Bowdun Offshore Wind Farm, Offshore EIA Report

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THISTLE WIND PARTNERS

BOWDUN OFFSHORE WIND FARM

Flight Height Data report

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EXECUTIVE SUMMARY

Thistle Wind Partners (TWP) contracted APEM Ltd. (APEM) to perform site-specific ornithology surveys in the development area of the Bowdun Offshore Wind Farm (OWF), Plan Option (PO) E3 and surrounding area using a buffer of 12km from the PO E3 boundary. These surveys provide baseline information on the abundance, distribution, and behaviour of ornithological features within the Survey Area, which will inform the Environmental Impact Assessment (EIA). The purpose of this document is to report on the flight height data of birds in the area which can be utilised for Collision Risk Modelling (CRM) to inform the Offshore Ornithology component of the EIA and Habitats Regulations Appraisal (HRA).

The site-specific survey flight height data includes that from Digital Aerial Surveys (DAS) and Aerial Light Detection and Ranging (LiDAR) Surveys. This report compared the results of these surveys, along with the "generic" flight heights described by Johnston *et al.,* 2014, which is widely used for CRM.

This report details a comparison exercise of flight heights data used for CRM, specifically the proportion of birds at collision risk for the three Project Design Envelope (PDE) Options. The key conclusions are:

- DAS based trigonometry flight height data vastly overestimated the proportion of birds flying at risk height (species specific), making it unreliable as a method to estimate flight height. For example, despite a large sample size of 5,427, 67.3% of black-legged kittiwake were found to fly at risk height (>23.4m mean sea level (MSL). for PDE Option 1 using DAS based trigonometry, whereas the LiDAR estimate (6.5%) was close to the "generic" percentage (11.2%).
- Sample sizes for LiDAR were relatively small for most species (range one to 83 individuals recorded), except black-legged kittiwake, for which 707 records were present.
- There was about an eightfold reduction in the percentage of kittiwake flying at risk height between PDE Option 1 (6.5%) and 2 (0.8%), whereas this reduction was only about twofold for "generic" data (11.2% versus 6.3%). However, this may be due to a combination of sample size (Johnston *et al*., 2014 had a much larger sample size) and differences in a modelling and raw data approach (Johnston *et al.,* 2014 modelled their distribution, whereas this report provides a raw data summary), but it is worth exploring further.
- Given that kittiwake is the key species identified as causing a high ornithological constraint for Bowdun OWF in the Sectoral Marine Plan (SMP), it is encouraging that site-specific LiDAR data puts more birds below collision risk levels compared to generic data, in particular for PDE Option 2.
- Johnston et al., 2014 is the current recommended reference for the generic flight heights of marine birds to be used within the sCRM (stochastic Collision Risk Model) tool (NatureScot1, 2023). Site-specific flight height data can be used to inform the CRM for black-legged kittiwake given the large sample size. However, this has to be agreed with NatureScot who require a 'full description of method, accuracy, precision and comparison with Johnston et al. (2014), with explanation of any differences to inform discussions with NatureScot,' (NatureScot1, 2023).

ACRONYMS

Acronym	Definition
BTO	British Trust for Ornithology
CRM	Collision Risk Modelling
DAS	Digital Aerial Survey
LiDAR	Light Detection and Ranging
MSL	Mean Sea Level
OWF	Offshore Wind Farm
PDE	Project Design Envelope
PO	Plan Option
SD	Standard Deviation
SMP	Sectoral Marine Plan
TWP	Thistle Wind Partners

TABLE OF UNITS

Unit	Definition
GW	GigaWatt
km	Kilometre
km^2	Square kilometre
MW	MegaWatt
m	Metre
nm	Nautical mile
s	Seconds

1 INTRODUCTION

1.1 Report Outline

1.1.1 Thistle Wind Partners (TWP) contracted APEM Ltd. (APEM) to perform site-specific ornithology surveys in the Bowdun Offshore Wind Farm (hereafter known as Bowdun OWF), Plan Option (PO) E3 and surrounding area using a minimum buffer of 12 km around the PO E3. The buffer area surveyed differed between the summer (April to August, inclusive) and winter (September to March, inclusive). During the summer months the buffer was extended to include the area up to the coast to help monitor the local breeding colonies and provide context for the observations within the PO These surveys provide baseline information on the abundance, distribution, and behaviour of ornithological features within the Survey Area, which will inform the Environmental Impact Assessment (EIA). The purpose of this document is to report on the current survey data collected, specifically flight height data of birds in the area which can be utilised for Collision Risk Modelling (CRM) to inform the Offshore Ornithology component of the EIA and Habitats Regulations Appraisal (HRA).

1.1.2 The site-specific survey flight height data includes that from Digital Aerial Surveys (DAS) and Aerial Light Detection and Ranging (LiDAR) Surveys. This report aims to compare the results of these surveys, along with the flight heights described by Johnston *et al.,* 2014, which are typically used for CRM assessment, to assess data collection methods and consider which is most appropriate for measuring species' flight heights accurately.

1.2 Project Description

1.2.1 Bowdun OWF is located off the northeast of Scotland, approximately 43 km east of the coast of Aberdeenshire (Figure 1.1). Whilst the project is still at the design and development phase, the current assumption is Bowdun OWF will consist of between 40 to 67 fixed or floating turbines, with each turbine being between 15 MW and 25MW (Table 2.1). Once operational, Bowdun OWF will have the capacity to generate approximately 1 GW of energy.

