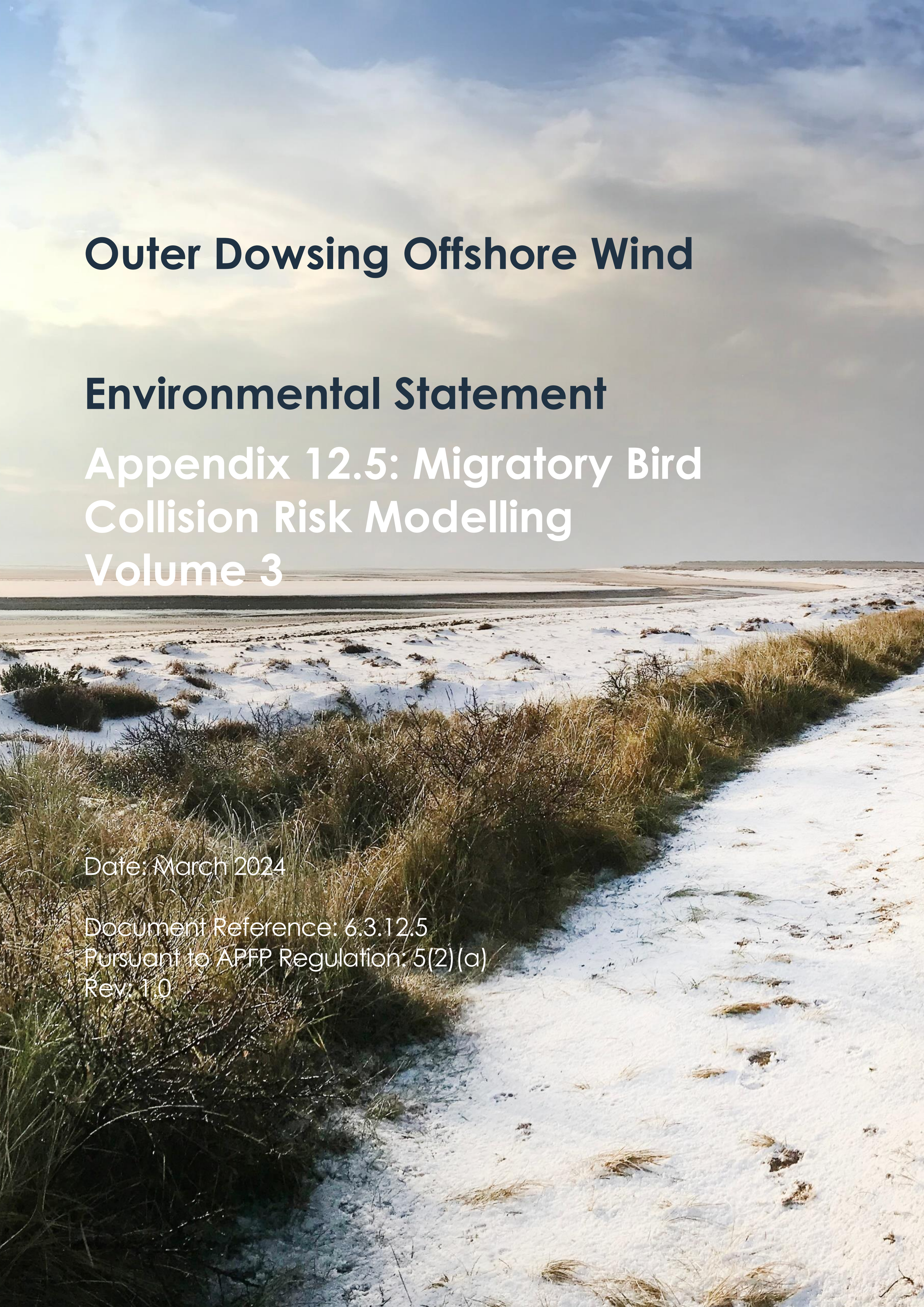

Outer Dowsing Offshore Wind

Environmental Statement

Appendix 12.5: Migratory Bird Collision Risk Modelling
Volume 3

Date: March 2024

Document Reference: 6.3.12.5
Pursuant to APFP Regulation: 5(2)(a)
Rev: 1.0

Company:	Outer Dowsing Offshore Wind	Asset:	Whole Asset
Project:	Whole Wind Farm	Sub Project/Package:	Whole Asset
Document Title or Description:	Appendix 12.5 Migratory Collision Risk Modelling Annex		
Internal Document Number:	PP1-ODOW-DEV-CS-REP-0203	3rd Party Doc No (If applicable):	N/A

Rev No.	Date	Status / Reason for Issue	Author	Checked by	Reviewed by	Approved by
1.0	Mar 2024	DCO Application	GoBe	GoBe	Shepherd and Wedderburn	Outer Dowsing

Table of Contents

Figures

Table of Tables

Acronyms & Terminology

Abbreviations / Acronyms

Abbreviation / Acronym	Description
BDMPS	Biologically Defined Minimum Population Scales
CRM	Collision Risk Model
DAS	Digital aerial survey
EEA	European Economic Area
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
ES	Environmental Statement
EU	European Union
HRA	Habitats Regulations Assessments
JNCC	Joint Nature Conservation Committee
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
mCRM	Migratory Collision Risk Modelling
MDS	Maximum Design Scenario
ODOW	Outer Dowsing Offshore Wind
ORCP	Offshore Reactive Compensation Platform
OSS	Offshore Substations
O&M	Operation and Maintenance
OWF	Offshore Windfarm
PCH	Potential Collision Height
RPM	Rotations per minute
RSPB	Royal Society for the Protection of Birds
SD	Standard Deviation
SPA	Special Protected Areas
SOSS	Strategic Ornithological Support Services
UK	United Kingdom
USSR	Union of Soviet Socialist Republics
WCS	Worst-Case Scenario
WTG	Wind Turbine Generator

Terminology

Term	Definition
Array area	The area offshore within which the generating station (including wind turbine generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling will be positioned.
Baseline	The status of the environment at the time of assessment without the development in place.

Term	Definition
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the sensitivity of the receptor, in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Regulations, including the publication of an Environmental Statement (ES).
Environmental Statement (ES)	The suite of documents that detail the processes and results of the EIA.
Evidence Plan	A voluntary process of stakeholder consultation with appropriate Expert Topic Groups (ETGs) that discusses and, where possible, agrees the detailed approach to the Environmental Impact Assessment (EIA) and information to support Habitats Regulations Assessment (HRA) for those relevant topics included in the process, undertaken during the pre-application period.
Export cables	High voltage cables which transmit power from the Offshore Substations (OSS) to the Onshore Substation (OnSS) via an Offshore Reactive Compensation Platform (ORCP) if required, which may include one or more auxiliary cables (normally fibre optic cables).
Habitats Regulations Assessment (HRA)	A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European conservation sites and Ramsar sites. The process consists of up to four stages of assessment: screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI) and compensatory measures.
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Intertidal	The area between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS).
Landfall	The location at the land-sea interface where the offshore export cables and fibre optic cables will come ashore.
Maximum Design Scenario	The project design parameters, or a combination of project design parameters that are likely to result in the greatest potential for change in relation to each impact assessed.
Offshore Export Cable Corridor (ECC)	The Offshore Export Cable Corridor (Offshore ECC) is the area within the Order Limits within which the export cable running from the array to landfall will be situated.
Offshore Reactive Compensation Platform (ORCP)	A structure attached to the seabed by means of a foundation, with one or more decks and a helicopter platform (including bird deterrents) housing electrical reactors and switchgear for the purpose of the efficient transfer of power in the course of HVAC transmission by providing reactive compensation.

