TECHNICAL APPENDIX 5.1: ORNITHOLOGY REPORT

List of Tables

1. INTRODUCTION

This technical appendix presents the results of baseline ornithology studies used to inform the assessment of potential impacts on bird populations arising from the proposed varied development. The report includes a summary of the studies undertaken up to 2009 which were used to inform the ornithology assessment of the consented Viking Wind Farm presented in 2010 ES Addendum. The report also summarises the results of ornithology studies undertaken since 2010 that are relevant to the assessment of the proposed varied development. The more recent studies were conducted to better understand the potential effects of the proposed varied development on whimbrel, to collect information needed to develop the Habitat Management Plan that has been further developed for the consented Viking Wind Farm (Habitat Management Plan RPS, 2016) ("HMP") and to update data sets on the distribution and abundance of breeding bird species. The 2017 and 2018 surveys were undertaken by Atlantic Ecology and the 2003 to 20016 surveys were undertaken by Natural Research (Projects) Ltd (NRP). This technical appendix was prepared by Atlantic Ecology.

The appendix aims to present baseline information required for the assessment of the proposed development. Nevertheless, in the interests of brevity it does not repeat all the information that supported the Ornithology Chapter of the 2010 ES Addendum (2010 ES Addendum: Appendices A11.1 to A11.4) nor aspects of the more recent studies that are not directly relevant to the assessment of the proposed development. The Applicant was granted consent for a 103 turbine wind farm in April 2012. The consented Viking Wind Farm is smaller than the proposed development for which the assessment reported upon in the 2010 ES Addendum had been carried out, as a consequence of the Scottish Ministers deciding not to grant consent for all 24 turbines in the Delting Quadrant. The survey results presented in this report are limited to the areas relevant to the 103 turbine layout, i.e. the Kergord and Nesting Quadrants.

The footprint of the proposed varied development lies entirely within the footprint of the consented Viking Wind Farm and which has been previously consulted on and subject to EIA in the 2010 ES Addendum. The red line boundary shown on Figure 5.1 is the revised Section 36C Variation Application Site Boundary (hereinafter referred to as "the site application boundary", and the area within the site application boundary is referred to as "the revised site area".

The proposed varied development concerns only a change in the proposed diameter and operating height of the wind turbines: the number of turbines (103), their location and the location and specifications supporting infrastructure remain unchanged from the consented Viking Wind Farm. The proposed varied development is expected to result in no material changes to the potential proposed wind farm to affect bird populations during the construction stage, and thus the 2010 ES Addendum assessment for the Kergord and Nesting areas for the construction stage remain relevant. The proposed varied development is however expected to result in changes to the potential proposedwind farm to affect bird populations during the operational stage, brought about by the larger size of the proposed turbines leading to potential for increases in collision risk and displacement. Assessment of these two potential effects has been identified as the key elements of the ornithology assessment of the proposed varied development (Viking Energy, 2018). Since the 2010 Addendum, SNH have started procedures to designate a new Special Protection Area (the East Coast Mainland, Shetland pSPA) parts of which are in close proximity to the proposed wind farm and so requires consideration in the assessment of the proposed project. Since the 2010 Addendum there have also been a number of new wind farm developments in Shetland that need to be taken into account through cumulative impact assessment.

Upland peatlands cover the bulk of the site. Most areas are covered in deep peat as a result of thousands of years of peat accumulation and support a varied mix of heather moorland and blanket bog habitats. These habitats support a diverse breeding assemblage of moorland birds including merlin, red grouse, eight species of wader, arctic and great skua, meadow pipit, skylark and (on the peatland lochs) red-throated diver.