1.2.2 The proposed Marine Licence application (and Section 36) date for the Bowdun OWF is October 2025. Subject to the necessary consents, construction will start in 2030 and the wind farm will become operational in 2032.

1.2.3 The offshore cable from the wind farm will landfall at Benholm, Aberdeenshire. The grid connection point is subject to final solution provided by National Grid connection agreement. The onshore routing currently subject to various environmental and technical investigations, and landowner engagement to inform selection of the onshore cable corridor.

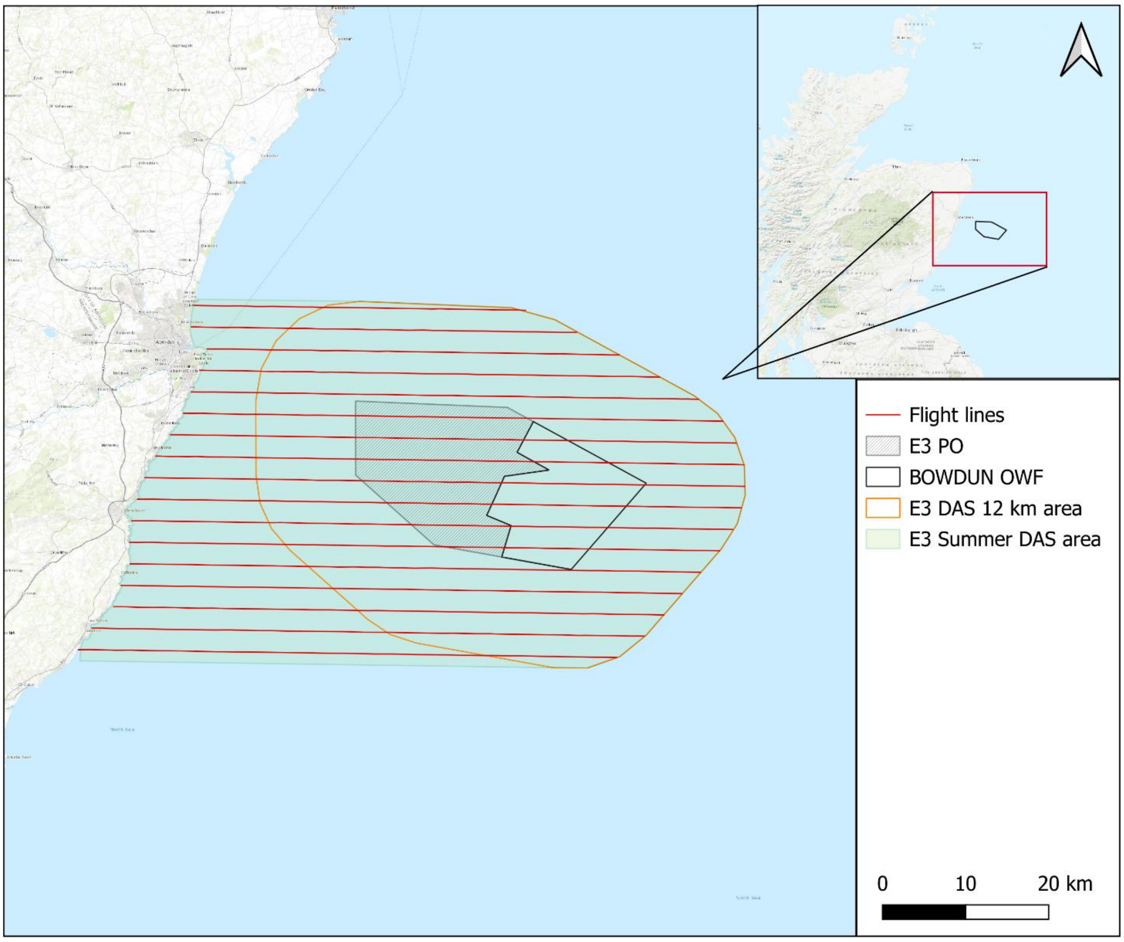

Figure 1.1. Ornithological Digital Aerial Survey (DAS) area for Bowdun Offshore Wind Farm.

1.3 Ornithology Background

1.3.1 The northern most part of the Bowdun OWF lies within approximately 21.6 km (approximately 10.3 km for the 12 km study area) off the Aberdeenshire coast in the western part of the North Sea, which reaches average depths of 90 m.

1.3.2 The development area of the Bowdun OWF will be used by seabird species that forage in offshore waters. These offshore seabirds will primarily be comprised of species that breed in the region, including but not limited to northern fulmar *Fulmarus glacialis*, northern gannet *Morus bassanus*, Arctic tern *Sterna paradisaea*, black-legged kittiwake *Rissa tridactyla*, herring gull *Larus argentatus*, common guillemot *Uria aalge*, razorbill *Alca torda* and Atlantic puffin *Fratercula arctica*. The seabirds using the offshore area originate primarily from colonies along the east coast of Scotland.

Collision Risk

1.3.4 During the operations and maintenance (O&M) phase of Bowdun OWF, there is a potential concern due to the risk of seabirds colliding with the turning rotors of the wind turbines. Stationary components, such as the tower or nacelle, as well as times when rotors are not in motion, are not expected to result in a significant risk of collision. When a collision occurs between the turning rotor blade and the bird, it is assumed to result in direct mortality of the bird, which could result in population level impacts.

1.3.5 The degree of susceptibility to collision risk varies among species, primarily depending on their flight behaviour and avoidance responses, and the vulnerability of their populations (Garthe and Hüppop, 2004; Furness *et al.,* 2012; Wade *et al.,* 2016). Additionally, various factors related to the structure and operation of the wind turbines can affect the risk to birds. These factors, such as rotor speed, blade size, pitch angle and height above the sea surface, all contribute to the overall risk.