Term	Definition
Onshore Infrastructure	The combined name for all onshore infrastructure associated with the Project from landfall to grid connection.
Offshore Substation	A structure attached to the seabed by means of a foundation, with one or more decks and a helicopter platform (including bird deterrents), containing— (a) electrical equipment required to switch, transform, convert electricity generated at the wind turbine generators to a higher voltage and provide reactive power compensation; and (b) housing accommodation, storage, workshop auxiliary equipment, radar and facilities for operating, maintaining and controlling the substation or wind turbine generators.
Outer Dowsing Offshore Wind (ODOW)	The Project.
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure.
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses etc.
Transboundary impacts	Transboundary effects arise when impacts from the development within one European Economic Area (EEA) state affects the environment of another EEA state(s)
Wind turbine generator (WTG)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation

12 Introduction

12.1 Project Background

1. GTR4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as the 'Applicant', is proposing to develop Outer Dowsing Offshore Wind (hereafter "The Project"). The Project array will be located approximately 54km from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, and connection to the electricity transmission network (see Volume 1, Chapter 3: Project Description (document reference 6.1.3) for full details).
2. This technical annex has been produced to provide the methodology and results of the migratory Collision Risk Modelling (CRM) that forms part of the ornithological assessment completed to date, and supports Volume 1, Chapter 12: Offshore and Intertidal Ornithology of Environmental Statement (ES) (document reference 6.1.12). A separate report (Volume 2, Appendix 12.1: Ornithology Technical Baseline) provides the findings from offshore and intertidal ornithology surveys to determine the receptors that characterise the baseline and are of relevance to the assessment of potential impacts from The Project.
3. The consideration of offshore and intertidal ornithology for The Project has been discussed with consultees (Natural England and the Royal Society for the Protection of Birds (RSPB) through The Project Evidence Plan Process (EPP). The latest Natural England advice has been followed (Parker *et al.*, 2022; Natural England, 2022). Where there is deviation from this guidance, any agreements made with consultees during the EPP regarding the migratory collision risk methodology can be found within Volume 1, Chapter 12: Offshore and Intertidal Ornithology, Section 12.3 (document reference 6.1.12).

12.2 Potential collision risk to migratory birds

4. Assessing the potential impact from collision risk with wind turbines is an essential part of the assessment process. The level of risk from collisions with turbines is estimated using CRM. The species that are unlikely to be impacted are screened out and excluded from the modelling.
5. Site specific digital aerial surveys (DAS) were conducted in The Project array area plus a 4km buffer. The results of these surveys provide information on the estimated abundance and density of birds in the area for each bio-season. This however has limitations as the survey methods are not guaranteed to provide reliable estimates of birds in the area during migration periods, particularly non-seabirds. This can be due to species moving through the area in poor weather, in short time periods or at night, making the recording of numbers complex using the standard methods.

6. To model the movement of migratory birds, The Project have used the software model 'Migropath', developed by APEM, to provide estimates of such movements. This builds on the work carried out by the British Trust for Ornithology (BTO) for the SOSS-05 project (Wright *et al.* 2012; Woodward *et al.,* 2023). Migropath can be used to estimate the proportion of a given population passing through a site's footprint, assuming point-to-point migration (for example from the coastline of continental Europe to designated Special Protected Areas (SPAs) within the United Kingdom (UK)). Further details are given below in Section 12.4.1.
7. The use of Migropath is not suitable for all species, in particular species which do not follow a point-to-point migration pattern (Alerstam, 1990). Many seabirds fall into this category (Wernham *et al.* 2002), with some seabirds known to take longer routes, for example following the coastline in preference to a more direct route over land (WWT & MacArthur Green, 2013). For such species, a 'broad front' pathway might better describe the movements that these birds are making within the North Sea. The risk to the population caused by the presence of The Project, relates to the proportion of the 'broad front' pathway crossing The Project array area. Further details are provided in Section 12.5.
8. The assessment in the main body of this report has been carried out using the Migropath tool to assess collision risk to non-seabird species. This tool is supported within Natural England guidance (Parker *et al.,* 2022c). However, for comparison an additional analysis can be found in Appendix 1 using the latest version of the Marine Scotland Science Stochastic Collision Risk Model Shiny Application ("mCRM App"; Donovan, 2018). The mCRM App is still a Beta version but it is anticipated that Natural England may choose to support this tool once it is fully operational.

12.3 Species selection/screening process

12.3.1 Screening methodology

9. Migratory tern, gull and waterbird species have been screened in for the assessment of O&M phase to assess the potential impact from collision during migration for the sites within 100km of The Project.
10. The standard threshold for migratory birds used is that the species is to be screened in if at least 1% of the UK population is expected to pass through The Project footprint each year. Species can also be screened in if there is evidence of increased risk of collision at the site, for example from site-specific data. This assessment is to identify the potential interaction of migratory species passing The Project array and not species that are in the area for long periods of time. A separate appendix lays out the approach to assessing collision impacts on seabird bird species that regularly use the site (Volume 3, Appendix 12.2: Collision Risk Modelling (Document reference 6.3.12.2)).
11. The screening in process is summarised in the flowchart below (Figure 12.1).

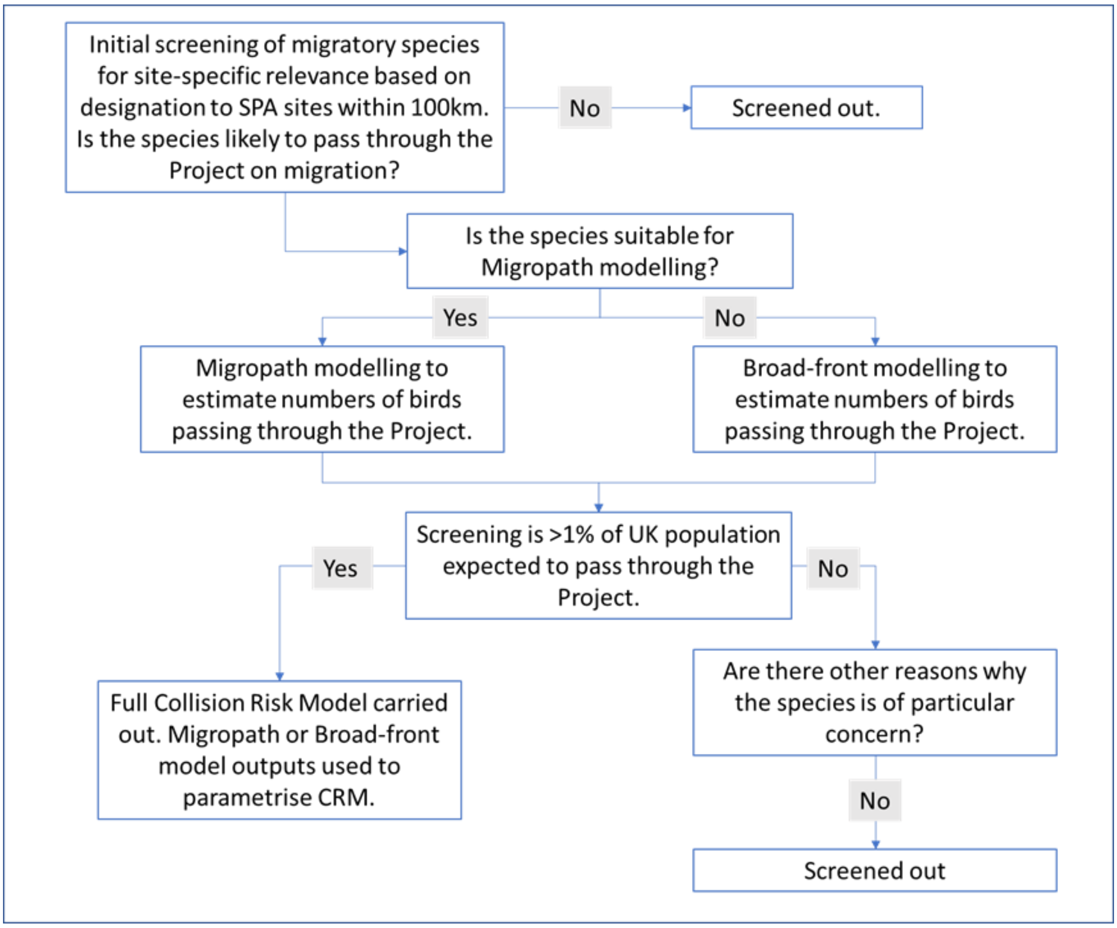

Figure 12.1 Flowchart illustrating the approach to screening for migratory collision risk modelling.

