Luggies Knowe Wind Energy

Collision Risk Modelling Report: September 2020 – August 2021

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Contents

1. Introduction

1.1 Overview

ITPEnergised was appointed by Shetland Aerogenerators Ltd to undertake a series of ornithological surveys in support of a proposed wind farm development at Luggies knowe in Shetland in September 2020. In order to assess the likely impacts of the Proposed Development on the local bird population analysis for the potential for collision risk has been undertaken on certain key species. The analysis has been undertaken using the design freeze layout and development boundary, as displayed in **Figure 7.1**, and a provisional turbine specification as outlined in **Table 1**.

Table 1 - Candidate Turbine - Vaestas V136 4.2MW

Parameter	Value
Viewshed Area	560.2 Ha (328.5 VP1: 231.7 VP2)
Overlap	49.4 Ha
No turbines	1
Rotor diameter	136 m
Hub height	82 m
Max rotor depth	4.2 m
Max chord	4.1 m
Pitch	Variable – Average 15°
Rotation period	(6-16 rpm, ave = 11 rpm) = 5.45 secs
Turbine 'lifetime'	25 years

2. Collision Risk Modelling

Band et al. (2007) described a method by which field data on bird flight activity can be gathered and used to quantify crudely the likelihood of collisions with turbines: the 'Band' Collision Risk Model (CRM). This method is more suitable for some species than others (Madders & Whitfield 2006). For example, fast moving raptors like merlin and most songbirds are difficult to detect beyond a distance of a few hundred metres and nocturnal species are difficult to detect at all. As a result, it is rarely possible to generate reliable estimates of flight activity for these species and collision risk is best determined qualitatively.

The Band CRM involves two methods to predict estimated collision fatalities, depending on the pattern of flight of the species involved: 'predictable' and 'unpredictable' flight methods. The predictable flight method (PFM) is appropriate when birds tend to move through an area in a relatively consistent direction, such as during migration or when moving between localised feeding and roosting sites. The unpredictable flight method (UFM) is more appropriate when flights are not in any particular direction and assumes that they are random.

2.1 Data Collection and Species Selection

Surveys were undertaken from two VP's, one facing south and one facing north between September 2020 and August 2021 with 72 hours undertaken per VP, this time period constitutes one complete year.

A total of 15 target species were recorded from the VP surveys and are summarised below in **Table 2**. All the survey flights were recorded onto ArcGIS and the data entered into an excel spreadsheet and further analysed in order to select all the flights which were recorded at potential collision height ('PCH') within the viewshed the VP. PCH is the height between the low and high points of the rotor sweep of the turbine blades, namely between 14 and 150m, all flights and the total number of individuals recorded at PCH within the viewshed of the VP are displayed below in **Table 2**.

The area covered by the viewshed is larger than the area of the Proposed Development and the collision risk modelling process adjusts the figures to allow for this, calculating the results to give an average amount for the collision risk zone ('CRZ'). The CRZ is a volume which covers the proposed turbines and a 500m buffer at PCH.

A total of nine species with less than 500 seconds of the total number of 'at-risk' flight seconds over the 12-month period are not considered to be significantly affected by collision with the proposed turbines (**Table 2**). Of the remaining six species greylag goose registered a total of 7,543 at risk seconds, the majority of which were recorded during the breeding season and likely to be the result of feral birds of this species which remain on Shetland throughout the full year and as such they are not a species of conservation concern.

Of the five remaining species, two were considered to use the site in a random way (curlew and great skua) and three were considered to use the Site in a predicable way and such assessed using the linear model (great back-backed gull, herring gull and red-throated diver). The two gull species were considered to fly generally in an east west direction across the Site accessing the rubbish dump which lies east of the Site. The flight activity for red-throated diver was less clear with birds noted leaving breeding lochans and flying in straight lines to and from open areas of water, generally on the sea, but other flights most notably early and late in the breeding season appeared less predictable and for this reason in addition to the linear model the collision risk value was calculated using the random model as well for this species only.

Table 2 - Target Species Recorded September 2020 – August 2021

Species	Flights	Total no birds in flights	Duration	During < PCH	Duration @ PCH	Duration > PCH	Total No. Of At Risk Flight Sec.	Collison Risk Modelling carried Out
Arctic tern	2	4	115	44	71		119	NO
Common gull	10	21	313	248	65		217	NO
Curlew	**12**	**57**	**531**	**155**	**376**		**2,249**	**YES**
Glaucous gull	2	2	104	58	46		46	NO
Great black-backed gull	**116**	**315**	**6,077**	**1,961**	**3,763**	**353**	**14,198**	**YES**
Great skua	**30**	**45**	**2,543**	**882**	**1,661**		**3,054**	**YES**
Greylag goose	18	134	1,870	218	1,371	281	7,543	NO
Hen harrier	1	1	211		136	75	136	NO
Herring gull	**105**	**271**	**5,507**	**1,824**	**3,374**	**309**	**12,551**	**YES**
Knot	1	8	46		46		368	NO
Long-tailed duck	1	2	94		94		188	NO
Merlin	2	2	76	31	45		45	NO
Oystercatcher	2	4	156	119	37		73	NO
Red-throated diver	**46**	**79**	**5,623**	**320**	**5,293**		**9,973**	**YES**
Snipe	2	2	208	27	181		181	NO

3. Methods

Collision risk has been calculated based as an average figure for the area covered by the viewsheds (**Figure 7.1**) and based on a layout of one wind turbine of the specifications outlined in **Table 1**. It should be noted that the resultant figures provide an average for the survey area as a whole and does not allow for the potential of configuring a layout in order to minimise the impacts of the proposed turbines.

The predicted level of collision mortality is based on results obtained from a collision risk model which uses flight activity data, species' parameters and turbine specifications to obtain a collision rate as outlined in SNH guidance (SNH, 2000). The collision risk modelling follows two models, firstly the random flight model which is used for foraging or displaying birds and secondly the regular model used for commuting or migrating birds.

The guidance also outlines bird biometrics including bird length and wingspan as well as flight speeds and recommended avoidance rates which are inputs into the model and the figures for the species carried forward for collision risk in this assessment are outlined in **Table 3** below.

Data on bird flight speed and biometrics were taken from Alerstam et al (2007) and the published avoidance rates was used (SNH 2017). For the two gulls species, a review of seabird avoidance rates conducted by the BTO for Marine Scotland (Cook et al., 2014) made use of data derived predominantly from terrestrial wind farms. The consequent SNCB advice to use an avoidance rate of 0.995 for herring gull, lesser black-backed gull and great black-backed gull, these rates have been adopted below.

Table 3 - Target Species Bird Biometrics

Species Name	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Avoidance Rate (%)
Curlew	0.55	0.9	16.3	98
Great black-backed gull	0.71	1.58	13.7	99.5
Great skua	0.56	1.36	14.9	99.5
Herring Gull	0.57	1.31	12.8	99.5
Red-throated diver	0.61	1.11	17	99.5

4. Results

Five species were taken forward for collision risk modelling, of which two used the random model (curlew and great skua) as these birds used the site for foraging and breeding display. The other three species (great black-backed gull, herring gull and red throated diver) commuted through the survey area and therefore the regular 'linear' model was applied to the analysis for this species.

Full working examples for each are outlined in Appendix A below and summary of all the results for clarity are shown in **Table 4** below.