Flight heights and collision risk modelling

1.3.7 CRM is the approach used to quantify the risk of collision by birds with offshore wind farm turbines using species-specific densities and metrics, including flight height data (Band 2012). Species-specific flight height data for CRM may take the form of proportions of flights above air gap height (i.e. at rotor swept height, where collision becomes a risk), or of species-specific flight height distributions. These can be derived from site-specific data collected during baseline surveys, but current guidance recommends using 'generic' flight height distributions in published literature (Johnston *et al.,* 2014), modelling thousands of flight height measurements largely from boat-based surveys conducted at 32 sites around the UK.

1.3.8 Seabirds seldom fly above 300 m (Spear and Ainley 1997; Garthe and Huppop 2004), and many fly within 20 m of the sea surface (Johnston *et al.,* 2014). However, it is important to assess the flight heights of species independently as there is much variation between species and locations. Furthermore, the flight heights of seabirds can be affected by several factors including foraging strategy, wind speed, time of day, time of year and whether the bird is foraging, commuting, or migrating (Johnston *et al*., 2014; Garthe & Huppop 2004; Shamoun-Baranes *et al.,* 2006; Blew *et al.,* 2008; Krijgsveld *et al.,* 2011; Wright *et al.,* 2012).

2 METHODS

2.1 Survey Area

2.1.1 The Bowdun OWF is located off the northeast of Scotland, approximately 43 km east of the coast of Aberdeenshire. Due to the wide-range and highly mobile nature of seabirds, and to consider the potential impacts of activities associated with the OWF on wider seabird populations, the study area for the assessment of offshore ornithology is the PO E3 plus a buffer (summer and winter buffers differ). These buffers are considered appropriate to the size, nature, and location of Bowdun OWF based on RPS' professional judgment and experience of similar developments.

2.2 Flight Height Data

2.2.1 For the Bowdun OWF, flight height data has been derived by two methods:

- **Light Detection and Ranging Surveys (LiDAR)**
  - Out of all currently available and regulator approved methods to determine seabird flight height, LiDAR provides the most accurate measure of an individual birds' height, relative to the water. Although relatively expensive to collect, use of LiDAR-derived data helps reduce CRM and EIA uncertainty through the use of accurate, site-specific flight height information.
  - LiDAR surveys were flown in July and September 2022, and April and July 2023. These surveys were undertaken within the Bowdun OWF Array Area only.
- **Digital Aerial Surveys (DAS)**
  - To determine baseline seabird populations, a programme of 24 monthly DAS was flown by APEM Ltd. from March 2022 to February 2024, covering the PO E3 plus a 12 km buffer (shown in orange within Figure 1.1). This report presents the flight height analysis of 18 months of the DAS data, from March 2022 to August 2023.
  - APEM has derived flight heights from DAS surveys, using trigonometry. Note the accuracy of the trigonometry method is much lower than LiDAR, and depends on the size and position of the bird, as well as the bird's behaviour.

2.2.2 It is intended that the site-specific flight heights can be incorporated as a scenario into the impact assessments for Bowdun OWF to inform project specific mitigation. This document provides an initial summary of the flight height data collected and compares the data to generic flight height data (Johnston *et al.,* 2014).

2.3 Project Design Envelope (PDE) Turbine Options

2.3.1 The PDE outlines specific information regarding each turbine option of the project. Bowdun OWF currently has three potential project designs as per the current PDE. The three options, from the scoping PDE freeze, provided by TWP, have been considered for this report and are presented in Table 2.1. These parameters set out in the PDE will be used in CRM to predict the magnitude of potential collisions based on each option.

Table 2.1: Bowdun Offshore Wind Farm wind turbine parameters used for collision risk modelling, taken from Project Design Envelope (PDE) provided by Thistle Wind Partners (TWP).

Parameter	PDE Option 1	PDE Option 2	PDE Option 3
Number of wind turbines	67	57	40
Number of rotor blades	3	3	3
Maximum chord width (m)	5	6	9
Average blade pitch (degrees)	5.5	5.5	5.5
Maximum rotor radius (m)	118	131	163

Parameter	PDE Option 1	PDE Option 2	PDE Option 3
Average rotation speed (rpm)	7.1	6.4	5.2
Tidal offset (m) (mean sea level (MSL))	1.96	1.96	1.96
Lower blade tip height above lowest astronomical tide (m)	25.36	31.36	43.36
Air gap (MSL) (m)	23.4	29.4	41.4
Wind farm width (km)	19.6	19.6	19.6
Latitude	56.98	56.98	56.98
Large array correction (standard)	Yes	Yes	Yes

2.3.2 For the purposes of this report, the air gap (height of the lowest blade tip above mean sea level) will be used as a guide to calculate the proportion of birds flying at bird species specific risk height. The outcomes of site-specific calculations will be compared to the generic flight height distributions (Johnston *et al.*, 2014).

3 RESULTS

3.1 LiDAR Flight Height Data

3.1.1 A summary of average LiDAR flight heights and proportions at risk across all species for different PDE options is shown in Table 3.1.

Table 3.1: Monthly mean flight height of birds recorded during LiDAR surveys conducted in Bowdun Offshore Wind Farm Array Area in July/September 2022 and April/July 2023, and sample sizes plus percentages of birds flying above turbine air gap height.