12.3.2 Screening results

12. The initial screening was carried out to consider the migratory species designated to sites within 100km of The Project, as advised by Natural England during the EPP (Volume 1, Chapter 12: Offshore and Intertidal Ornithology, Section 12.3 (document reference 6.1.12)). These are presented in Table 12.1.

13. The migratory species that are suitable for collision risk analysis were included in the assessment and the results are found in 7.3 Collision Risk Results. The species that have <1% proportion of UK population at risk of collision within The Projects were screened out at this stage (Table 12.3).

Table 12.1. SPAs designated for migratory birds relevant to The Project (within 100km).

Designated site	Distance to Array (km)	Features screened in for collision risk
Greater wash SPA	23.4	Little gull, Common tern
Humber Estuary SPA	52.7	Marsh harrier; Redshank; Ruff; Shelduck; Pink-footed goose; Wigeon; Ringed plover; Curlew; Sanderling; Oystercatcher;

Designated site	Distance to Array (km)	Features screened in for collision risk
		Dark-bellied brent goose; Mallard; Pochard; Goldeneye; and Scaup.
North Norfolk Coast SPA	56.3	Sandwich tern, Common tern, Dark-bellied brent goose; marsh harrier; wigeon; bittern; avocet; Pink-footed goose; knot; and Assemblage features.
Gibraltar Point SPA	62.1	Bar-tailed godwit; Grey plover; and Eurasian oystercatcher; Grey plover; knot; Sanderling; curlew; redshank; turnstone; Pink-footed goose; Dark-bellied brent goose; shelduck; pintail; Dunlin; and Bar-tailed godwit
The Wash SPA	65.5	Bar-tailed godwit; Common scoter; Black-tailed godwit; goldeneye; redshank; shelduck; Dark-bellied brent goose; Dunlin; curlew; oystercatcher; wigeon; Gadwall; Grey plover; pintail; Pink-footed goose; knot; turnstone; Sanderling; Bewick's swan; and Assemblage features.

Table 12.2. Species screened in for assessment and modelling approach.

Migropath tool		
Avocet (*Recurvirostra avosetta*)	Bar-tailed Godwit (*Limosa lapponica*)	Bewick's Swan (*Cygnus columbianus*)
Bittern (*Botaurus stellaris*)	Black-tailed Godwit (*Limosa limosa*)	Common Scoter (*Melanitta nigra)*
Curlew (*Numenius arquata*)	Dark-bellied Brent Goose (*Branta bernicla*)	Dunlin (*Calidris alpina*)
Gadwall (*Mareca strepera*)	Golden plover (*Pluvialis apricaria*)	Goldeneye (*Bucephala clangula*)
Grey Plover (*Pluvialis squatarola*)	Hen harrier (*Circus cyaneus*)	Knot (*Calidris canutus*)
Mallard (*Anas platyrhynchos*)	Marsh Harrier (*Circus aeruginosus*)	Oystercatcher (*Haematopus ostralegus*)
Pink-footed Goose (*Anser brachyrhynchus*)	Pintail (*Anas acuta*)	Pochard (*Aythya farina*)
Redshank (*Tringa tetanus*)	Ringed Plover (*Charadrius hiaticula*)	Ruff (*Calidris pugnax*)
Sanderling (*Calidris alba*)	Scaup (*Aythya marila*)	Shelduck (*Tadorna tadorna*)
Turnstone (*Arenaria interpres*)	Wigeon (*Mareca Penelope*)	
'Broad front' modelling		
Common tern (*Sterna hirundo*)	Little gull (*Hydrocoloeus minutus*)	

12.4 Migropath modelling methodology (migratory non-seabirds)

12.4.1 Migropath modelling approach

14. The non-breeding waterbird populations of UK SPAs (UK National Site Network) are regularly surveyed annually by the Wetland Bird Survey (Frost *et al.* 2020). Occasional surveys of non-breeding SPA features have been carried out, for example the inshore 2000/01 and 2001/02 Joint Nature Conservation Committee (JNCC) Winter Seaduck Survey (Dean *et al.* 2003). Each SPA has its original designation figures. There is therefore information on the numbers of birds over-wintering or breeding on these sites. From ringing / tagging data, as well as other literature, there is also information on the likely origin of some or all of these populations, including transboundary migrations (Wernham *et al.* 2002). A general migration route or zone can therefore be defined for a given population of birds (Woodward *et al.,* 2023). Furthermore, data from continental sites (e.g. staging posts, observatories) can be used to further refine the likely fronts, as well as provide information on temporal components of migration (for example, daily passage rate and duration of migration events).
15. It is therefore possible to estimate the numbers of birds associated with one SPA, with a defined group of SPAs, or with a regional suite of SPAs that will encounter one or more windfarms by defining appropriate migratory corridors.
16. The approach is a relatively uncomplicated method to answer a pressing set of questions. To develop more complex models simulating bird movement, additional environmental variables such as weather and photoperiod, and biological factors such as flight speed, energy budget, flocking behaviour and manoeuvrability would need to be considered.

12.4.1.1 Migropath modelling assumptions

17. Migropath was developed alongside BTO's SOSS-05 project (Wright *et al.* 2012) and therefore is limited to the species considered in that project, specifically species that are either designated features of UK SPAs ('SPA species'), or other rare or vulnerable species listed in Annex 1 of the European Union (EU) Birds Directive ('Annex 1 species') that regularly migrate across UK waters. Annex 1 species that only occasionally migrate across UK waters are excluded.
18. Migropath inevitably makes several assumptions. Chief amongst these is the assumption that migration is in a straight line between the SPA of interest and a given point (or defined area) outside the UK. Birds migrating between breeding/wintering grounds outside the UK and UK SPAs that do not pass through The Project array area are not considered to be at collision risk from The Project, based on the assumption of straight-line migration. Such 'no-risk' (no risk from The Project) movements can be factored in to estimated proportions of birds arriving on / departing from SPAs but not encountering The Project array area.
19. Another key assumption is that all migration of a particular species to a particular suite of SPAs can be defined within a set corridor. This corridor should aim to realistically represent the area across which birds must move.
20. Migropath does not consider any macro-avoidance behaviour of birds (i.e. birds may alter their route to avoid the array area). It therefore represents the number of birds expected to pass through The Project array area in the absence of any turbines. This ensures avoidance is not double-counted, as the CRM model includes an avoidance factor.

21. Migropath does not consider flight height, and as a precautionary assumption where the migratory route intersects The Project array area, it is assumed that this leads to a potential for collisions to occur. The proportion of birds at potential collision height is included as an input into the CRM model.