2. HISTORY OF STUDIES

An extensive programme of field studies has been undertaken between 2003 and 2018 to quantify the distribution, abundance and flight activity metrics of birds breeding in the vicinity of the site. The studies relevant to the assessment of the proposed varied development are as follows:

- Moorland Bird Surveys (MBS) undertaken 2005-2008 to quantify the distribution and abundance of moorland species (e.g. waders, skuas, gulls, wildfowl and passerine species) over the original section 36 area to provide baseline data for the ornithological sensitivity mapping (used to inform the design of the consented Viking Wind Farm), the 2009 ES and the 2010 ES Addendum. Results of these MBS surveys are presented in full in the Appendix A11.1 of the 2010 ES Addendum; the results relevant to the assessment of the proposed varied development are presented in Tables 5.1.1 and 5.1.2.
- MBS surveys to quantify the distribution, abundance of waders, gulls, wildfowl and passerine species to inform the development of HMP and to monitor whimbrel population trends. Undertaken at selected sites (including some parts of the revised site area) every year between 2010 and 2017. Results of these MBS surveys relevant to the assessment of the Variation are presented in Tables 5.1.1 and 5.1.2.
- MBS surveys to inform the assessment of the proposed varied development undertaken 2018 and covering approx. 75% of revised site area; the remaining areas were all covered between 2014 and 2017). Results of these MBS surveys are presented in Tables 5.1.1 and 5.1.2.
- Surveys of red-throated diver to determine the number of breeding pairs, breeding success and the location of breeding lochs and lochans in the vicinity of the site. Conducted annually from 2003 to 2018 (except 2015). Results of these diver surveys up to 2009 are presented in full in the Appendix A11.1 of the 2010 ES Addendum; the results relevant to the assessment of the proposed varied development are presented in Tables 5.1.3 and 5.1.4.
- Surveys of merlin across Central Mainland to determine the number of breeding pairs, breeding success and the location of breeding sites. Conducted annually 2005 to 2018. Results of these merlin surveys up to 2009 are presented in full in the Appendix A11.1 of the 2010 ES Addendum; the results relevant to the assessment of the proposed varied development are presented in Tables 5.1.5 and 5.1.6.
- Generic vantage point flight activity surveys to determine the amounts of flight activity by priority bird species in different parts of the site. Conducted 2005 to 2007. Results of these surveys are presented in full in the Appendix A11.1 of the 2010 ES Addendum; the results relevant to the assessment of the proposed varied development are summarised in Table 5.1.7.
- Flight activity studies of red-throated diver aimed at mapping flight lines across the site and collecting information required for collision rate modelling. Conducted mainly from 2005 to 2008; minor additional flight line data collected since 2009 incidentally to other survey work. Results of the diver flight activity surveys are presented in full in the Appendix A11.1 of the 2010 ES Addendum; the results relevant to the assessment of the proposed varied development are summarised in Table 5.1.8.
- Flight activity studies of priority bird species aimed at quantifying distance-from-observer related bias in the detection of flight activity, flight height distribution and other species-specific metrics required to undertake collision rate modelling from the generic vantage point flight activity data. Conducted in 2007 and 2008. Results of this study are presented

in full in the Appendix A11.1 of the 2010 ES Addendum; the findings relevant to the assessment of the proposed varied development are summarised in Table 5.1.8

- Studies conducted in 2011 to better understand the flight behaviour of whimbrel breeding in Petta Dale in the vicinity of the Mid Kame Ridge turbines. The Applicant shared the findings of this study with SNH during consultation process leading up to the grant of the existing consent. The finding of the study are summarised in section 5.2.

3. SURVEY METHODS

The field survey team comprised, Mark Chapman, Digger Jackson, Karen Yearsley and Logan Johnson. Field surveyors received training prior to and during survey work. The training included, but was not restricted to, aspects of navigation, the various survey methods, techniques to minimise fieldworker effects on bird detection, and the recognition of birds and bird behaviour. Training was provided irrespective of the field surveyors' previous experience. Emphasis was placed on the importance of carrying out surveys in a systematic and standardised way to enable direct comparison of data from different sites and survey periods. All surveyors were covered by Schedule 1 disturbance licence issued by SNH.

3.1 Moorland Bird Surveys (MBS)

MBS field methods

Breeding bird territories were surveyed using the modified Brown and Shepherd (1993) method for upland waders. Two survey visits were undertaken during a breeding season. In the survey work undertaken prior to 2010, the first visit was made in the period 01 May to 05 June and the second between 06 June and 02 July. Since 2010, following an examination of the encounter dates of priority species (in particular whimbrel and Arctic skua) the survey period for the first visit was changed to 15 May to 15 June, and the period for the second visit changed to 16 June to 5 July. All species were surveyed with the exception of meadow pipit (a very common small passerine species). Survey work for skylark (another very common small passerine species) was limited to mapping the locations of singing males only on the first survey visit. Surveys were only carried in weather conditions favourable for detecting birds, in particular winds ≤ Force 4, a lack of persistent rain and good visibility (at least 300m visibility).