Table 4- Collision Risk Modelling Results

Species Name	Annual Collison rate	Collisions - Scheme Lifetime (using notional 25 years for comparison)	Years per collision
Curlew	0.04	1.09	22.88
Great black-backed gull	0.12	3.1	8.06
Great skua (breeding season)	0.02	0.39	64.84
Herring gull	0.14	6.96	3.58
Red-throated diver -linear (breeding season)	0.073	1.82	13.5
Red-throated diver - random (breeding season)	0.069	1.74	14.35

Table 5- Breeding Season - Survey Hours

Mean Daylight hours	Apr	May	Jun	Jul	Aug
daylight hours	14.62	17.23	18.77	18.05	15.68
5% night	0.469	0.3385	0.2615	0.2975	0.416
Total per day	15.089	17.5685	19.0315	18.3475	16.096
total days	30	31	30	31	31
total flight hours	438.6	534.13	563.1	559.55	486.08
total flight hours – 5% night	452.67	544.6235	570.945	568.7725	498.976
total flight hours - 25% night	508.95	586.5975	602.325	605.6625	550.56

Total hours breeding season = 2581

Total hours breeding season – 5% night = 2636

Total hours breeding season – 25% night = 2854

Table 6-Non- Breeding Season - Survey Hours

Mean Daylight hours	Sep	Oct	Nov	Dec	Jan	Feb	Mar
daylight hours	12.88	10.05	7.45	5.98	6.8	9.08	11.78
5% night	0.556	0.6975	0.8275	0.901	0.86	0.746	0.611
Total per day	13.436	10.7475	8.2775	6.881	7.66	9.826	12.391
total days	30	31	30	31	31	28	31
total flight hours	386.4	311.55	223.5	185.38	210.8	254.24	365.18
total flight hours – 5% night	403.08	333.1725	248.325	213.311	237.46	275.128	384.121
total flight hours - 25% night	469.8	419.6625	347.625	325.035	344.1	358.68	459.885

Total hours = 4519

Total hours– 5% night = 4730.5

Total hours – 25% night = 5578

CRM calculations

Stage 1: Number of Birds Flying Through the Rotors per Year

<u>Calculate the number of hours of observation expressed in hectare hours.</u>

Hectare hours = viewshed (to 2 km and within 500m of site boundary) * survey duration (hrs)

VP 1 viewshed = 328.484 Ha

VP 2 viewshed = 231.722 Ha

Overlap = 49.4 Ha

Date	VP	Start Time	End Time	Hours	Ha hours
26-Sep-20	1	15:00	18:00	3	985.452
12-Oct-20	1	07:41	10:41	3	985.452
12-Oct-20	1	11:11	14:11	3	985.452
11-Oct-20	1	15:09	18:09	3	985.452
14-Nov-20	1	09:07	12:07	3	985.452
14-Nov-20	1	12:37	15:37	3	985.452
03-Feb-21	1	11:10	14:10	3	985.452
03-Feb-21	1	14:40	16:20	3	985.452
05-Feb-21	1	15:08	16:28	3	985.452
10-Mar-21	1	09:30	12:30	3	985.452
10-Mar-21	1	13:00	16:00	3	985.452
13-Mar-21	1	06:25	09:25	1	328.484
13-Mar-21	1	09:55	12:55	2	656.968
27-Apr-21	1	09:45	12:45	3	985.452
29-Apr-21	1	05:05	08:05	3	985.452
14-May-21	1	15:00	18:00	3	985.452
14-May-21	1	18:35	21:35	3	985.452
14-Jun-21	1	09:15	12:15	3	985.452
14-Jun-21	1	12:45	15:45	3	985.452
12-Jul-21	1	13:45	15:45	3	985.452
12-Jul-21	1	17:15	20:15	3	985.452
16-Aug-21	1	14:28	17:28	3	985.452
17-Aug-21	1	05:27	08:27	3	985.452
17-Aug-21	1	08:57	11:57	3	985.452
18-Aug-21	1	17:53	20:53	3	985.452

27-Sep-20	2	12:20	15:20	3	695.166
10-Oct-20	2	15:11	18:11	3	695.166
11-Oct-20	2	11:39	14:39	3	695.166
12-Nov-20	2	07:48	10:13	2.5	579.305
12-Nov-20	2	12:42	15:42	3	695.166
13-Nov-20	2	11:15	11:48	0.5	115.861
13-Nov-20	2	12:18	15:18	3	695.166
04-Feb-21	2	09:45	12:45	3	695.166
04-Feb-21	2	13:26	16:26	3	695.166
05-Feb-21	2	08:08	11:08	3	695.166
05-Feb-21	2	11:38	14:38	3	695.166
11-Mar-21	2	10:30	13:30	3	695.166
11-Mar-21	2	14:00	17:00	3	695.166
28-Apr-21	2	05:05	08:05	3	695.166
28-Apr-21	2	08:38	11:38	3	695.166
15-May-21	2	15:05	18:05	3	695.166
15-May-21	2	18:38	21:38	3	695.166
15-Jun-21	2	09:30	12:30	3	695.166
15-Jun-21	2	13:00	16:00	3	695.166
13-Jul-21	2	13:40	16:40	3	695.166
13-Jul-21	2	17:10	20:10	3	695.166
18-Aug-21	2	05:29	08:29	3	695.166
18-Aug-21	2	08:59	11:59	3	695.166
19-Aug-21	2	14:20	17:20	3	695.166
19-Aug-21	2	17:50	20:50	3	695.166
Total					40334.832

Calculate hectare seconds = hectare hours * 3600

= 40334.832 * 3600

= 145205395.2

4.1 Curlew

A total of 12 curlew flights were recorded including a combined total of 57 curlew. All 12 flights were 'at-risk' and included in the collision risk modelling (See **Appendix 7.1 : Figure 4**).

Collision Risk Calculations – Full detail of the calculations are included for curlew, summary included for other 5 species.

Calculate the bird observation in all areas and percentage of time birds active in overall observed area.

Table 4-1 - All Curlew Flights September 2020 - August 2021

Date	Number	VP	<PCH	PCH	>PCH	At-risk seconds
11-Sep-20	18	1	0	39	0	702
12-Nov-20	8	2	32	21	0	168
12-Nov-20	7	2	18	27	0	189
12-Nov-20	2	2	0	31	0	62
13-Nov-20	1	2	12	27	0	27
13-Nov-20	1	2	16	28	0	28
14-Nov-20	12	1	0	75	0	900
28-Apr-21	2	2	10.8	16.2	0	32.4
15-May-21	1	2	14.8	22.2	0	22.2
14-Jun-21	1	1	0	47	0	47
15-Jun-21	1	2	18.8	28.2	0	28.2
16-Aug-21	3	1	32.6	14.4	0	43.2
Total						**2249**

Bird Activity = Total bird flight time / hectare seconds

= 2249 / 145205395.2

BA = 0.0000154884

Overall Area covered by VPs = 510.806

Proportion of time potentially active = Area x BA = 0.00791157

Hours potentially active (See **Table 5** and **6**) = 4731

Seconds potentially active (4731 * 3600) = 17030104.2

Number of seconds of bird occur in airspace = sec potentially active * bird activity

= 17030104 * 0.00791157

= 134734

<u>Calculate flight risk volume (Vw)</u>

Vw = 5108060 (m2) * rotor diameter (m)

Vw = 694696160

Calculate combined rotor swept volume

Vr = number of turbines (n) * pi * r2 * (max chord + bird length)
Vr = 1 * (pi * 4624) * (4.1 + 0.55)
Vr = 67515.024