12.4.2 Migropath modelling technical methodology

22. The centroid of each SPA was calculated using the geometry function within ESRI® ArcMapTM 9.2 or QGIS 3.10. The coastlines of continental Europe and Iceland were split into 1km segments, and each segment labelled with a unique ID. Using the ET Geowizard or MMQGIS Hub Lines tool, each segment along the European or Icelandic coast was joined to the centre of each SPA, with each line classified as either passing within or out from The Project array area. Flight pathways connecting the UK to Iceland are referred to as the North route, while flight pathways to continental Europe are referred to as the South route (notwithstanding that continental Europe includes Scandinavia and therefore some flight pathways on the South route have a northerly bearing).
23. A list of SPAs that each of the species is associated with was collated (JNCC, no date; Stroud *et al.* 2001). This information, along with the migratory pathways, was then fed into the statistical software 'R' (R Core Team 2021).
24. Shapefiles produced as part of the SOSS_05 project (Wright *et al.* 2012) were used to determine which parts of the European or Icelandic coastline migrants of each species are expected to use. Where species have known staging sites in Europe, the locations of these were also extracted from the shapefiles.
25. Within R, all possible flight paths for each species determined in the previous step were then considered - i.e. all flight paths between the portion the European or Icelandic coast identified for each species and SPAs associated with each species. The proportion of birds following each individual flight path was allocated randomly across those flight paths. For species which are known to stage or moult in known staging sites, an extra step was carried out to ensure that the proportion of birds departing from the staging area equalled the proportion of the population known to use the staging area. For birds staging in the Wadden sea, this proportion was extracted from Laursen *et al.* (2010).
26. Note that the model is not directional and can be run separately for autumn and spring migrations, allowing these to be parameterised differently if appropriate. For example, the proportion of birds using staging areas may differ between migration periods.
27. For some species, distinct races, sub-species, or populations were modelled separately, where there is evidence that migratory patterns differ between them.
28. The proportion of birds modelled to pass through The Project array area in one year was then calculated. The model re-runs the random allocation of flight paths 200 times in order to estimate the confidence surrounding this result.
29. Where the proportion of birds passing through The Project array area exceeded the threshold of 1% of the UK population, this was then converted to absolute numbers of birds to feed into CRM. Estimates of the flyway and UK populations were obtained from Woodward *et al.* (2023).

12.5 'Broad Front' modelling (Migratory seabirds)

12.5.1 Methodology

30. The 'broad front' method is based on species-specific information on population estimates and migration patterns derived from desk-based studies. The findings are summarised below for common tern and little gull. The methods to calculate the 'broad front' migration follows the stepwise method below:
    - Identify the population of birds undertaking the 'broad front' migration;
    - Identify the width of the 'broad front' based on the migratory pathway or corridor that is being used;
    - Calculate the proportion of the 'broad front' occupied by The Project array area perpendicular to the direction of flight;
    - Where possible, identify if there is any skewed distribution of birds within the 'broad front' such as a preference to fly along the coast; and
    - Calculate the numbers of birds flying across the array area based on the proportion of the 'broad front' occupied by the array area factoring in any skewed migratory distribution.
31. To ensure the estimates are precautionary, the maximum 'broad front' corridor is assumed to extend from the UK coast to the edge of the UK waters boundary. This represents the width intersecting The Project array area perpendicular to birds migrating in a North/South flight pattern and was measured as being 460km. The width of the array area within that corridor is calculated to be 32.9km based on the Maximum Design Scenario (MDS). This is the widest point across The Project array area and when presuming an even distribution of birds migrating within the 'broad front' represents the Worst-Case Scenario (WCS) for collision risk.

12.5.2 Results of Migropath Modelling (Migratory Non-Seabirds)

32. The total number of bird species determined to be required to be screened in for Migropath modelling was 30 (Table 12.3). Other than hen harrier and marsh harrier, these were all waterfowl and waders. The majority were included due to the importance of populations which migrate to the UK for the non-breeding seasons; however, for species which breed in the UK, the breeding population was also included in the model.
33. The mean proportion of the UK population expected to pass through The Project array area and the number of birds this equates to is presented in Table 12.3. As a precautionary assumption, where more than one separate population may be present, the total number of birds passing through The Project array area is assessed against the smallest population.
34. Where the UK population is uncertain, the range of outputs has been presented in Table 12.3. The lowest number of birds was then used for the CRM results presented in Section 12.7.3 to provide a worst-case scenario.
35. Where different populations or seasons were modelled separately in Migropath, all results were included in the CRM to give an annual total across all populations for each species.

Table 12.3. Results from Migropath modelling to estimate the number of birds of each species passing through The Project array area on migration (and the proportion of the migratory population it represents). Species screened out are shown in italics.

Species/ Population	UK Population	Migration Season	Number of birds passing through The Project array area each migration (mean; see Appendix 2)	Percentage (%) of migratory population passing through The Project array area each migration (mean)	Percentage (%) of UK population passing through The Project array area annually (mean)
Avocet (Wintering)	8,700	Spring/Autumn	208	0.21	2.39
Bar-tailed Godwit (Wintering)	53,500	Spring/Autumn	2,759	1.84	5.16
Bewick's Swan (Wintering)	4,317	Spring/Autumn	208	1.03	4.82
Bittern (Wintering)	795	Spring/Autumn	23	0.31	2.85
Black-tailed Godwit (Wintering)	41,000	Spring/Autumn	584	0.41	1.42
Common Scoter (Wintering)	135,000	Spring/Autumn	8,437	1.23	6.25
Curlew (Breeding)	117,000	Spring/Autumn	-	0.00	0.00
Curlew (Wintering)	125,000	Spring/Autumn	5,360	0.88	4.29
Dark-bellied Brent Goose (Wintering)	98,500	Spring/Autumn	1,897	0.90	1.93
Dunlin (Wintering)	350,000	Spring/Autumn	13,453	1.03	3.84
Gadwall (Breeding)	6,400	Spring/Autumn	113	0.08	1.76
Gadwall (Wintering)	31,000	Spring/Autumn	544	0.39	1.76
Golden Plover (Breeding)	101,000	Spring/Autumn	-	0.00	0.00

Species/ Population	UK Population	Migration Season	Number of birds passing through The Project array area each migration (mean; see Appendix 2)	Percentage (%) of migratory population passing through The Project array area each migration (mean)	Percentage (%) of UK population passing through The Project array area annually (mean)
Golden Plover (Wintering)	410,000	Spring/Autumn	23,286	0.97	5.68
Goldeneye (Wintering)	21,000	Spring/Autumn	944	0.13	4.50
Hen harrier (Wintering)	1,090	Spring/Autumn	38	0.13	3.48
Knot (Wintering)	265,000	Spring/Autumn	12,522	4.04	4.73
Mallard (Wintering)	675,000	Spring/Autumn	39,575	0.88	5.86
Marsh Harrier (Wintering)	1,390	Spring/Autumn	-	0.00	0.00
Oystercatcher (Wintering)	305,000	Spring/Autumn	12,259	1.63	4.02
Pink-footed Goose (Wintering)	510,000	Spring/Autumn	22,426	4.49	4.40
Pintail (Wintering)	20,000	Spring/Autumn	872	1.18	4.36
Pochard (Wintering)	29,000	Spring/Autumn	1,013	0.68	3.49
Redshank britannica (Breeding)	44,000	Spring/Autumn	772	1.17	1.75
Redshank robustica (Wintering)	100,000	Spring/Autumn	2,370	1.03	2.37
Redshank totanus (Wintering)	100,000	Spring/Autumn	2,377	1.49	2.38
Ringed Plover (Breeding)	11,200	Spring/Autumn	68	0.14	0.61
Ringed Plover (Passage)	42,500	Spring/Autumn	1,923	0.80	4.53
Ruff (Wintering)	920	Spring/Autumn	32	0.00	3.47

Species/ Population	UK Population	Migration Season	Number of birds passing through The Project array area each migration (mean; see Appendix 2)	Percentage (%) of migratory population passing through The Project array area each migration (mean)	Percentage (%) of UK population passing through The Project array area annually (mean)
Sanderling (Wintering)	20,500	Spring/Autumn	946	0.47	4.62
Scaup (Wintering)	6,400	Spring/Autumn	311	0.13	4.86
Shelduck (Wintering)	51,000	Spring/Autumn	2,131	0.69	4.18
Wigeon (Wintering)	450,000	Spring/Autumn	18,468	1.42	4.10

12.6 Results of ‘Broad Front’ Modelling (Migratory Seabirds)

12.6.1 Species Screened In

36. Two bird species were screened in for ‘broad front’ modelling due to their presence in the array being isolated to peak migratory months: common tern and little gull (Table 12.2). To determine the number of migratory seabirds that are considered within the ‘broad front’ modelling process, a full literature review was undertaken for each species. The summaries below were used for the basis of how these populations are apportioned for the CRM.