Surveys were conducted by lone working surveyors, all of whom were experienced with the MBS survey method and familiar with Shetland breeding bird species. Survey routes were designed to cover the ground systematically, approximating to a series of parallel lines approximately 200 m apart (depending on terrain), but with the exact route determined to maximise detection of birds, for example by following raised ground in order to maximise ground visibility and choosing to closely examine habitat features likely to be attractive to birds such as blanket bog pool systems, loch edges and marshes. Every few minutes surveyors stopped walking to watch and listen for birds. Typically, on each visit, it took a surveyor two to three hours to survey each 1 km^2 of study area.

When a bird(s) was encountered its location was accurately determined with the help of a handheld Garmin GPS unit and its location recorded onto enlarged copies of OS 1:25,000 scale maps using standard BTO codes (Marchant, 1983). Standard BTO notation was used to annotate records to indicate the behaviour, the presence of nests or chicks and flight lines. Fieldworkers took care to assess if a bird(s) was different from those previously encountered that day and whether or not it was exhibiting behaviour indicative of breeding. Where necessary, surveyors retraced their steps in order to check the continued presence of previously recorded birds. In the case of curlew, whimbrel and golden plover, species that undertake aerial displays over their territory and that may range over large areas (up to approx. 1 km^2), the geographic extent of display flights and the locations where birds landed were also mapped. The accurate counting and mapping of curlew territories is more difficult than for other species on account of the high detectability of displaying birds (easily seen and heard from distances of up to at least 600m), the large size of the territories (up to at least 500m across) and the relatively high abundance of this species (almost ubiquitous across the survey area). In the surveys undertaken since 2010, greater time was spent mapping the extent of curlew song flights and indicating on field maps when simultaneous observations of two (or more) displaying birds confirmed the existence and relative position of two (or more) nearby territories. This additional attention to display curlew reduces the potential for double recording, especially in the lower density areas of the study area where territories cover particularly large areas.

MBS effort and purpose

2005-2008 surveys over the whole of the original section 36 area buffered to 500m. Some parts were surveyed twice, in different two years. Results of these surveys provided the baseline data used in the 2010 ES Addendum. They also provide data to compare against the recently collected MBS data, for example to establish population trends over the intervening period.

2010 and 2017 surveys of selected plots conducted every year between 2010 and 2017. These plots were selected from across Central and Western Mainland to provide information to develop the proposed HMP and to monitor whimbrel. Results from those plots surveyed in 2014, 2015, 2016 or 2017 and that overlap the revised site area are used as a source of recent MBS data for the assessment of the Variation (Figure 5.2).

2018 surveys covered an area of 61.5 km^2 (Figure 5.2). This primarily consisted of those parts of the revised site area that had received no MBS coverage since 2014 (approx. 75 % of the revised site area). In addition, some adjacent areas of interest for monitoring purposes were also surveyed in 2018. The 2018 MBS are the primary source of recent MBS data used in the assessment of the proposed development.

3.2 Red-throated Diver Surveys

Red throated divers were surveyed by making a series of visits to each potential breeding loch/lochan (all freshwater bodies >15m long) between early May and late August. Sites were visited at least once between early May and mid-June to establish occupancy and visited again at least once between mid-June and late July to establish if young were successfully reared. Unless nest sites could be seen from afar, nests were located by undertaking a systematic search of the perimeter of the site. Breeding sites with chicks were checked at least once in the period 30 and 40 days after hatching to estimate chick survival to fledging age (about 42 days).

Fieldworkers were acutely aware of the susceptibility of divers to disturbance, particularly at the incubation stage; great care was taken to minimise disturbance.