Calculate bird occurrence in swept volume

Occurrence = no of sec of bird occ * combined rotor swept volume/flight risk volume

= 134734 * (Vr/Vw)

= 134734 * (67515.024 / 694696160)

= 13.09439765

Calculate bird transits time and potential number of transits per year

Transit time = (max chord + bird length) / bird speed (m2)
= (4.1 + 0.55) / 16.3
= 0.285

No. of transits = occurrence / transit time
= 13.1 / 0.28

= 45.9

Stage 2: Collision Risk of Bird Passing through Rotor (Assuming No Avoidance)

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Only enter input parameters in blue										W Band	08/09/2020
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	8.32	27.03	0.91	0.00114	25.81	0.87	0.00109
Wingspan	0.9	m	0.075	0.575	2.77	9.42	0.32	0.00239	8.20	0.28	0.00208
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.66	6.86	0.23	0.00290	5.37	0.18	0.00227
			0.175	0.860	1.19	6.03	0.20	0.00356	4.20	0.14	0.00248
Bird speed	16.3	m/sec	0.225	0.994	0.92	5.53	0.19	0.00420	3.42	0.12	0.00260
RotorDiam	136	m	0.275	0.947	0.76	4.52	0.15	0.00420	2.51	0.08	0.00233
RotationPeriod	5.45	sec	0.325	0.899	0.64	3.81	0.13	0.00418	1.90	0.06	0.00208
			0.375	0.851	0.55	3.32	0.11	0.00421	1.52	0.05	0.00192
			0.425	0.804	0.49	2.96	0.10	0.00425	1.25	0.04	0.00180
			0.475	0.756	0.44	2.66	0.09	0.00427	1.06	0.04	0.00170
Bird aspect ratioo: β	0.61		0.525	0.708	0.40	2.41	0.08	0.00428	0.91	0.03	0.00161
			0.575	0.660	0.36	2.20	0.07	0.00427	0.79	0.03	0.00154
			0.625	0.613	0.33	2.01	0.07	0.00424	0.71	0.02	0.00149
			0.675	0.565	0.31	1.84	0.06	0.00419	0.64	0.02	0.00146
			0.725	0.517	0.29	1.69	0.06	0.00413	0.59	0.02	0.00144
			0.775	0.470	0.27	1.55	0.05	0.00405	0.55	0.02	0.00144
			0.825	0.422	0.25	1.42	0.05	0.00395	0.58	0.02	0.00161
			0.875	0.374	0.24	1.30	0.04	0.00384	0.59	0.02	0.00176
			0.925	0.327	0.22	1.19	0.04	0.00371	0.61	0.02	0.00189
			0.975	0.279	0.21	1.08	0.04	0.00356	0.61	0.02	0.00201
				Overall p(collision) =			**Upwind**	**7.5%**		**Downwind**	**3.7%**
								Average	**5.6%**		

Annual Collision Rate assuming no avoidance

= No. of transits * Ave probability of collision
= (45.9 / 100) x 5.6

= 2.57

Corrected for avoidance

= 2.57– ((2.57/ 100) *98)

= 0.051

Corrected for downtime

= 0.051 * 0.85

= 0.043 collisions per year (22.88 years per collision)

Over notional lifetime of the scheme (25 years)

0.043 * 25 = **1.09**

4.2 Great Skua

A total of 30 great skua registrations totalling 45 individuals were recorded from VP surveys. All registrations were recorded during the breeding season April to August. Of the 30 registrations, 29 were at some point noted as being 'at-risk' and are shown in **Appendix 7.1: Figure 7**.

		Year 1 sweep 13-149.9m
hectare secs		72602697.6
total bird flight time		3054
Bird Activity (ba)		0.0000420646
Overall Area covered by VPs (excluding overlap) =		510.806
		5108060
proportion of time active in area		0.021486826
hours potentially active		2635.987
seconds potentially active (hours*3600)		9489553.2
no of seconds of bird occ in airspace = sec potentially active * bird activity		203900.3776
Calculate flight risk volume (Vw)		Vw = Overall area (m^2) * rotor diameter (m)
		694696160
Calculate combined rotor swept volume (Vr)		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
		67660.2176
Calculate bird occurrence in swept volume		Occurrence
		19.85896095
Calculate bird transits time and potential number of transits per year		max chord+bird length / bird speed
		0.312751678
No. of transits occurrence / transit time		63.4975361
Annual Collision Rate assuming no avoidance		3.682857094
Corrected for avoidance		0.018414285
Corrected for downtime		0.015652143
		63.88901651
Over lifetime of the scheme		0.391303566

4.3 Great black-backed gull

A total of 116 registrations of a combined 315 great black-backed gull were recorded from VP surveys of which a total of 71 pass through the risk-window of which 57 including 121 individuals were recorded flying through the risk window at risk-height, see **Figure 1**.

Stage 1: Number of Birds Flying Through the Rotors per Year

Calculation of the 'risk window'; Cross section area equal to the width of the wind farm across the general direction of flight multiplied by the height of turbine to rotor tip. Width of wind farm was determined using GIS.

Width of transit flight (Ws)	= 1000m
Turbine height (th)	= 150m
Risk Window (W)	= Ws * th
	= 1000m * 150m
	= 150,000 m^2

Calculate the area occupied by rotor blades (A)

Number of turbine (n)	= 1
Rotor radius (r)	= 68
A	= n * π *r2
A	= 1 * 3.14* 4624
A	= 14,519.36 m^2

Express the area occupied by rotor blades (A) as a proportion of the risk window (W)

Proportion (P)	= A/W
	= 14,519.36 /150,000
	= 0.0968

Calculate the number of bird potentially flying through the site per year (N)

N	= number of great black-backed gull transits at PCH per year
	= hourly rate of transit * available hours for flight

Hours surveyed between September2020 and August 2021

	= hectare hours (correcting for overlap) / hectares visible in Study area
	= (510.806 *144)/ 560.206
	= 73,556.064 / 560.206
	= 131.3

Number of great black-backed gull observed in the same period = 121

Hourly rate of transit = 121 / 131.3

= 0.922

Hours available for flight are equal to number of daylight hours in the same period plus 5% of night hours.

(See Table 5 and 6) = 4731

Hours available = 4730.5845

N = 4730.5845 * 0.922

= 4,359.49

Calculate the number of birds flights (Nf) to fly through the rotor (P)

Nf = N * P

= 4,359.49 * 0.0968

= 421.998

Stage 2: Collision Risk of Bird Passing Through Rotor (Assuming No Avoidance)

Stage 2 was calculated using the prepopulated spreadsheet provided by Scottish Natural Heritage (SNH) for calculating the probability of collision for any species (available at: http://www.snh.gov.uk/docs/C234672.xls)

Variable highlighted in blue where entered into the spreadsheet. Bird biometrics where determined using the British Trust for Ornithology website (http://www.bto.org/about-birds/birdfacts) bird flight speeds were assumed using the flight speeds characterised by Bruderer and Boldt (2001).