12.6.1.1 Common tern

37. The common tern has a circumpolar distribution and can be found breeding in most of Europe, Asia and North America except the extreme north and south with a total population at least 250,000 pairs, possibly 500,000 pairs, consisting of 140,000 pairs in Europe, approximately 35,000 pairs in North America and several 100,000's pairs in the former Union of Soviet Socialist Republics (USSR) (del Hoyo *et al.*, 1992-2013). Birds that breed in the British Isles, Netherlands, Belgium, France, Spain, Switzerland, Austria, and western Germany winter principally along the West African coast (BirdGuides, 2011) and those from eastern Europe along the east and southern African coast. Birds from eastern Europe take an easterly route through northeast Africa and then along the coast or overland through the Rift Valley to their wintering grounds (del Hoyo *et al.*, 1992-2013).
38. Between 30-70% of the summer resident terns use the English Channel to leave the North Sea (Stienen *et al.*, 2007). Post-fledging dispersal of juveniles occurs between July and October, with adults migrating mainly between August and October. This coincides with the peak months within DAS. Much of the movement of these coastal birds within Britain may be overland (Ward, 2000; Wernham *et al.*, 2012). During September, and especially October, there is a strong southward movement of common terns along the coast of southwest Europe and away from Britain and Ireland, migration follows the coasts (Wernham *et al.*, 2012). Many UK breeding birds are back at their breeding areas by April. The lack of records at west coast observatories implies that there is little movement through the Irish Sea to the Scottish colonies, and the frequency of inland sightings suggests that much of the spring passage takes place directly overland to the breeding sites. In fact, the only British observatories to record substantial numbers in spring are Dungeness and Portland Bill. At both sites, spring passage peaks in late April and early May and is mainly eastward, suggesting that these birds are most likely to be on their way to breeding areas elsewhere in northern Europe (Wernham *et al.*, 2012).
39. Another assessment of common tern migration undertaken by WWT and MacArthur Green (2013) concluded that the majority of UK common terns migrate within 10km of the UK coastline based on observations from coastal watches and offshore surveys.

40. The Biologically Defined Minimum Population Scale (BDMPS) for common terns is defined by Furness (2015) as 144,911 for both the spring and autumn migration seasons (April to May and late July to early September). Understanding of common tern movements is relatively poor, especially with regards to overseas populations due to limited ring recoveries in the UK and no studies conducted using geolocators.
41. During the 30 months of site-specific DAS conducted for The Project (Detailed Volume 2, Appendix 12.1: Ornithology Technical Baseline), common tern was recorded in 16 surveys. In general, common tern had low abundance, however there was peak abundance of 1,655 birds within The Project array area in September 2021. Given the season and low counts in all other months it was agreed with Natural England that these birds are likely to be migrating though in a pulse and should be assessed as migratory birds (Volume 1, Chapter 12: Offshore and Intertidal Ornithology, Section 12.3 (document reference 6.1.12)).

12.6.1.2 Little Gull

42. Little gulls are primarily passage migrants to Britain and Ireland, occurring in both spring and autumn (Stone *et al.*, 1995). The numbers of little gulls on passage through Britain and Ireland, and passing Helgoland Bight, have increased dramatically since the 1970's. This increase matches a documented westward expansion in breeding range that has taken place over a similar time period. This range expansion also resulted in a pair breeding in Scotland in 2016 (Birdguides 2016), which represented the first successful breeding attempt in the UK for little gull. There has also been a recent northerly extension to the wintering range (Hagemeijer and Blair 1997). Passage during migration is usually rapid and judging from observations at sea, most gulls remain closely inshore (Skov *et al.*, 1995). The little gull is listed in Stienen *et al.*, (2007) as an inshore species that is most abundant within 20km from the shoreline.
43. The great majority (40-100%) of the flyway population of little gull use the English Channel to leave the North Sea (Stienen *et al.*, 2007). Movements of little gulls out of the North Sea take place in October, with birds moving to wintering areas in the western Mediterranean, with seemingly smaller numbers in the Irish Sea, the English Channel and off northwest Africa. Relatively large numbers cross the North Sea in autumn, and internationally important numbers occur near the river Tees (Skov *et al.*, 1995). Within the Irish Sea, the largest numbers are associated with the County Wicklow coast, with numbers reported to be steadily increasing matching the recent Northernly extension to the wintering range (Wernham *et al.*, 2012). As numbers reported from Wicklow fall off in early spring, an increase in the numbers reported on passage overland across the North of England to reach the North Sea during April and May is noted (Messenger, 1993).

44. The number of little gulls that migrate via the North Sea has not been assessed by Furness (2015) or Musgrove *et al.*, (2013); the standard sources used for population estimates. A population estimate for little gull using the UK waters of the North Sea has been prepared from a review of the literature and available databases relating to north-west Europe. This has considered both breeding populations from which the number of non-breeding individuals can be derived, and non-breeding individuals recorded using particular sites, or on migration along the coast. The findings of the literature review proposed an estimate of the autumn migration BDMPS for use in assessments of Offshore Windfarms (OWFs) occurring in English waters of the North Sea as 30,500 individuals.
45. Another assessment of little gull migration undertaken by WWT and MacArthur Green (2013) concluded that the majority of UK little gull migrate within 20km from the UK coastline based on observations from coastal watches and offshore surveys.
46. During the 30 months of site-specific DAS conducted for The Project (Detailed in Volume 2, Appendix 12.1: Ornithology Technical Baseline (Document reference: 6.2.12.1)), little gull was recorded in 12 surveys within The Project array area, with peak abundance estimates of 191 and 167 in October 2021 and September 2022, respectively. Peak abundance estimates outside of those months was 19. Similarly, to common tern, given that peak counts fell in the migratory season and were considerably higher than all other months it was agreed with Natural England that these birds are likely to be migrating though in a pulse and should be assessed as migratory birds (Volume 1, Chapter 12: Offshore and Intertidal Ornithology, Section 12.3 (document reference 6.1.12)).

12.6.2 Summary of 'Broad Front' Modelling Assumptions

47. The Project array area is located 54km offshore at its nearest point, which is further offshore than the migration corridors summarised above (10km and 20km offshore). Following the same methodology for apportioning migratory seabirds used by Norfolk Boreas (2019) in their final DCO application submissions, it can be concluded that none of the UK population of migratory seabirds are at risk of collision from The Project due to evidence supporting their migratory flights being closer to the coast. Therefore, in relation to the assessment of collision risk to migratory seabirds, only the overseas populations presented in Furness (2015) have been included in this assessment unless otherwise stated. The proportion the regional population intersecting the array was calculated by dividing the array width (32.9km) by the migration corridor width (460km). Overseas populations, proportion of array intersections, and the predicted number of flight paths through the array are presented in Table 12.4.