3.3 Breeding Merlin Surveys

Breeding merlins have been surveyed annually to inform the Viking development across Central Mainland annually since 2005. Survey methods followed those described in Hardy *et al*., 2006)

All historical nest locations, together with other areas of apparently suitable breeding habitat (slopes and stream sides with extensive areas of deep heather) were searched in April and May for signs of occupation. Initial searches consisted of systematically walking through suitable nesting areas and watching out for merlin and signs of their activity. If a search of a historical location was not initially successful, the search was extended to include all apparently suitable habitat within 1 km of that site. Sites where birds were not located on the first visit were visited again typically within two weeks.

It was not assumed that merlins would only occur within historical territories. Surveyors undertaking other fieldwork (e.g. MBS and flight activity surveys) were vigilant for merlin, their signs and areas of heather that looked suitable for breeding. Thus in addition to the dedicated merlin checks described above the wind farm site received considerable additional incidental coverage.

Where possible, nests in occupied territories were found and visits made at approximately monthly intervals from May to late July to determine breeding success.

This merlin survey work has been coordinated with the raptor monitoring coordinated by the Shetland Raptor Study Group (SRSG) (previously coordinated by RSPB). The assistance with monitoring merlin in Central Mainland freely given by local ornithologists, in particular Pete Ellis, Dave Okill, George Petrie and Nick Diamond, is gratefully acknowledged.

3.4 Diver Flight Behaviour

Red-throated divers undertake a considerable amount of flight activity during their breeding period. In particular, breeding birds fly to and from the freshwater sites breeding sites and coastal marine feeding areas and immature birds undertake prospecting flights in their search of potential breeding sites. Flight behaviour studies quantified the spatial and temporal aspects of all types of diver flight activity. The main objectives were to map a sample of flight routes at breeding and non-breeding diver lochs spread across the originally proposed wind farm site (buffered to 2 km), to determine flight heights and to quantify how flight activity changes with the stage of breeding and time of day. This was achieved through undertaking a programme of focal watches at breeding and non-breeding diver sites and selected vantage points elsewhere.

A minimum of 15 incoming flights (from the sea) for each breeding pair was used as the aim for providing a reasonable sample of flight routes for a given breeding lochan. In practice, as flights of all types were logged during watches, normally at least as many outgoing flights and flights by visiting non-breeders were logged and mapped. Indeed, outgoing flights tended to provide considerably more information on flight routes because they could typically be followed for much longer than incoming flights.

Between 2004 and 2006, watches were conducted at 45 diver breeding lochs (this figure includes sites in the Delting and Collafirth quadrants). Most of these watches were undertaken during the chick-rearing stage (36 lochs, 945 hours) as watches conducted at this time gave the greatest return (number of flights seen) on effort. Watches were undertaken at eight lochs during the pre-laying stage (totalling 69 hours), at nine lochs during the incubation stage (totalling 135 hours) and at six lochs after breeding failure / fledging had occurred (totalling 42 hours). Additional focal watches were undertaken at two breeding sites in 2007 and at a single newly occupied site in 2016 and 2017, and diver flights seen incidentally during other field work were logged and mapped.

Watches of breeding lochs were made from a vantage point overlooking the site, typically from 200-400m away. Vantage points were chosen on the basis of having an adequate view of the loch and surrounding areas, not being so close as to disturb the birds (judged from their behaviour) yet not so far that flights, particularly incoming flights, were difficult to detect. Watches were made at all times of day, but especially in the five-hour periods following dawn and prior to dusk. For about a third of the watches a small tent was erected at the VP to act as a hide, provide shelter and to sleep in overnight; this proved to be very effective and greatly facilitated early morning sessions.

Watches at breeding lochs with chicks typically lasted between three and eight hours, though a few were shorter. Other flight watches were almost always of three hours duration. Watches were conducted in all weather conditions though some had to be abandoned due to fog. During a watch the observer recorded all diver flights observed to pass within 1 km of the loch and mapped the flight lines onto 1:25,000 scale OS maps. For each flight the following data were recorded: time, the number of birds, type of flight (e.g., incoming, outgoing flights by residents, flight by visiting non-breeding bird), estimated height above ground (every 15 seconds) and whether the birds vocalised or carried food.