Date of Survey	Total Count (individuals)	Mean Flight Height Across Species (m)	Standard Deviation (SD)	Number of birds flying above PDE Option Air Gap Height (%)		
				Option 1 23.4m	Option 2 29.4m	Option 3 41.4m
July 2022	160	11.742	11.926	21 (13.1%)	10 (6.3%)	6 (3.8%)
September 2022	45	7.821	9.353	7 (15.6%)	1 (2.2%)	0 (0%)
April 2023	110	2.578	4.447	2 (1.8%)	2 (1.8%)	0 (0%)
July 2023	631	10.429	10.347	34 (5.4%)	6 (1.0%)	2 (0.3%)
All combined	**946**	**9.614**	**10.430**	**64 (6.8%)**	**19 (2.0%)**	**8 (0.8%)**

Species' Flight Heights

3.1.2 A total of 946 birds were recorded during the LiDAR surveys conducted in July and September 2022 and April and July 2023. The species recorded and associated numbers are shown in Table 3.2. The most abundant species was black-legged kittiwake with 707 records, while other species such as Arctic skua *Stercorarius parasiticus* and Manx shearwater were recorded just once during the survey effort.

3.1.3 Table 3.2 shows the minimum, maximum, and mean (and standard deviation) of each recorded species' flight height. The maximum flight height was 131.442 m recorded in northern gannet. Other species with high maximum flight heights were European herring gull (56.290 m), northern fulmar (48.390 m), and black-legged kittiwake (32.874 m).

3.1.4 The highest mean flight height was recorded in herring gull (31.791 m ± 18.928 SD), followed by black legged kittiwake (10.951 m ± 8.142 SD). Although northern gannet was recorded having the highest maximum flight height (131.442 m), the mean flight height for this species was 6.495 m (± 19.750 SD). Sample sizes became too low to give meaningful outputs for other species.

Table 3.2: Summary of species recorded and their flight heights during LiDAR surveys conducted in Bowdun Offshore Wind Farm Array Area in July/September 2022 and April/July 2023. Note that the "All species" summary at the bottom is a combined mean and SD, largely consisting of kittiwake.

Species	Total Count (individuals)	Flight Height (m)			
		Minimum	Maximum	Mean	Standard Deviation (SD)
Black-legged kittiwake	707	0.028	32.874	10.951	8.142
Northern gannet	81	0.148	131.442	6.495	19.750
Northern fulmar	45	0.170	48.390	2.301	7.115
Common guillemot	39	0.113	4.077	1.165	1.055
Arctic tern	25	1.367	14.399	4.447	3.030
'Commic' tern	24	0.351	16.188	3.506	3.491

Species	Total Count (individuals)	Flight Height (m)			
		Minimum	Maximum	Mean	Standard Deviation (SD)
European herring gull	15	0.350	56.290	31.791	18.928
Guillemot/razorbill	5	0.282	0.631	0.422	0.152
Atlantic puffin	2	0.509	0.541	0.525	0.023
Arctic skua	1	0.803	0.803	0.803	NA
Manx shearwater	1	0.229	0.229	0.229	NA
Small shearwater species	1	0.940	0.940	0.940	NA
All species combined	**946**	**0.028**	**131.442**	**9.614**	**10.430**

3.1.3 Considering PDE Options 1, 2, and 3 with air gap heights of 23.4 m, 29.4 m, and 41.4 m respectively, Table 3.3 shows the proportion of individuals of recorded species which are at risk of collision. Turbine Option 1 has the lowest air gap height of 23.4 m, which puts 6.8% of the birds recorded at risk of collision. Option 2 (air gap height 29.4 m) and Option 3 (air gap height 41.4 m) put 2.0% and 0.8% of birds at risk, respectively (Table 3.3).

3.1.4 When looking at different species, black-legged kittiwake sees an eightfold reduction in collision risk between PDE Option 1 and Option 2, with 6.5% and 0.8% of individuals at risk respectively (Table 3.3).

3.1.5 Of the 81 northern gannet recorded, 8.6% were at risk of turbine collision when considering PDE Option 1 (Table 3.3), which was reduced to 2.5% for Option 2 and Option 3.

3.1.6 For remaining species, sample sizes were too low for meaningful inference.

Table 3.3: Proportion of individuals of species flying above wind turbine air gap height options of the Bowdun Offshore Wind Farm. Data from during LiDAR surveys conducted in Bowdun Offshore Wind Farm Array Area in July/September 2022 and April/July 2023.

Species	Total Count (individuals)	Proportion flying above PDE Option Air Gap Height		
		Option 1 23.4 m	Option 2 29.4 m	Option 3 41.4 m
Black-legged kittiwake	707	6.5%	0.8%	0.0%
Northern gannet	81	8.6%	2.5%	2.5%
Northern fulmar	45	2.2%	2.2%	2.2%
Common guillemot	39	0.0%	0.0%	0.0%
Arctic tern	25	0.0%	0.0%	0.0%
‘Commic’ tern	24	0.0%	0.0%	0.0%
Herring gull	15	66.7%	66.7%	33.3%
Guillemot/razorbill	5	0.0%	0.0%	0.0%
Atlantic puffin	2	0.0%	0.0%	0.0%
Arctic skua	1	0.0%	0.0%	0.0%
Manx shearwater	1	0.0%	0.0%	0.0%
Small shearwater species	1	0.0%	0.0%	0.0%
Total	**946**	**6.8%**	**2.0%**	**0.8%**

3.2 DAS Flight Height Data

3.2.1 A summary of average flight heights and proportions at risk across all species for different PDE options is shown in Table 3.4.