Table 12.4. Overseas population counts, and proportion of array intersection values, used within 'Broad Front' modelling approach.

Species	Overseas population (Furness, 2015)	Proportion of array intersections	Individuals migrating through the array area
Common tern	125,969	0.07	9,010

Species	Overseas population (Furness, 2015)	Proportion of array intersections	Individuals migrating through the array area
Little gull	30,500[1]	0.07	2,181

48. An estimate of the number of individuals predicted to be migrating through The Project array area for all seabird species based on an even distribution within the 'broad front' corridor are presented in Table 12.5.[1]

Table 12.5. Estimated number of non-UK migratory seabirds predicted to pass through The Project array area in migration periods.

Species	Pre-breeding migration	Post-breeding migration
Common tern	9,010	9,010
Little gull	2,181	2,181

12.7 Collision Risk Modelling (CRM) for Migratory Birds

12.7.1 Collision Risk Modelling Methodology

49. There is potential risk to migratory birds from OWFs through collision with wind turbines and associated infrastructure. The risk to migratory birds can occur when passing through the area on seasonal migrations. The potential collision risk can be estimated using CRM.

50. CRM was carried out using the Band (2012) model. The Band (2012) model is still the only model that is supported by Natural England to estimate collision risk for migratory species (Parker *et al.,* 2022c). However, for comparison an additional analysis can be found in Appendix 1 using the latest version of the Marine Scotland Science Stochastic Collision Risk Model Shiny Application ("mCRM App"; Donovan, 2018). The mCRM App is still a Beta version but it is anticipated that Natural England may choose to support this tool once it is fully tested.

12.7.2 CRM Input Parameters

51. The CRM input parameters for each species run through the Band (2012) model are presented in Table 12.6. Species biometrics for all species were obtained from the Marine Science Scotland Stochastic Collision Risk Model Shiny Application ("mCRM App"; Donovan, 2018). The mCRM tool collates biometric information from multiple sources including Robinson (2005).

52. The Large Array Correction factor was applied, using the longest line through the array area as the width (32.9km).

53. The "width of migration corridor" value used within the Band model for calculating migrant flux density was also calculated as the width of The Project array area (32.9km).

[1] Used overseas population value presented in Horsea Project Four: Environmental Statement (ES) (2021), Volume A5, Annex 5.5: Offshore Ornithology Migratory Birds Report.

Table 12.6. Species biometrics used in the migratory collision risk modelling of the proposed Project for all species selected.

Species	Body Length (m)	Wingspan (m)	Flight Speed (ms-1)	Nocturnal Activity	Flight Type
Avocet	0.44 (0.01)	0.78 (0.01)	13.0 (2.5)	5[2]	Flapping
Bar-tailed Godwit	0.38 (0.02)	0.75 (0.02)	18.3 (2.1)	5	Flapping
Bewick's Swan	1.21 (0.04)	1.96 (0.04)	24.0 (7.6)	5	Flapping
Bittern	0.75 (0.02)	1.30 (0.02)	8.8 (2.0)	5[3]	Flapping
Black-tailed Godwit	0.42 (0.02)	0.76 (0.02)	18.1 (6.0)	5	Flapping
Common Scoter	0.49 (0.03)	0.84 (0.03)	22.1 (4.0)	3	Flapping
Curlew	0.55 (0.02)	0.90 (0.02)	15.4 (3.3)	5	Flapping
Dark-bellied Brent Goose	0.58 (0.02)	1.15 (0.02)	17.9 (6.1)	5	Flapping
Dunlin	0.18 (0.01)	0.40 (0.01)	15.3 (1.9)	5	Flapping
Gadwall	0.51 (0.02)	0.90 (0.02)	19.6 (2.0)		Flapping
Goldeneye	0.46 (0.01)	0.72 (0.01)	20.3 (3.8)	3	Flapping
Golden Plover	0.28 (0.01)	0.72 (0.01)	16.5 (1.8)	5	Flapping
Hen Harrier	0.48 (0.02)	1.10 (0.02)	11.4 (1.1)	2	Flapping
Knot	0.24 (0.01)	0.59 (0.01)	24.6 (3.3)	5	Flapping
Mallard	0.58 (0.02)	0.90 (0.02)	15.9 (2.0)	5[4]	Flapping
Marsh Harrier	0.53 (0.02)	1.22 (0.02)	13.2 (2.9)	2[5]	Flapping
Oystercatcher	0.42 (0.02)	0.83 (0.02)	13.0 (2.5)	5	Flapping
Pink-footed Goose	0.68 (0.06)	1.52 (0.06)	16.9 (0.2)	5	Flapping
Pintail	0.58 (0.02)	0.88 (0.02)	21.9 (2.0)	5[6]	Flapping
Pochard	0.46 (0.01)	0.77 (0.01)	23.6 (2.0)	5[7]	Flapping
Redshank	0.28 (0.01)	0.62 (0.01)	15.3 (4.1)	5	Flapping
Ringed Plover	0.19 (0.01)	0.52 (0.01)	16.0 (1.1)	5	Flapping
Ruff	0.25 (0.01)	0.53 (0.01)	16.9 (1.8)	5	Flapping
Sanderling	0.20 (0.01)	0.42 (0.01)	21.4 (1.1)	5	Flapping
Scaup	0.46 (0.01)	0.78 (0.01)	21.1 (2.0)	5	Flapping
Shelduck	0.62 (0.02)	1.12 (0.02)	18.2 (4.3)	5	Flapping
Wigeon	0.48 (0.02)	0.80 (0.02)	18.5 (2.0)	5	Flapping

[2] Used Hötker, H. (2019). What determines the time-activity budgets of Avocets (*Recurvirostra avosetta*)?. Bulletin of Experimental Biology & Medicine, 166(6).

[3] Used Korner, P., Sauter, A., Fiedler, W., & Jenni, L. (2016). Variable allocation of activity to daylight and night in the mallard. Animal Behaviour, 115, 69-79.

[4] Used Korner, P., Sauter, A., Fiedler, W., & Jenni, L. (2016). Variable allocation of activity to daylight and night in the mallard. Animal Behaviour, 115, 69-79.

[5] Used *Circus cyaneus* value.

[6] Used *Tadorna tadorna* value.

[7] Used *Aythya marila* value.

Species	Body Length (m)	Wingspan (m)	Flight Speed (ms-1)	Nocturnal Activity	Flight Type
Common Tern	0.33	0.88	10.1	1	Flapping
Little Gull	0.26	0.78	11.5	2	Flapping

12.7.2.1 Avoidance Rates

54. A bird's ability to avoid colliding with a wind turbine's rotating blades is a critical factor in predicting mortality rates. This ability will vary between species and is a measure of how sensitive each species is to those turbines and the windfarm in its entirety.
55. CRM following the standard Band model (Band, 2012) was carried out using the following range of avoidance rates, 95%, 98%, 99%, and 99.5% for all species. For species where no specific avoidance rate has been calculated, Cook *et al.* (2014) recommend using an avoidance rate of 98% for evaluation of collision risk. For little gull, an additional avoidance rate of 99.2% has been selected as recommended by Cook *et al.* (2014).