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.71	m	0.025	0.575	6.99	27.57	1.00	0.00125	26.35	1.00	0.00125
Wingspan	1.58	m	0.075	0.575	2.33	9.60	0.39	0.00289	8.38	0.34	0.00252
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.40	6.84	0.27	0.00343	5.35	0.21	0.00269
			0.175	0.860	1.00	5.89	0.24	0.00414	4.07	0.16	0.00286
Bird speed	13.7	m/sec	0.225	0.994	0.78	5.34	0.21	0.00483	3.23	0.13	0.00292
RotorDiam	136	m	0.275	0.947	0.64	4.39	0.18	0.00485	2.38	0.10	0.00263
RotationPeriod	5.45	sec	0.325	0.899	0.54	3.72	0.15	0.00485	1.81	0.07	0.00236
			0.375	0.851	0.47	3.21	0.13	0.00484	1.40	0.06	0.00212
			0.425	0.804	0.41	2.87	0.12	0.00490	1.17	0.05	0.00199
			0.475	0.756	0.37	2.61	0.11	0.00499	1.01	0.04	0.00193
Bird aspect ratioo: β	0.45		0.525	0.708	0.33	2.39	0.10	0.00505	0.89	0.04	0.00188
			0.575	0.660	0.30	2.21	0.09	0.00510	0.80	0.03	0.00186
			0.625	0.613	0.28	2.04	0.08	0.00512	0.74	0.03	0.00185
			0.675	0.565	0.26	1.89	0.08	0.00512	0.73	0.03	0.00198
			0.725	0.517	0.24	1.75	0.07	0.00511	0.77	0.03	0.00223
			0.775	0.470	0.23	1.63	0.07	0.00507	0.79	0.03	0.00246
			0.825	0.422	0.21	1.51	0.06	0.00501	0.80	0.03	0.00266
			0.875	0.374	0.20	1.40	0.06	0.00493	0.81	0.03	0.00285
			0.925	0.327	0.19	1.30	0.05	0.00483	0.81	0.03	0.00302
			0.975	0.279	0.18	1.20	0.05	0.00472	0.81	0.03	0.00317
				Overall p(collision) =			**Upwind**	**9.1%**		**Downwind**	**4.7%**
								Average	**6.9%**		

Calculation of collision rate

Collision rate = Nf * average probability of collision

= 421.998 * 0.069

= 29.118

Calculation of collision rate applying 99.5% avoidance rate

= 29.118 * 0.005

= 0.146

Correct collision rate for down time (assuming wind farm operates at 85%)

= (0.146/ 100) * 85

= 0.124

Calculate the number of years per collision

= 1 / 0.12

= 8.06

Calculate the number of collisions per lifetime of the scheme (given a 25 value for comparison)

= 0.12 * 25

= 3.1

4.4 Herring Gull

A total of 105 registrations of a combined 271 herring gull were recorded from VP surveys of which a total of 59 flights pass through the risk window and 53 including 149 individuals were recorded flying through the risk window at collision height, see **Figure 2**.

Stage 1: Number of Birds Flying Through the Rotors per Year

Calculation of the 'risk window'; Cross section area equal to the width of the wind farm across the general direction of flight multiplied by the height of turbine to rotor tip. Width of wind farm was determined using GIS.

was determined using GIS.

Width of transit flight (Ws) = 1000m

Turbine height (th) = 150m

Risk Window (W) = Ws * th

= 1000m * 150m

= 150,000 m^2

Calculate the area occupied by rotor blades (A)

Number of turbine (n) = 1

Rotor radius (r) = 68

A = n * π *r2

A = 1 * 3.14* 4624

A = 14,519.36 m^2

Express the area occupied by rotor blades (A) as a proportion of the risk window (W)

Proportion (P) = A/W

= 14,519.36 /150,000

= 0.0968

Calculate the number of bird potentially flying through the site per year (N)

N = number of herring gull transits at PCH per year

= hourly rate of transit * available hours for flight

Hours surveyed between September 2020 and August 2021

= hectare hours (correcting for overlap) / hectares visible in Study area

= (510.806 *144)/ 560.206

= 73,556.064 / 560.206

= 131.3

Number of herring gull observed in the same period = 149

Hourly rate of transit = 149 / 131.3

= 1.13

Hours available for flight are equal to number of daylight hours in the same period plus 5% of night hours.

Hours available = 4730.5845

N = 4730.5845 * 1.13

= 5,368.3

Calculate the number of birds flights (Nf) to fly through the rotor (P)

Nf = N * P

= 5,368.3 * 0.0968

= 519.65

Stage 2: Collision Risk of Bird Passing Through Rotor (Assuming No Avoidance)

Stage 2 was calculated using the prepopulated spreadsheet provided by Scottish Natural Heritage (SNH) for calculating the probability of collision for any species (available at: http://www.snh.gov.uk/docs/C234672.xls)

Variable highlighted in blue where entered into the spreadsheet. Bird biometrics where determined using the British Trust for Ornithology website (http://www.bto.org/about-birds/birdfacts) bird flight speeds were assumed using the flight speeds characterised by Bruderer and Boldt (2001).

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Only enter input parameters in blue										W Band	20/12/2021
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3							Upwind:		Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.57	m	0.025	0.575	6.53	24.04	1.00	0.00125	22.82	0.98	0.00123
Wingspan	1.31	m	0.075	0.575	2.18	8.42	0.36	0.00272	7.20	0.31	0.00232
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.31	6.08	0.26	0.00327	4.60	0.20	0.00247
			0.175	0.860	0.93	5.31	0.23	0.00400	3.49	0.15	0.00262
Bird speed	12.8	m/sec	0.225	0.994	0.73	4.86	0.21	0.00471	2.75	0.12	0.00266
RotorDiam	136	m	0.275	0.947	0.59	4.01	0.17	0.00474	2.00	0.09	0.00236
RotationPeriod	5.45	sec	0.325	0.899	0.50	3.40	0.15	0.00475	1.49	0.06	0.00209
			0.375	0.851	0.44	2.94	0.13	0.00474	1.13	0.05	0.00183
			0.425	0.804	0.38	2.65	0.11	0.00483	0.94	0.04	0.00172
			0.475	0.756	0.34	2.40	0.10	0.00490	0.80	0.03	0.00163
Bird aspect ratioo: β	0.44		0.525	0.708	0.31	2.19	0.09	0.00495	0.69	0.03	0.00156
			0.575	0.660	0.28	2.01	0.09	0.00498	0.61	0.03	0.00151
			0.625	0.613	0.26	1.85	0.08	0.00498	0.59	0.03	0.00158
			0.675	0.565	0.24	1.71	0.07	0.00497	0.63	0.03	0.00182
			0.725	0.517	0.23	1.58	0.07	0.00493	0.66	0.03	0.00205
			0.775	0.470	0.21	1.46	0.06	0.00487	0.68	0.03	0.00225
			0.825	0.422	0.20	1.35	0.06	0.00478	0.69	0.03	0.00244
			0.875	0.374	0.19	1.24	0.05	0.00468	0.69	0.03	0.00260
			0.925	0.327	0.18	1.14	0.05	0.00455	0.69	0.03	0.00274
			0.975	0.279	0.17	1.05	0.05	0.00441	0.68	0.03	0.00286
				Overall p(collision) =			**Upwind**	**8.8%**		**Downwind**	**4.2%**
								Average	**6.5%**		

Calculation of collision rate

Collision rate = Nf * average probability of collision

= 519.65*0.065

= 33.778

Calculation of collision rate applying 99.5% avoidance rate

= 33.778 * 0.005

= 0.169

Correct collision rate for down time (assuming wind farm operates at 85%)

= (0.169 / 100) * 85

= 0.144

Calculate the number of year per collision

= 1 / 0.144

= 6.96

Calculate the number of collisions per lifetime of the scheme (given a 25 value for comparison)

= 0.29 * 25

= 3.59

4.5 Red-throated diver – Linear

A total of 46 red-throated diver registrations were recorded totalling 79 individuals from VP surveys, of which 11 flights (crossing the risk window on 12 occasions) totalling 21 (inclusive of the repeat crossing) individuals were recorded through the risk window. The 11 flights included in the linear model and are shown in Figure 3.