Table 3.4: Monthly mean flight height of birds recorded during DAS conducted in Bowdun Offshore Wind Farm Array Area plus 12km buffer during April 2022 to August 2023, and number of birds flying above turbine air gap height.

Date of Survey	Total Count (individuals)	Mean Flight Height Across Species (m)	Standard Deviation (SD)	Number of birds flying above PDE Option Air Gap Height (proportion)		
				Option 1 23.4 m	Option 2 29.4 m	Option 3 41.4 m
2022	**4,928**	**53.364**	**38.733**	3,597 (73.0%)	3,290 (73.0%)	2,695 (73.0%)
March	134	57.813	42.412	106 (79.1%)	96 (79.1%)	74 (79.1%)
April	607	56.168	40.630	447 (73.6%)	420 (73.6%)	349 (73.6%)
May	1,624	61.535	39.758	1,308 (80.5%)	1,214 (80.5%)	1,052 (80.5%)
June	1,581	45.739	35.054	1,056 (66.8%)	940 (66.8%)	735 (66.8%)
July	281	52.865	38.075	214 (76.2%)	197 (76.2%)	147 (76.2%)
August	256	41.242	34.898	153 (59.8%)	135 (59.8%)	98 (59.8%)
September	135	54.802	40.413	95 (70.4%)	87 (70.4%)	73 (70.4%)
October	124	49.058	39.381	81 (65.3%)	76 (65.3%)	63 (65.3%)
November	58	46.212	35.799	37 (63.8%)	33 (63.8%)	27 (63.8%)
December	128	57.153	39.002	100 (78.1%)	92 (78.1%)	77 (78.1%)
2023	**3,312**	**39.541**	**36.507**	**1,895 (57.2%)**	**1,636 (57.2%)**	**1,212 (57.2%)**
January	61	74.920	46.842	49 (80.3%)	48 (80.3%)	40 (80.3%)
February	87	59.966	36.509	74 (85.1%)	70 (85.1%)	56 (85.1%)
March	80	44.434	43.138	49 (61.3%)	44 (61.3%)	29 (61.3%)
April	1,150	41.184	33.295	708 (61.6%)	624 (61.6%)	473 (61.6%)
May	684	33.080	40.776	307 (44.9%)	250 (44.9%)	147 (44.9%)
June	921	44.364	34.648	607 (65.9%)	534 (65.9%)	430 (65.9%)
July	192	16.380	14.430	53 (27.6%)	32 (27.6%)	13 (27.6%)
August	137	26.451	35.547	48 (35.0%)	34 (35.0%)	24 (35.0%)
All combined	**8,240**	**47.808**	**38.454**	**5,492 (66.7%)**	**4,926 (66.7%)**	**3,907 (66.7%)**

Species' Flight Heights

3.2.2 During the DAS conducted by APEM Ltd. in April 2022 to August 2023, a total of 8,240 flight heights were recorded from 20 species. Table 3.5 shows the minimum, maximum, and mean (and standard deviation) of each recorded species' flight height.

3.2.3 The mean flight heights recorded using DAS based trigonometry were markedly higher than flight heights from LiDAR data. For example, the mean flight height for black-legged kittiwake was 48.226m (± 38.401 SD) for DAS versus 10.951m (± 8.142 SD) for LiDAR.

Table 3.5: Summary of species recorded and their flight heights during DAS conducted in Bowdun Offshore Wind Farm Array Area plus 12km buffer from April 2022 to August 2023.

Species	Total Count (individuals)	Flight Height (m)			
		Minimum	Maximum	Mean	Standard Deviation (SD)
Black-legged kittiwake	5,427	0.008	307.480	48.226	38.401
Herring gull	1,621	0.112	247.130	52.769	40.006
Northern gannet	826	0.043	159.019	43.427	35.065
Common guillemot	97	0.060	32.740	10.197	9.349
Northern fulmar	81	0.009	154.724	32.098	31.858
Black-headed gull	37	0.243	138.205	33.220	32.603
Great black-backed gull	36	3.236	240.520	65.141	49.310
Common gull	34	1.500	115.526	38.442	33.351
Arctic tern	22	0.284	109.870	33.478	30.374
Razorbill	12	1.311	39.715	15.482	12.126
Sandwich tern *Thalasseus sandvicensis*	12	1.784	59.257	22.449	17.576
Common redshank	11	0.796	60.287	19.503	18.991
Lesser black-backed gull	10	13.970	143.573	59.897	41.813
Great skua	3	23.947	41.390	33.436	8.822
Atlantic puffin	2	9.100	37.924	23.512	20.382
Great cormorant *Phalacrocorax carbo*	2	13.846	17.211	15.528	2.380
Eurasian oystercatcher *Haematopus ostralegus*	2	15.402	18.977	17.190	2.528
Grey plover *Pluvialis squatarola.*	2	8.245	16.303	12.274	5.697
Red-throated diver *Gavia stellata*	2	10.852	49.870	30.361	27.590
Arctic skua	1	31.524	31.524	31.524	NA
Grand Total	**8,240**	**0.008**	**307.480**	**47.808**	**38.454**

3.2.4 Considering PDE Options 1, 2 and 3 with air gap heights of 23.4 m, 29.4 m and 41.4 m respectively, Table 3.6 shows the proportion of individuals of each species which are at risk of collision using trigonometry based flight height data. Turbine Option 1 has the lowest air gap height of 24.3 m, which puts 66.7% of the birds recorded at risk of collision. Option 2 (air gap height 29.4 m) and Option 3 (air gap height 41.4 m) put 59.8% and 47.4% of birds at risk, respectively (Table 3.6).