12.7.2.2 Proportion at Potential Collision Height

56. Band Option 1 (BO1) and / or Band Option 2 (BO2) have been used to carry out all of the CRM. BO1 uses a fixed proportion at Potential Collision Height (PCH). For all species considered in this report, the proportions of birds at PCH from literature sources have been used as the sample sizes from site-based survey data were too low for reliable estimates (Table 12.7). For BO1, for little gull and common tern, proportion at PCH values were taken from Cook *et al.* (2012), which assessed the flight height data from 32 OWFs. For the remaining species, the generic species group values put forward by the migratory CRM Tool, utilising BTO 2021 data, were selected in the absence of any species-specific proportion at PCH data. BO2 uses flight height distribution data and turbine parameters (air gap and rotor radius) to calculate the proportion of birds at PCH. BO2 is therefore reliant on availability of flight height distribution data. For little gull and common tern, BO2 CRM was run using the maximum likelihood values in the Johnson *et al.* (2014) flight height spreadsheets, which supplemented the SOSS-02 project (Cook *et al.* 2012).

Table 12.7. Proportion at Potential Collision Height (PCH) for all migratory species used for BO1 CRM.

Species	Proportion at PCH (%)
Avocet	100.0
Bar-tailed Godwit	100.0
Bewick's Swan	50.0
Bittern	100.0
Black-tailed Godwit	100.0
Common Scoter	100.0
Curlew	100.0
Dark-bellied Brent Goose	50.0
Dunlin	100.0

Species	Proportion at PCH (%)
Gadwall	100.0
Goldeneye	100.0
Golden Plover	100.0
Hen Harrier	100.0
Knot	100.0
Mallard	100.0
Marsh Harrier	50.0
Oystercatcher	100.0
Pink-footed Goose	50.0
Pintail	100.0
Pochard	100.0
Redshank	100.0
Ringed Plover	100.0
Ruff	100.0
Sanderling	100.0
Scaup	100.0
Shelduck	50.0
Wigeon	50.0
Common Tern	12.7
Little Gull	5.5

12.7.2.3 Turbine Parameters

57. The input parameters for the wind turbine specifications used within in the CRM are presented in Table 12.8 and Table 12.9. These values are based on the MDS WTGs, as described in Volume 1, Chapter 3: Project Description (document reference 6.1.3). A 'Large Array Correction' factor was applied in all cases.

Table 12.8. Windfarm and turbine parameters used for migratory CRM.

Parameter	Value
No. WTGs	100
Windfarm width (km)	32.9
Latitude (deg)	53.6
Proportion of upwind flight	50
Rotor radius (m)	118
No. Blades	3
Blade Width	6.0
Rotation Speed (RPM)	8.11
Blade Pitch	6.5
No. WTGs	100
Windfarm width (km)	32.9

Table 12.9. Wind availability, time operational and downtime windfarm parameters.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind availability (%)	92.1	91.1	90.7	87.7	86.7	83.1	83.6	84.7	87.7	91.4	92.8	91.7
Time operational (%)	89.3	88.4	88	85.1	84.1	80.6	81.1	82.2	85.1	88.7	90.0	88.9
Mean downtime (%)	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.6	2.7	2.8	2.8
Mean downtime Standard Deviation (SD)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

12.7.3 CRM Results

59. Species for which less than 1% of the UK population are expected to pass through The Project array area were screened out, and the Band (2012) CRM was run for remaining species. The species screened out were curlew (breeding), golden plover (breeding), marsh harrier and ringed plover (breeding). The annual total number of collisions for each species, using the most appropriate avoidance rates for each species and based on the mean population size and mean results from Migropath and 'broad front' modelling, are presented in Table 12.10. Results are presented using both Band Option 1 (BO1) and Band Option 2 (BO2), where possible.

Table 12.10. Summary of annual collision risk for species screened-in.

Species	Avoidance Rate (%)	Annual Collision Rate BO1	Annual Collision Rate BO2
Avocet	98.0	0.18	NA
Bar-tailed Godwit	98.0	2.15	NA
Bewick's Swan	98.0	0.11	NA
Bittern	98.0	0.03	NA
Black-tailed Godwit	98.0	0.46	NA
Common Scoter	98.0	6.59	NA
Curlew (Wintering)	98.0	4.73	NA
Dark-bellied Brent Goose	98.0	0.85	NA
Dunlin	98.0	9.32	NA
Gadwall (Breeding)	98.0	0.08	NA
Gadwall (Wintering)	98.0	0.40	NA
Goldeneye	98.0	0.76	NA
Golden Plover	98.0	17.49	NA
Hen Harrier	98.0	0.04	NA
Knot	98.0	8.72	NA
Mallard	98.0	53.76	NA
Oystercatcher	98.0	10.79	NA
Pink-footed Goose	98.0	10.83	NA
Pintail	98.0	0.73	NA
Pochard	98.0	0.79	NA
Redshank britannica	98.0	0.58	NA
Redshank robustica	98.0	1.77	NA
Redshank totanus	98.0	1.77	NA
Ringed Plover (Wintering)	98.0	1.36	NA
Ruff	98.0	0.02	NA
Sanderling	98.0	0.64	NA
Scaup	98.0	0.25	NA
Shelduck	98.0	1.42	NA
Wigeon	98.0	15.28	NA
Common Tern	98.0	0.97	0.04

Species	Avoidance Rate (%)	Annual Collision Rate BO1	Annual Collision Rate BO2
Little Gull	98.0	0.09	0.01

References

Alerstam T, Rosen M, Backman J, Ericson PGP, Hellgren O. (2007). Flight speeds among bird species: Allometric and phylogenetic effects. PLoS Biol 5(8): e197. doi:10.1371/journal.pbio.0050197

Alerstam, T. (1990), 'Bird Migration', Cambridge: Cambridge University Press

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.

BirdGuides (2011), 'BWPi: Birds of the Western Palearctic interactive (version 2.0)', BirdGuides Ltd.,Norfolk.

Birdguides (2016), https://www.birdguides.com/news/little-gulls-breeding-in-scotland-for-first-time/

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.

Del Hoyo, J., Elliott, A. and Sargatal, J. (1992-2013), 'Handbook of the Birds of the World Volumes 1-16. Lynx Edicions', Barcelona, Spain.

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

Furness, R.W. (2015), 'Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS)', Natural England Commissioned Reports, Number 164.

Hagemeijer, W. J. M. and Blair, M. J. (eds) (1997), 'The EBCC Atlas of European Breeding Birds', T. & A.D. Poyser.

Horsea 4 (2021). Horsea Project Four: Environmental Statement (ES), Volume A5, Annex 5.5: Offshore Ornithology Migratory Birds Report. Report for Orsted.

MacArthur Green, APEM and Royal Haskoning DHV (2015), 'Appendix 13.1 Offshore Ornithology Evidence Plan', Document Reference 6.3.13 (1).

Messenger, D. (1993), 'Spring passage of Little Gulls across Northern England,' British Birds, 86(9).

Musgrove, A., Aebischer, N., Eaton, M., Hearn, R., Newson, S., Noble, D., Parsons, M., Risely, K. and Stroud, D. (2013), 'Population estimates of birds in Great Britain and the United Kingdom', British Birds 106: 64-100.

Norfolk Boreas. (2019). Volume 1 Environmental Statement Chapter 13 Offshore Ornithology. Norfolk Boreas Offshore Wind Farm.

Ozsanlav-Harris, L, Inger, R & Sherley R. (in prep). Review of data used to calculate avoidance rates for collision risk modelling of seabirds. JNCC Report No. X (Research & review report), JNCC, Peterborough, ISSN 0963-8091.

Parker, J., Fawcett, A., Banks, A., Rowson, T., Allen, S., Rowell, H., Harwood, A., Ludgate, C., Humphrey, O., Axelsson, M., Baker, A. & Copley, V. (2022c). Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Phase III: Expectations for data analysis and presentation at examination for offshore wind applications. Natural England. Version 1.2. 140 pp.