Stage 1: Number of Birds Flying Through the Rotors per Year

Calculation of the 'risk window'; Cross section area equal to the width of the wind farm across the general direction of flight multiplied by the height of turbine to rotor tip. Width of wind farm was determined using GIS.

Width of transit flight (Ws) = 1000m

Turbine height (th) = 150m

Risk Window (W) = Ws * th

= 1000m * 150m

= 150,000 m^2

Calculate the area occupied by rotor blades (A)

Number of turbine (n) = 1

Rotor radius (r) = 68

A = n * π *r2

A = 1 * 3.14* 4624

A = 14,519.36 m^2

Express the area occupied by rotor blades (A) as a proportion of the risk window (W)

Proportion (P) = A/W

= 14,519.36 /150,000

= 0.0968

Calculate the number of bird potentially flying through the site per year (N)

N = number of red-throated diver transits at PCH per year

= hourly rate of transit * available hours for flight

Hours surveyed between April 2021 and August 2021

= hectare hours (correcting for overlap) / hectares visible in Study area

= (510.806*72)/560.206

= 36,778.032 / 560.206

= 65.651

Number of divers observed in the same period = 21

Hourly rate of transit = 21 / 65.651

= 0.3199

Hours available for flight are equal to number of daylight hours in the same period plus 25% of night hours.

Hours available (See Table 5) - N = 2854.095

Calculate the number of birds flights (Nf) to fly through the rotor (P)

Nf = N * P

= 2,854.1 * 0.0968

= 276.276

Stage 2: Collision Risk of Bird Passing Through Rotor (Assuming No Avoidance)

Stage 2 was calculated using the prepopulated spreadsheet provided by Scottish Natural Heritage (SNH) for calculating the probability of collision for any species (available at: http://www.snh.gov.uk/docs/C234672.xls)

Variable highlighted in blue where entered into the spreadsheet. Bird biometrics where determined using the British Trust for Ornithology website (http://www.bto.org/about-birds/birdfacts) bird flight speeds were assumed using the flight speeds characterised by Bruderer and Boldt (2001).

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Only enter input parameters in blue										W Band	29/09/2020
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	15		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.55	m	0.025	0.575	6.63	21.68	0.92	0.00115	20.46	0.87	0.00108
Wingspan	0.9	m	0.075	0.575	2.21	7.63	0.32	0.00242	6.41	0.27	0.00204
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.33	5.62	0.24	0.00298	4.14	0.18	0.00219
			0.175	0.860	0.95	4.99	0.21	0.00370	3.17	0.13	0.00235
Bird speed	13	m/sec	0.225	0.994	0.74	4.62	0.20	0.00440	2.51	0.11	0.00239
RotorDiam	136	m	0.275	0.947	0.60	3.82	0.16	0.00444	1.81	0.08	0.00210
RotationPeriod	5.45	sec	0.325	0.899	0.51	3.32	0.14	0.00457	1.41	0.06	0.00194
			0.375	0.851	0.44	2.94	0.12	0.00467	1.14	0.05	0.00181
			0.425	0.804	0.39	2.64	0.11	0.00476	0.94	0.04	0.00169
			0.475	0.756	0.35	2.40	0.10	0.00482	0.79	0.03	0.00159
Bird aspect ratioo: β	0.61		0.525	0.708	0.32	2.19	0.09	0.00486	0.68	0.03	0.00152
			0.575	0.660	0.29	2.01	0.08	0.00488	0.60	0.03	0.00147
			0.625	0.613	0.27	1.84	0.08	0.00488	0.56	0.02	0.00147
			0.675	0.565	0.25	1.70	0.07	0.00486	0.60	0.03	0.00171
			0.725	0.517	0.23	1.57	0.07	0.00481	0.63	0.03	0.00194
			0.775	0.470	0.21	1.45	0.06	0.00475	0.65	0.03	0.00213
			0.825	0.422	0.20	1.33	0.06	0.00466	0.66	0.03	0.00231
			0.875	0.374	0.19	1.23	0.05	0.00455	0.67	0.03	0.00247
			0.925	0.327	0.18	1.13	0.05	0.00442	0.66	0.03	0.00260
			0.975	0.279	0.17	1.03	0.04	0.00427	0.66	0.03	0.00272
				Overall p(collision) =		**Upwind**		**8.5%**		**Downwind**	**4.0%**
								Average	**6.2%**		

Calculation of collision rate

Collision rate = Nf * average probability of collision

= 276.276 * 0.062

= 17.13

Calculation of collision rate applying 99.5% avoidance rate

= 17.13 *0.005

= 0.086

1. Correct collision rate for down time (assuming wind farm operates at 85%)

= (0.086/ 100) *85

= <u>0.073</u>

2. Calculate the number of year per collision

= 1 / 0.073

= <u>13.5</u>

3. Calculate the number of collisions per lifetime of the scheme (given a 25 value for comparison)

= 0.073 * 25

= <u>1.825</u>

4.6 Red-throated diver – Random

A total of 46 red-throated diver registrations were recorded totalling 79 individuals from VP surveys, all of which were recorded 'at-risk' at part or all of the flight. The 46 flights were all included in the random model and are shown in Figure 3.

		Option A Year 1 sweep 14-150m
hectare secs		72602697.6
total bird flight time		9973
Bird Activity (ba)		0.0001373640
Overall Area covered by VPs (excluding overlap) =		510.806
		5108060
proportion of time active in area		0.070166377
hours potentially active		2854.095
seconds potentially active (hours*3600)		10274742
no of seconds of bird occ in airspace = sec potentially active * bird activity		720941.4189
Calculate flight risk volume (Vw)		Vw = Overall area (m^2) * rotor diameter (m)
		694696160
Calculate combined rotor swept volume (Vr)		Vr = number of turbines (n) * pi * r^2 * (max chord + bird length)
		68386.1856
Calculate bird occurrence in swept volume		Occurrence
		70.96978005
Calculate bird transits time and potential number of transits per year		max chord+bird length / bird speed
		0.277058824
No. of transits occurrence / transit time		256.1541955
Annual Collision Rate assuming no avoidance		16.39386851
Corrected for avoidance		0.081969343
Corrected for downtime		0.069673941
		14.35256831
Over lifetime of the scheme		1.74184853

5. References

Alerstam T., Rosén M., Bäckman J., Ericson P.G.P., Hellgren O., (2007). Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biol, 5, 1656-1662. DOI:10.1371/journal.pbio.0050197