3.2.5 When looking at different species for which meaningful inference is possible based on their sample size (e.g. black-legged kittiwake, herring gull and gannet), only minor reductions in proportions at risk height are achieved across PDE options. For example, kittiwake proportions at risk height are 0.673, 0.602, and 0.480 for PDE Option 1, 2, and 3 respectively.

3.2.6 However, given the very large proportions of birds at risk height compared to LiDAR data and generic data, it is unlikely that DAS based trigonometry is a useful method for determining flight heights.

Table 3.6: Proportion of individuals of species flying above wind turbine air gap height options of Bowdun Offshore Wind Farm. Data from during DAS conducted in Bowdun Offshore Wind Farm Array Area buffer plus 12km buffer during April 2022 to August 2023.

Species	Total Count (individuals)	Proportion flying above PDE Option Air Gap Height		
		Option 1 23.4 m	Option 2 29.4 m	Option 3 41.4 m
Black-legged kittiwake	5,427	67.3%	60.2%	48.0%
Herring gull	1,621	71.5%	65.6%	52.7%
Northern gannet	826	63.7%	56.9%	43.7%
Common guillemot	97	15.5%	7.2%	0.0%
Northern fulmar	81	50.6%	40.7%	28.4%
Black-headed gull	37	48.6%	40.5%	21.6%
Great black-backed gull	36	80.6%	69.4%	63.9%
Common gull	34	55.9%	50.0%	41.2%
Arctic tern	22	50.0%	40.9%	31.8%
Razorbill	12	25.0%	16.7%	0.0%
Sandwich tern	12	33.3%	25.0%	16.7%
Common redshank	11	27.3%	18.2%	18.2%
Lesser black-backed gull	10	70.0%	70.0%	70.0%
Great skua	3	100.0%	66.7%	0.0%
Atlantic puffin	2	50.0%	50.0%	0.0%
Cormorant	2	0.0%	0.0%	0.0%
Eurasian oystercatcher	2	0.0%	0.0%	0.0%
Grey plover	2	0.0%	0.0%	0.0%
Red-throated diver	2	50.0%	50.0%	50.0%
Arctic skua	1	100.0%	100.0%	0.0%
Total	**8,240**	**66.7%**	**59.8%**	**47.4%**

3.3 Johnston *et al.* (2014) Flight Height Data

3.3.1 Johnston *et al.* (2014) used flight height data collected from surveys of 32 constructed and potential offshore wind farm sites to provide a reference for the flight heights of 25 seabird species. The data gives an estimate of species' flight height distributions, allowing calculations to determine whether sea bird populations are at risk from offshore wind farms, and the variable risk presented by different turbine designs. Johnston *et al.* (2014) data has been presented in this report along with site-specific survey data (DAS and LiDAR survey data) to compare the risks to bird populations suggested by each.

3.3.2 Table 3.7 shows the estimated proportions of each bird species recorded by Johnston *et al.* (2014) that would be at risk of collision from proposed turbines from PDE Options 1, 2 and 3 of the proposed Bowdun OWF.

3.3.3 The 12-month report analysed five species for collision risk, listed here in order of abundance, along with their associated collision risk percentages using "generic" flight height data (Johnston *et al.*, 2014) for PDE options 1, 2, and 3, respectively: black-legged kittiwake (11.2%, 6.3%, and 2.0%), northern gannet (9.2%, 4.9%, and 1.4%), northern fulmar (0.5%, 0.1%, and 0.0%), European herring gull (26.9%, 19.1%, and 9.5%), and Arctic tern (2.5%, 0.9%, and 0.1%).

Table 3.7: Estimated proportion of individuals of species flying above wind turbine air gap height options of Bowdun Offshore Wind Farm. Data generated from Johnston et al., 2014.

Species	Total Count (individuals)	Proportion flying above PDE Option Air Gap Height		
		Option 1 23.4 m	Option 2 29.4 m	Option 3 41.4 m
Atlantic puffin	5,979	0.0%	0.0%	0.0%
Arctic skua	331	1.5%	0.5%	0.1%
Arctic tern	2,571	2.5%	0.9%	0.1%
Black-headed gull	4,436	10.4%	5.8%	1.8%
Black-legged kittiwake	62,939	11.2%	6.3%	2.0%
Black-throated diver *Gavia arctica*	126	5.5%	2.6%	0.5%
Common eider	34,513	29.5%	21.3%	10.9%
Common guillemot	36,256	0.2%	0.0%	0.0%
Common gull	10,190	17.5%	11.1%	4.5%
Common scoter	30,847	1.1%	0.3%	0.0%
Common tern	19,329	5.0%	2.3%	0.5%
European herring gull	25,253	26.9%	19.1%	9.5%
European shag	233	9.2%	4.8%	1.3%
Great black-backed gull	8,911	27.5%	19.7%	10.1%
Great cormorant	20,227	0.9%	0.3%	0.0%
Great skua	1,202	3.8%	1.6%	0.3%
Lesser black-backed gull	35,045	23.3%	15.9%	7.4%
Little auk *Alle alle*	1,287	2.2%	0.8%	0.1%
Little gull	3,907	11.3%	6.3%	1.9%
Manx shearwater	6,801	0.0%	0.0%	0.0%
Northern gannet	44,851	9.2%	4.9%	1.4%
Northern fulmar	26,168	0.5%	0.1%	0.0%
Razorbill	13,172	1.5%	0.5%	0.1%