Pennycuick, C.J. (1997). Actual and optimum flight speeds: field data reassessed. The Journal of Experimental Biology 200, 2355–2361

R Core Team (2021), 'R: A language and environment for statistical computing', R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Skov, Henrik and Durinck, Jan and Leopold, Mardik and Tasker, M.L.. (1995), 'Important Bird Areas for seabirds in the North Sea', BirdLife International.

Stienen, Eric., van Waeyenberge, Jeroen., Kuijken, Eckhart., Seys, J. (2007), 'Trapped within the corridor of the southern North Sea: the potential impact of offshore wind farms on seabirds,' in de Lucas, M., Janss, G. F. E., and Ferrer, M. (eds). Birds and wind farms: Risk assessment and mitigation. Madrid: Quercus/Libreria Linneo, pp. 71–80.

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J. & Pienkowski, M.W. (1995), 'An atlas of seabird distribution in north-west European waters', Peterborough: JNCC.

Ward, R. M. (2000), 'Migration patterns and moult of Common Terns Sterna hirundo and Sandwich Terns Sterna sandvicensis using Teesmouth in late summer,' Ringing & Migration, 20(1), pp. 19–28.doi: 10.1080/03078698.2000.9674223

Wernham, C.V., Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. and Baillie, S.R. (eds) (2002), 'The migration atlas: movements of the birds of Britain and Ireland', London: T. & A.D. Poyser.

Woodward, I.D., Franks, S.E., Bowgen, K., Davies, J.G., Green, R.M.W., Griffin, L.R., Mitchell, C., O'Hanlon, N., Pollock, C., Rees, E.C., Tremlett, C., Wright, L. & Cook, A.S.C.P. (2023). Strategic study of collision risk for birds on migration and further development of the stochastic collision risk modelling tool (Work Package 1: Strategic review of birds on migration in Scottish waters). Link to publication ISBN: 978-1-83521-034-5

WWT & MacArthur Green. (2013). Strategic Assessment of collision risk of Scottish offshore wind farms to migrating birds. Report for Marine Scotland.

Appendix 1: Migratory Collision Risk Modelling for Migratory Birds

12.8 Migratory Collision Risk Modelling Methodology

60. For completeness The Project has also undertaken collision risk modelling using the Marine Scotland Science Stochastic Collision Risk Model Shiny Application ("mCRM App"; Donovan, 2018). Considering this tool is not currently supported by Natural England the results are only for comparison with the Band 2012 model, and no further analysis has been undertaken on the results.
61. The mCRM tool is a stochastic adaptation of the Band (2012) offshore migratory CRM. The mCRM was accessed via the 'Shiny App' interface, which is a user-friendly graphical interface accessible via a standard web-browser or within R statistical software (R Core Team, 2021) that uses an R code to estimate migratory collision risk (Donovan 2018). For this assessment the latest version of the model was downloaded and run locally within R (v0.4.1). The advantage of the mCRM over the Band (2012) model is that it provides a clear and transparent audit trail for all modelling runs, which enables regulators to easily access and reproduce the results of any modelling scenario.
62. The mCRM tool provides two functions:
    - Creates population estimates in windfarms by sampling migratory pathways via straight lines drawn between UK and non-UK countries; and
    - Runs a stochastic version of the migratory collision risk model based on the population estimates and use-input parameters.

12.9 CRM Input Parameters

12.9.1 WTG Parameters

63. The OWF and turbine parameters used in the mCRM are presented in Table 0-1 and Table 0-2. These values are based on the MDS WTGs, as described in XXX (Project background). A 'Large Array Correction' factor was applied to the mCRM.

Table 0-1. Windfarm and turbine parameters used for mCRM.

Parameter	Value
No. WTGs	100
Windfarm width (km)	32.9
Latitude (deg)	53.6
Proportion of upwind flight	50
Rotor radius (m)	118
No. Blades	3
Blade Width	6.0
Rotation Speed (RPM)	8.11
Rotation Speed SD	0.40
Blade Pitch	6.5
Blade Pitch SD	1.75

Table 0-2. Wind availability and downtime windfarm parameters.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind availability (%)	92.1	91.1	90.7	87.7	86.7	83.1	83.6	84.7	87.7	91.4	92.8	91.7
Mean downtime (%)	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.6	2.7	2.8	2.8
Mean downtime SD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

12.10 mCRM Results

64. The results from the mCRM analysis are presented within the sections, with a summary of the results for each species presented in Table 0-3. This shows the number of predicted mortalities of migratory species during the O&M phase of The Project based on the pre- and post-breeding migrations (Table 0-3). The results using the mCRM tool generally provided considerably lower estimates than the Migropath equivalent.

Table 0-3. Summary of pre-breeding and post-breeding mCRM results (mortality of birds).

Species	Pre-breeding	Post-breeding	Other total	Total
Avocet	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Bar-tailed Godwit	0.235 ± 0.041	0.229 ± 0.04	0 ± 0	0.464 ± 0.057
Bewick's Swan	0.041 ± 0.018	0.041 ± 0.019	0 ± 0	0.082 ± 0.026
Bittern	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Black-tailed Godwit	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Common Scoter	0.787 ± 0.151	0.777 ± 0.149	0 ± 0	1.564 ± 0.212
Curlew	0.073 ± 0.013	0.072 ± 0.012	0 ± 0	0.145 ± 0.018
Dark-bellied Brent Goose	0.02 ± 0.008	0.021 ± 0.008	0 ± 0	0.041 ± 0.011
Dunlin	0.672 ± 0.106	0.655 ± 0.103	0 ± 0	1.327 ± 0.148
Gadwall	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Golden Plover	0.924 ± 0.172	0.901 ± 0.168	0 ± 0	1.825 ± 0.24
Goldeneye	0.308 ± 0.046	0.31 ± 0.047	0 ± 0	0.618 ± 0.066
Hen Harrier	0.006 ± 0.001	0.006 ± 0.001	0 ± 0	0.012 ± 0.001
Knot	0.119 ± 0.017	0.115 ± 0.016	0 ± 0	0.234 ± 0.023
Mallard	5.682 ± 1.033	5.928 ± 1.077	6.044 ± 1.098	17.654 ± 1.853
Marsh Harrier	0.004 ± 0.001	0.004 ± 0.001	0 ± 0	0.008 ± 0.001
Oystercatcher	0.183 ± 0.031	0.176 ± 0.03	0 ± 0	0.359 ± 0.043
Pink-footed Goose	0 ± 0.001	0 ± 0.001	0 ± 0	0 ± 0.001
Pintail	0.128 ± 0.023	0.129 ± 0.023	0 ± 0	0.257 ± 0.033
Pochard	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Redshank	0.158 ± 0.029	0.153 ± 0.028	0 ± 0	0.311 ± 0.04

Species	Pre-breeding	Post-breeding	Other total	Total
Ringed Plover	0.06 ± 0.012	0.059 ± 0.012	0 ± 0	0.119 ± 0.017
Ruff	0.011 ± 0.002	0.011 ± 0.002	0 ± 0	0.022 ± 0.003
Sanderling	0.056 ± 0.009	0.057 ± 0.009	0 ± 0	0.113 ± 0.013
Scaup	0.047 ± 0.008	0.048 ± 0.008	0 ± 0	0.095 ± 0.011
Shelduck	0.225 ± 0.04	0.205 ± 0.037	0.22 ± 0.04	0.65 ± 0.068
Wigeon	2.937 ± 0.479	2.935 ± 0.479	0 ± 0	5.872 ± 0.677

Appendix 2

All model inputs and outputs, including 95% CIs, are available on request from the Applicant.