0
May	0.265	0.251	0.945	0.199	0.012	0.081	0.363	0.881
Jun	0.499	0.458	0.919	0.371	0.015	0.174	0.683	1.583
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.189	0.181	0.959	0.133	0.007	0.064	0.251	0.682
Nov	1.67	1.38	0.826	1.318	0.091	0.675	2.284	5.297
Dec	1.864	1.145	0.614	1.601	0.397	0.992	2.472	4.561

Table F 2: Monthly great black-backed gull collision risk estimates for Option 2.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	2.185	1.612	0.738	1.745	0.347	1.035	2.942	6.36
Feb	0.267	0.169	0.633	0.231	0.054	0.141	0.351	0.696
Mar	0.775	0.537	0.692	0.642	0.124	0.391	1.022	2.162
Apr	0	0	NaN	0	0	0	0	0
May	0.266	0.258	0.97	0.193	0.011	0.079	0.356	0.936
Jun	0.503	0.483	0.96	0.354	0.016	0.17	0.684	1.675
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.188	0.181	0.966	0.131	0.008	0.062	0.256	0.668
Nov	1.666	1.421	0.853	1.295	0.088	0.666	2.198	5.286
Dec	1.868	1.2	0.642	1.582	0.362	1.003	2.437	5.003

Table F 3: Monthly great black-backed gull collision risk estimates for Option 3.

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Jan	2.066	1.423	0.689	1.762	0.365	1.061	2.682	5.686
Feb	0.256	0.157	0.616	0.225	0.054	0.143	0.329	0.64
Mar	0.746	0.518	0.695	0.63	0.129	0.384	0.981	1.934
Apr	0	0	NaN	0	0	0	0	0
May	0.259	0.251	0.971	0.177	0.01	0.083	0.35	0.901
Jun	0.506	0.51	1.008	0.345	0.016	0.157	0.69	1.853
Jul	0	0	NaN	0	0	0	0	0
Aug	0	0	NaN	0	0	0	0	0
Sep	0	0	NaN	0	0	0	0	0
Oct	0.181	0.165	0.911	0.133	0.008	0.06	0.25	0.633

Month	Mean	SD	CV	Median	2.50%	25%	75%	97.50%
Nov	1.584	1.329	0.839	1.197	0.095	0.636	2.245	5.001
Dec	1.779	1.096	0.616	1.543	0.369	0.987	2.296	4.5

Table F 4: Great black-backed gull sampled bird input parameters.

Parameter	Mean	SD	Median	IQR
AvoidanceBasic	0.997	0.0018	0.9974	0.0023
AvoidanceExtended	0.9902	0.0051	0.9911	0.0067
WingSpan	1.5802	0.0388	1.5803	0.0521
BodyLength	0.7105	0.0358	0.7103	0.0476
PCH	0.1721	0	0.1721	0
FlightSpeed	13.6856	1.2196	13.6502	1.5766
NocturnalActivity	0.25	0	0.25	0

Table F 5: Great black-backed gull sampled turbine input parameters.

Parameter	Mean	SD	Median	IQR
RotorRadius	152.5	0	152.5	0
HubHeight	182.79	0	182.79	0
BladeWidth	6	0	6	0
WindSpeed	0	0	0	0
RotorSpeed	6.4985	0.1974	6.4876	0.2698
Pitch_rad	0.0789	0.0168	0.0788	0.0228
JanOp	88.0898	2.1348	88.1852	2.7537
FebOp	88.5356	2.002	88.5657	2.5885
MarOp	88.4348	2.0387	88.4064	2.7566
AprOp	87.4426	1.9626	87.46	2.5693
MayOp	87.1232	1.9424	87.1063	2.5917
JunOp	85.9545	1.9514	85.8859	2.6221
JulOp	85.8424	2.0054	85.8865	2.6882
AugOp	86.5481	2.0165	86.4917	2.8137
SepOp	87.78	2.1261	87.808	2.9238
OctOp	88.5721	2.009	88.5696	2.7611
NovOp	88.5871	2.0335	88.5459	2.7234
DecOp	88.4393	1.9443	88.4411	2.5902