Species	Total Count (individuals)	Proportion flying above PDE Option Air Gap Height		
		Option 1 23.4 m	Option 2 29.4 m	Option 3 41.4 m
Red-throated diver	9,686	4.1%	1.7%	0.3%
Sandwich tern	33,982	4.7%	2.1%	0.4%
Total	**438,242**	8.4%	5.2%	2.1%

4 CONCLUSION

4.1.1 Seabird species' flight height data is used to inform the CRM Technical Report which will form part of the EIA and HRA required for Bowdun OWF consents. It is therefore important to assess data collection methods and consider which is most appropriate for measuring species' flight heights accurately. To compare the flight height data gathered from DAS, LiDAR surveys and Johnston *et al.* (2014), black-legged kittiwake has been selected as an example, since it is an important species as per the SMP for PO E3, to consider in CRM and presents the largest sample size (DAS surveys *N* = 5,427; LiDAR surveys *N* = 707; Johnston *et al.,* 2014 *N* = 62,939).

4.1.2 Figure 4.1 displays the black-legged kittiwake risk height percentages for three different data sources and PDE Options. From this graph and the data shown in previous sections, it is evident that DAS based trigonometry vastly overestimates the percentages of birds flying at risk height. Where generic and LiDAR data estimates the birds at risk height to range between 6.5% and 11.2% for PDE Option 1, DAS estimates it to be 67.3%. Given the vast sample size available for the generic data, and the LiDAR data with a smaller sample size being quite close to the generic data, DAS-based trigonometry can be dismissed as a reliable method to estimate flight heights.

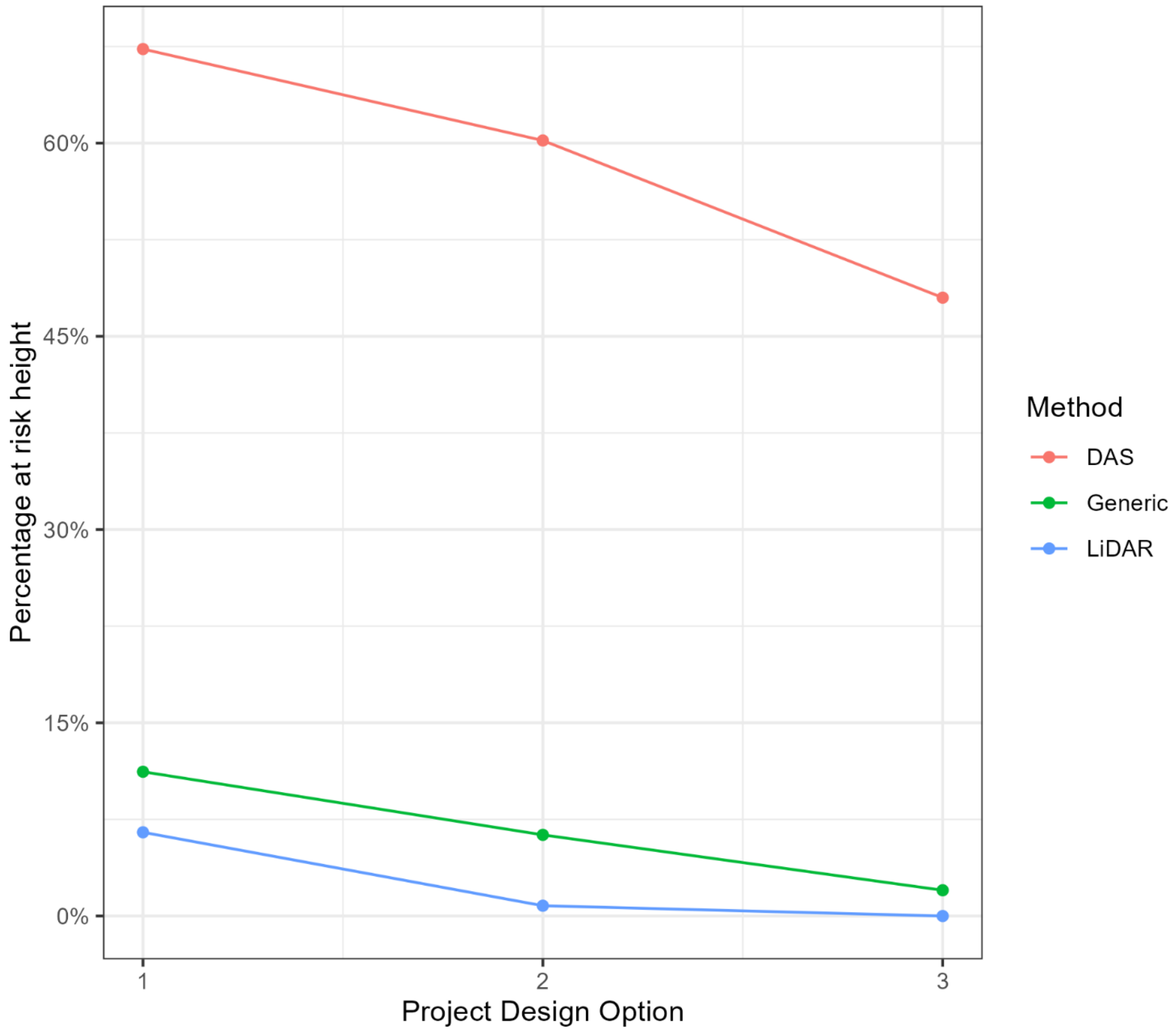

Figure 4.1: Black-legged kittiwake flight height data from three different data sources, showing percentages of birds flying at risk height (m) for the three Plan Options.