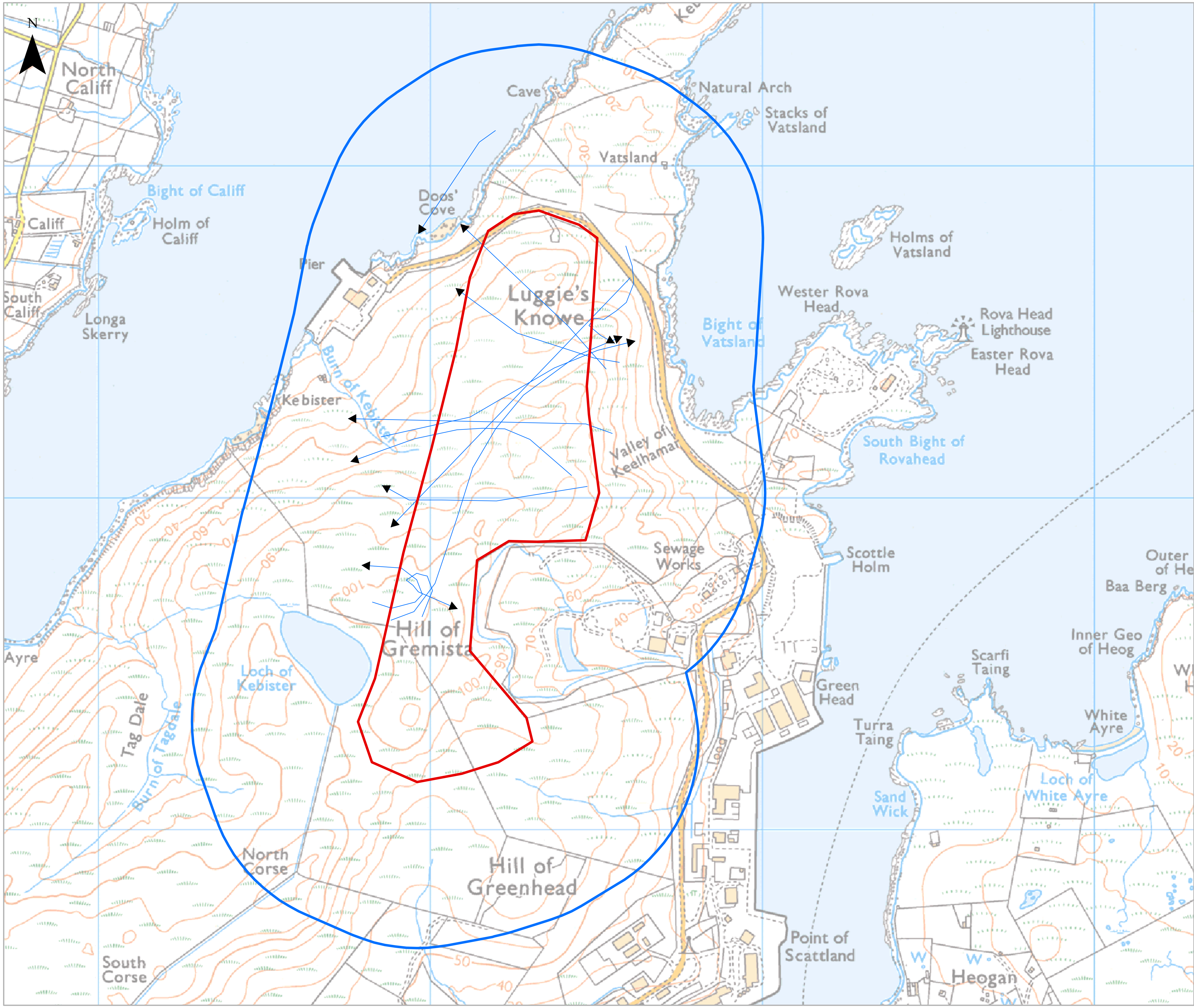
Band, W., Madders, M. & Whitfield, D.P. (2007*).* Developing field and analytical methods to assess avian collision risk at wind farms. In de Lucas, M, Janss, G. and Ferrer, M. (eds) *Birds and Wind Power*. Lynx Edicions, Barcelona.

Cook, A.S.C.P., Humphreys, 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.

SNH (2017). *Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model*. SNH Information and Guidance Note. SNH, Battleby.

Figures

Figure 1 – Curlew at-risk flights



KEY

- Site Boundary
- 500m buffer
- Curlew flights

Coordinate System: British National Grid
Projection: Transverse Mercator

0 0.175 0.35 0.7 km

1:11,000

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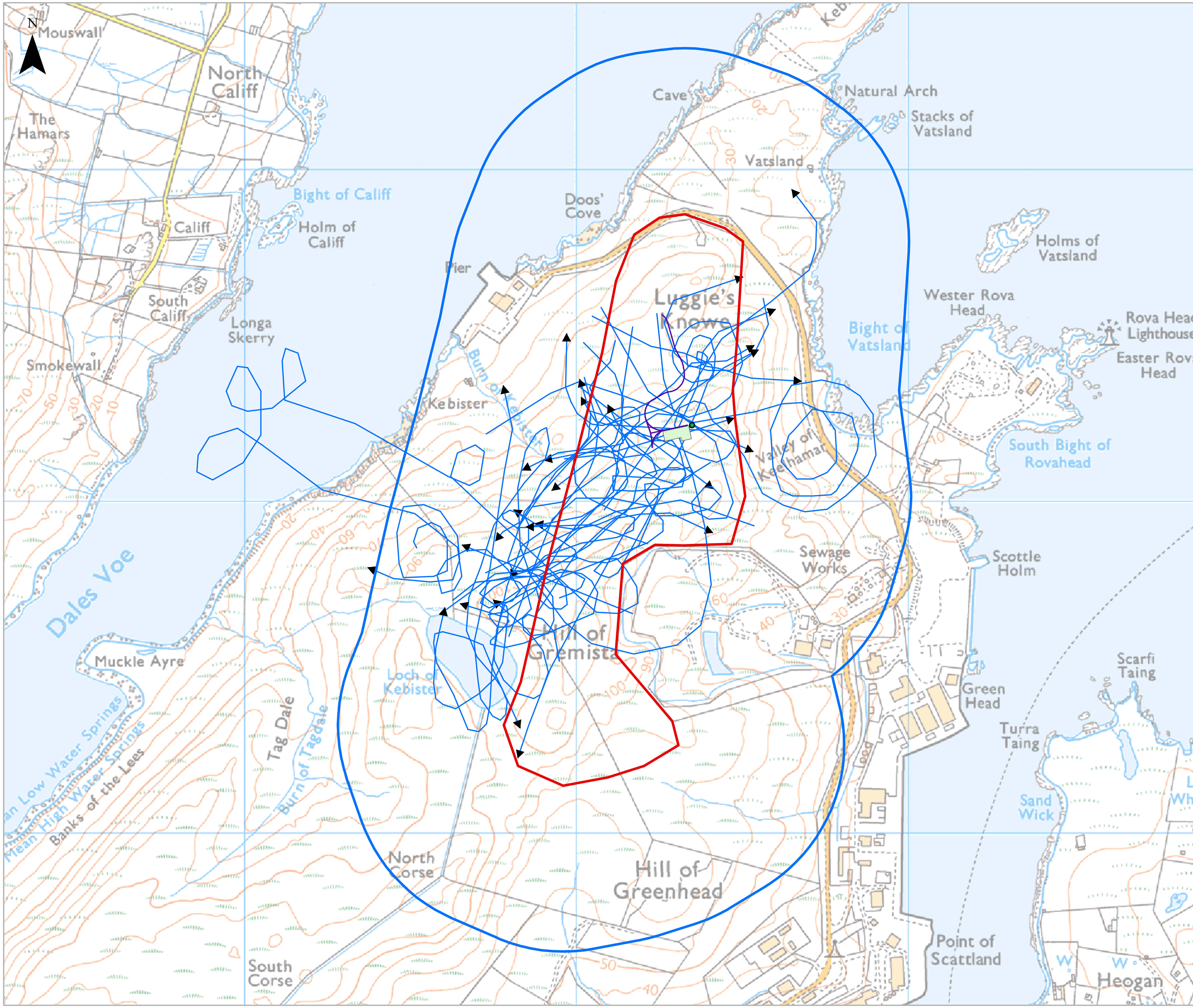
Figure 3
Curlew at-risk flights