4.1.3 Johnston *et al.,* 2014 is the current recommended reference for the generic flight heights of marine birds to be used within the sCRM (stochastic Collision Risk Model) tool (NatureScot[1], 2023). Site-specific flight height data can be used to inform the CRM for black-legged kittiwake given the large sample size. However, this has to be agreed with NatureScot who require a 'full description of method, accuracy, precision and comparison with Johnston *et al.* (2014), with explanation of any differences to inform discussions with NatureScot,' (NatureScot[1], 2023).

5 REFERENCES

Band, B. (2012). Using a collision risk model to assess bird collision risks for offshore windfarms. SOSS report, The Crown Estate

Blew, J., Hoffman, M., Nehls, G. and Hennig, V. (2008). Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark. Part I: Birds. Universitat Hamburg and BioConsult SH Report. Available at: https://www.researchgate.net/publication/289504708_Investigations_of_the_birds_collision_risk_and_the_response_of_harbour_porpoises_in_the_offshore_wind_farms_Horns_Rev_North_Sea_and_Nysted_Baltic_Sea_in_Denmark_Part_I_Birds (Accessed: 23/02/2024).

BTO (2023). BTO Birdfacts. British Trust for Ornithology. Available online at: https://www.bto.org/understanding-birds/welcome-birdfacts (Accessed: 12/01/2024).

Furness, R.W. and Wade, H. (2012). Vulnerability of Scottish seabirds to offshore wind turbines. Available at: http://www.scotland.gov.uk/Resource/0040/00401641.pdf (Accessed: 12/01/2024).

Garthe, S and 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. Available at: https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.0021-8901.2004.00918.x (Accessed: 23/02/2024).

Huppop, O., Diershcke, J., Exo, K.-M., Fredrich, E. and Hill, R. (2006). Bird migration studies and potential collision risk with offshore wind turbines. Ibis, 148, 90–109. Available at: https://www.researchgate.net/publication/227769181_Bird_migration_studies_and_potential_collision_risk_with_wind_turbines (Accessed: 23/02/2024).

Johnston, A., Cook, A. S., Wright, L. J., Humphreys, E. M., and Burton, N. H. (2014). Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. *Journal of Applied Ecology*, 51(1),31-41. Available at: https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.12191 (Accessed: 23/02/2024).

Krijgsveld, K.L., Fijn, R.C., Japink, M., van Horssen, P.W., Heunks, C., Collier, M.P., Poot, M.J.M. and Dirken, S. (2011). Effect studies Offshore Wind Farm Egmond aan Zee: Final report on fluxes, flight altitudes and behaviour of flying birds. Bureau Waardenburg report no. 10-219. Commissioned by NordzeeWind. Avaialble at: https://tethys.pnnl.gov/sites/default/files/publications/Krijgsveldetal2014.pdf (Accessed: 23/02/2024).

NatureScot (2023). Marine Renewable Development Guidance Notes 1-8. Available online at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/marine-renewables/advice-marine-renewables-development (Accessed: 23/02/2024).

NatureScot[1] (2023). Guidance Note 7: Guidance to support Offshore Wind Applications: Marine Ornithology - Advice for assessing collision risk of marine birds. https://www.nature.scot/doc/guidance-note-7-guidance-support-offshore-wind-applications-marine-ornithology-advice-assessing#5.+Flight+height (Accessed: 22/02/2024).

Newton, I. (2010) Bird Migration. Collins, London.

Shamoun-Baranes, J., van Loon, E., van Gastern, H., van Belle, J., Bouten, W. and Buurma, L. (2006). A comparative analysis of the influence of weather on the flight height of birds. *Bulletin of the American Meteorological Society*, **87**,47–61. https://www.researchgate.net/publication/249615905_A_Comparitive_Analysis_of_the_Influence_of_Weather_on_the_Flight_Altitudes_of_Birds (Accessed: 24/01/2024).

Spear, L.B. and Ainley, D.G. (1997). Flight behaviour of seabirds in relation to wind direction and wing morphology. *Ibis*, **139**,221–233. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1474-919X.1997.tb04621.x (Accessed: 23/02/2024).

Wade, H.M., Masden, E.A., Jackson, A.C., and Furness, R.W. (2016). Incorporating data uncertainty when estimating potential vulnerability of Scottish seabirds to marine renewable energy developments. *Marine Policy*, **70**,108-113. Available at: https://www.researchgate.net/publication/302971929_Incorporating_data_uncertainty_when_estimating_potential_vulnerability_of_Scottish_seabirds_to_marine_renewable_energy_developments (Accessed: 24/01/2024).

Woodward, I., Thaxter, C.B., Owen, E. and Cook, A.S.C.P. (2019). Desk-based revision of seabird foraging ranges used for HRA screening. Report of work carried out by the British Trust for Ornithology on behalf of NIRAS and The Crown Estate. BTO Research Report No. 724. (Accessed: 12/01/2024).

Wright, L.J., Ross-Smith, V.H., Austin, G.E., Massimino, D., Dadam, D., Cook, A.S.C.P., Calbrade, N.A. and Burton, N.H.K. (2012). Assessing the risk of offshore wind farm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species). Strategic Ornithological Support Services Project SOSS-05. BTO Research Report No. 592. BTO, Thetford. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Wrightetal2012.pdf (Accessed: 12/01/2024).