Date:	Lead:	Review:	Version:
15/06/2023	AJM	EB	V1

Figure 2 – Great skua at-risk flights



KEY

Site Boundary

500m buffer

At Risk Flights

Great Skua

Coordinate System: British National Grid
Projection: Transverse Mercator

0 0.175 0.35 0.7 km

1:11,000

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Figure 2
Great skua at-risk flights

Date:	Lead:	Review:	Version:
15/06/2023	AJM	EB	V1

Figure 3 – Great Black-backed Gull at-risk flights

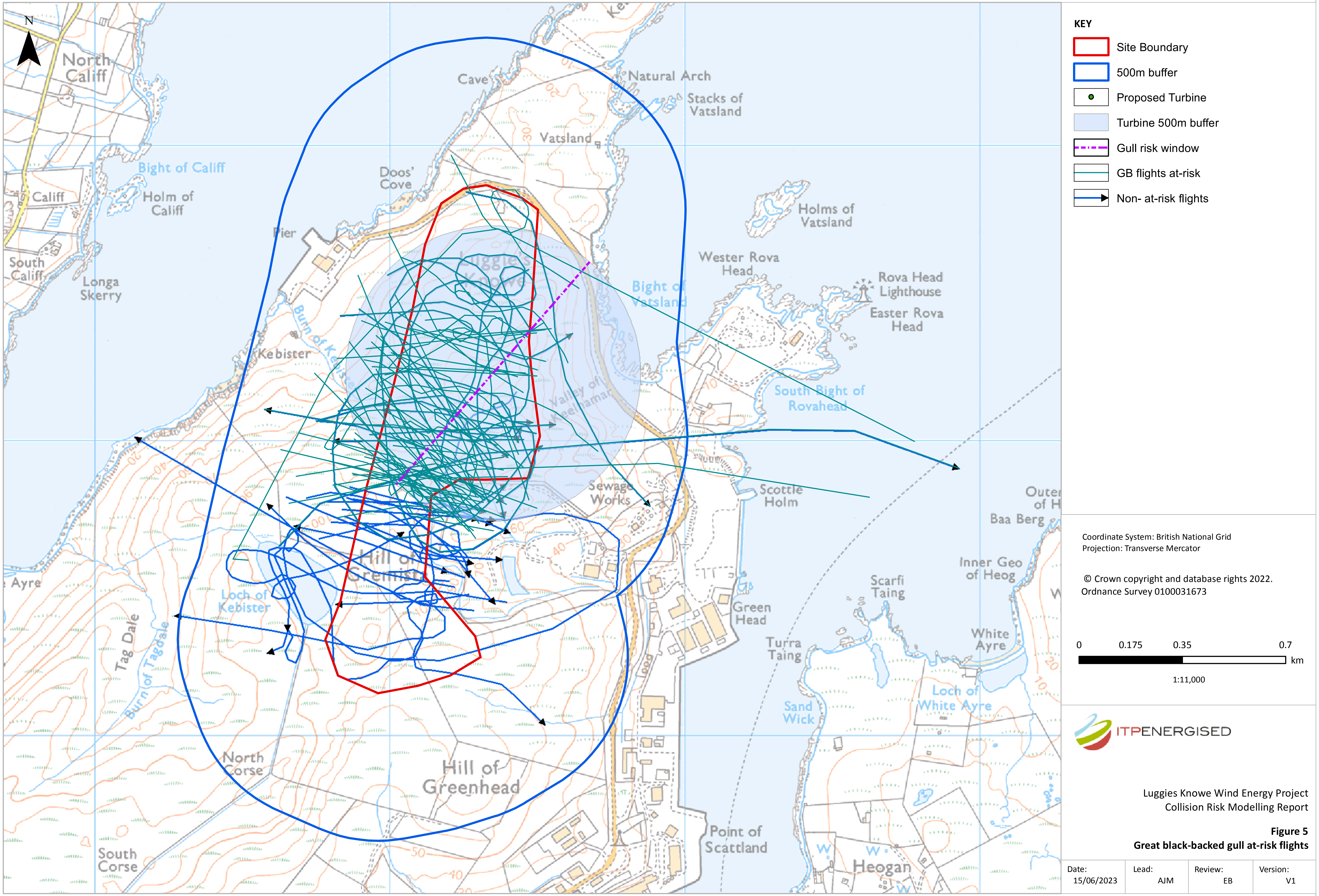

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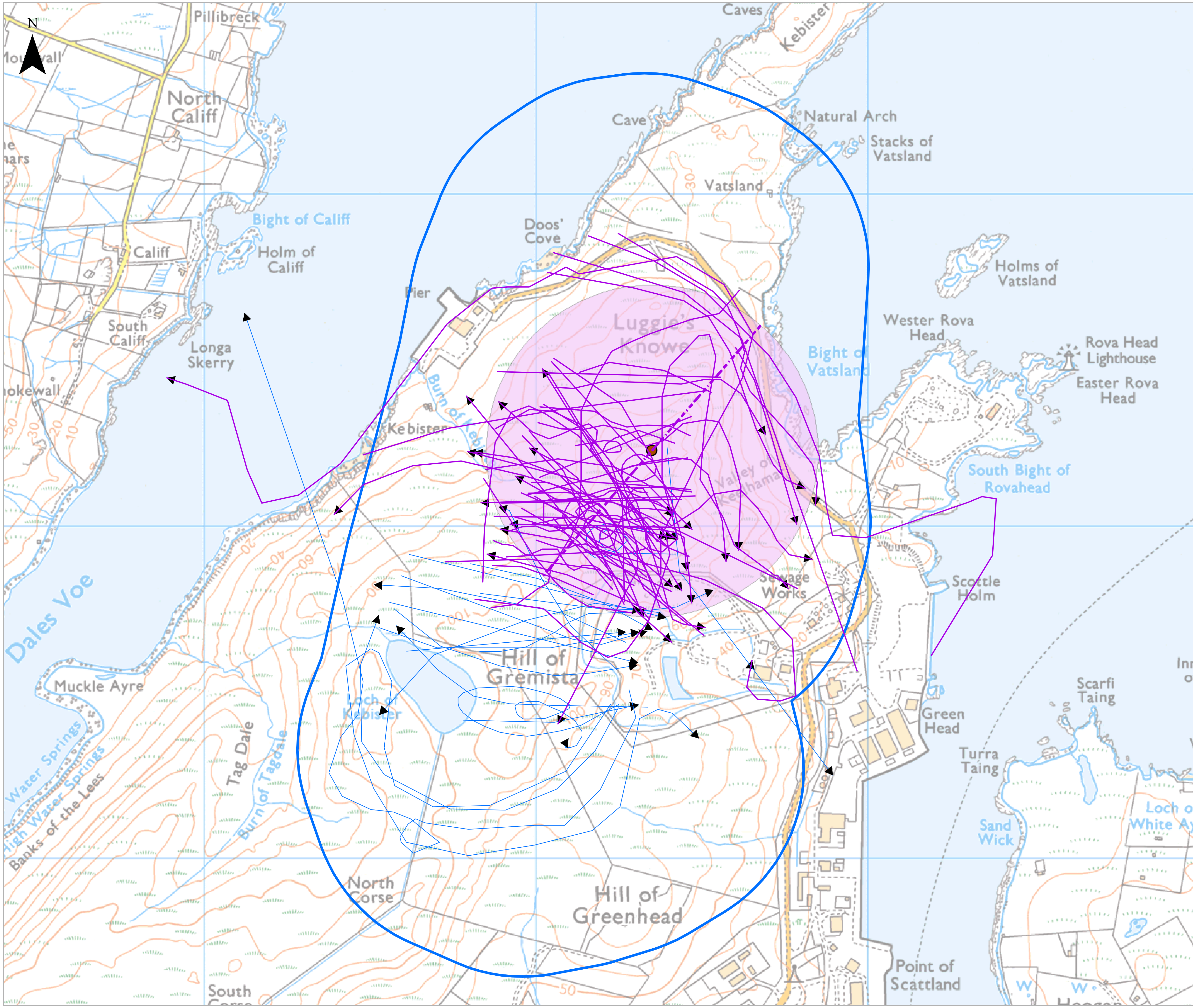
Figure 5
Great black-backed gull at-risk flights

Date:	Lead:	Review:	Version:
15/06/2023	AJM	EB	V1

Figure 4 – Herring Gull at-risk flights



KEY

- Site Boundary
- 500m buffer
- Risk window
- Proposed Turbine
- Turbine 500m buffer
- At risk flights
- Non at-risk flights

Coordinate System: British National Grid
Projection: Transverse Mercator

0 0.175 0.35 0.7 km

1:11,000

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Figure 4
Herring gull at-risk flights

Date:	Lead:	Review:	Version:
15/06/2023	AJM	EB	V1

Figure 5a – Red-Throated Diver at-risk linear

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Figure 5b – Red-Throated Diver at-risk random

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Appendix A: Survey Data Summary

Table A1 - Vantage point survey timings and weather

Date	Vantage Point	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
26-Sep-20	1	15:00	18:00	3	NNE	4	4	0	0	0
27-Sep-20	2	12:20	15:20	3	NNE	3	8	1	0	0
10-Oct-20	2	15:11	18:11	3	NNW	3	7	0	0	0
11-Oct-20	2	11:39	14:39	3	NNW	4	5	0	0	0
12-Oct-20	1	07:41	10:41	3	SE	3	8	1	0	0
12-Oct-20	1	11:11	14:11	3	ESE	4	8	1	0	0
11-Oct-20	1	15:09	18:09	3	WNW	4	6	1	0	0
12-Nov-20	2	07:48	10:13	2.5	S	5	8	3	0	0
12-Nov-20	2	12:42	15:42	3	SSW	4	8	3	0	0
13-Nov-20	2	11:15	11:48	0.5	SE	3	8	3	0	0
13-Nov-20	2	12:18	15:18	3	SSW	5	7	0	0	0
14-Nov-20	1	09:07	12:07	3	SE	4	6	3	0	0
14-Nov-20	1	12:37	15:37	3	S	5	5	0	0	0
03-Feb-21	1	11:10	14:10	3	SE	4	4	0	1	2
03-Feb-21	1	14:40	16:20	2	E	4	4	0	1	1
05-Feb-21	1	15:08	16:28	1	SE	5	8	0	1	1
04-Feb-21	2	09:45	12:45	3	SSE	4	6	0	1	1
04-Feb-21	2	13:26	16:26	3	ESE	4	6	0	1	1
05-Feb-21	2	08:08	11:08	3	SE	5	7	0	1	1
05-Feb-21	2	11:38	14:38	3	SE	5	7	0	1	1
10-Mar-21	1	09:30	12:30	3	S	4	4	0	0	0
10-Mar-21	1	13:00	16:00	3	S	4	5	0	0	0
11-Mar-21	2	10:30	13:30	3	W	5	7	1	0	0
11-Mar-21	2	14:00	17:00	3	W	5	7	1	0	0
13-Mar-21	1	06:25	09:25	3	WSW	5	7	4	1	0
13-Mar-21	1	09:55	12:55	3	SW	4	4	3	1	0
27-Apr-21	1	09:45	12:45	3	NNE	5	6	0	0	0
29-Apr-21	1	05:05	08:05	3	NE	5	7	4	0	1
28-Apr-21	2	05:05	08:05	3	NE	5	7	4	0	0
28-Apr-21	2	08:38	11:38	3	NW	3	7	1	0	0
14-May-21	1	15:00	18:00	3	NNE	4	8	0	0	0
14-May-21	1	18:35	21:35	3	NNW	4	8	2	0	0
15-May-21	2	15:05	18:05	3	E	3	8	2	0	0
15-May-21	2	18:38	21:38	3	E	2	8	2	0	0
14-Jun-21	1	09:15	12:15	3	WSW	4	5	0	0	0
14-Jun-21	1	12:45	15:45	3	SW	4	6	0	0	0
15-Jun-21	2	09:30	12:30	3	SSE	5	8	0	0	0
15-Jun-21	2	13:00	16:00	3	SSE	4	8	0	0	0
12-Jul-21	1	13:45	15:45	3	SSE	3	8	0	0	0
12-Jul-21	1	17:15	20:15	3	S	4	8	2	0	0

Date	Vantage Point	Start time	Stop Time	Time (Hrs)	Wind Direction	Wind speed	Cloud cover	Rain	Snow	Frost
13-Jul-21	2	13:40	16:40	3	ENE	1	8	0	0	0
13-Jul-21	2	17:10	20:10	3	NE	2	8	0	0	0

Meteorological Key:

Wind speed	Cloud cover	Rain	Snow	Frost
calm = 0 light air = 1 Light breeze = 2 Gentle Breeze = 3 Mod. Breeze = 4 fresh breeze = 5 strong breeze = 6 mod. gale = 7 fresh gale = 8 strong gale = 9	In eighths e.g 0/8 = no cloud 8/8 = full cloud cover	None = 0 Occasional=1 Drizzle / mist = 2 Light shower = 3 Heavy shower = 4 Heavy rain = 5	None = 0 On Site = 1 Snowing = 2	None = 0 Ground = 1 All day = 2

Table A4 - Summary of Target Species Flight Time

Species	Flights	Total No birds	Sum of Duration (Seconds)	HB1 - 0-10	HB2 - 11-20	HB3 - 21-30	HB4 - 31-40	HB5 - 41-50	HB6 51-150 (PCH)	HB7 - 150+
Arctic tern	115	2	4	23	52	40				
Common gull	313	10	21	205	108					
Curlew	484	11	54	20	256	86	47	30	45	
Glaucous gull	104	2	2	46	30	28				
Great black-backed gull	5,824	109	306	962	2172	1174	579	288	296	353
Great skua	1,725	21	35	384	841	419	81			
Greylag goose	1,870	18	134	45	432	521	246	77	268	281
Hen harrier	211	1	1						136	75
Herring gull	5,289	100	264	1002	1832	833	528	392	393	309
Knot	46	1	8			46				
Long-tailed duck	94	1	2						94	
Merlin	76	2	2	27	10	29	10			
Oystercatcher	156	2	4	95	61					
Red-throated diver	3,238	28	45	110	308	692	962	945	227	
Snipe	208	2	2	15	30	75	88			

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