During the focal point watches of breeding lochs, visiting non-breeding birds were usually readily distinguishable from the resident and any neighbouring breeding birds by differences in their behaviour. In particular, breeding birds were those that tended eggs and chicks and were typically present on their territory most of the time, whereas visiting non-breeding birds were only present for short periods and evoked territorial behaviour from the residents. Away from a breeding territory, unless carrying food, breeding birds could not be distinguished with certainty from non-breeding birds.

In addition to the breeding loch focal watches, VP watches totalling 259 hours were also conducted in 2006 at eleven lochs frequented by non-breeding birds. The sampling strategy at these lochs was to map and log all flights seen in a series of 3-hour watches undertaken at approximately fortnightly intervals through the breeding season. In addition, all flights associated with these lochs that were seen incidentally during other diver work were mapped and logged.

Also in 2006, 188 hours of watches were conducted from twelve selected vantage points overlooking areas more than 1.5 km away from any lochs frequented by divers. These were chosen to fill strategic geographic gaps in coverage of diver flight line acquisition. These additional watches typically consisted of 3-hour observation sessions at approximately fortnightly intervals through the breeding season.

3.5 Generic Flight Activity Surveys

Generic flight activity fieldwork

Generic information on bird flight activity was collected across the site area buffered to 500 m (referred to as the flight activity survey area) during timed watches from strategic vantage points (VPs) using the methods described by Band *et al* (2007). VPs were selected to maximise visibility of the flight activity survey area, using the minimum number of points.

Observers at VPs positioned themselves to minimise their effects on bird behaviour. A viewing arc not exceeding 180 degrees was scanned. Watches were undertaken during daylight hours by a single observer in conditions of good ground visibility (e.g. greater than ~3km) and when the cloud base was higher than the most elevated ground observed. Otherwise a wide range of meteorological conditions was sampled.

During each watch, two recording methods were used, as follows:

- Focal bird flight lines. The viewing arc was scanned constantly until a Target Species was detected in flight. Target Species included red-throated diver, merlin and whooper swan. Once detected, the bird was followed until it ceased flying or was lost to view. The time the bird was initially detected and the time it spent within the flight activity survey area (to the nearest second) were recorded. The route followed by the bird was marked onto a 1:25,000 scale map, with the direction of flight indicated. The bird's flying elevation above the ground was estimated at the point of detection and at 15 sec intervals thereafter, using a countdown timer with an audible alarm. Flying elevation was classified as <10m, 10-50m, 50-100m, 100-150m or >150m. Each flight was numbered consecutively and these numbers used to cross-reference the flight lines on the field maps to the information on height and species (etc) on the recording forms.
- Flight activity summaries. At the end of each 5-min period, flight activity by Secondary Species seen within the viewing arc was summarised on a recording form. Secondary species included wader, skua, and tern species. The number of birds of a species recorded in any one 5-minute period was the minimum number of individuals that could account for the activity observed.

Generic flight activity survey effort

Generic flight activity watches were undertaken from 25 VPs which between them covered the revised site area. From these VPs a total of 799 hours of observation were made during the breeding season (April to August) and 379 hours of observation in the other months of the year.

This level of effort was in line with the SNH survey guidance at the time (SNH, 2004). These watches recorded flights by over 50 species.

The area observed from at least one of the VPs (i.e. the cumulative visible area) measured 79.4 km^2.

3.6 Additional Flight Activity Study 1

In the generic vantage point surveys described above all wader and skua species were treated as Secondary Species, and thus the information collected for these species was limited to the 5-minute interval summary data. As the work progressed it became apparent that it would be desirable to undertake collision risk modelling (CRM) for some of these Secondary Species, in particular whimbrel, golden plover, dunlin, arctic skua and great skua. However, in order to use the 5-minute interval summary data in CRM a number of parameters needed first to be quantified and this required the undertaking of additional flight activity studies.

The aims of the study were to quantify for whimbrel, golden plover, dunlin, arctic skua and great skua the following:

- flight height above ground level,
- changes in the detectability with distance,
- the duration of flights,
- changes in flight activity through the day.

These additional flight activity watches were undertaken in the 2007 and 2008 breeding seasons at VPs selected to cover areas where these species were known to occur in reasonable densities. The field recording method employed were the same as that used for the generic flight activity surveys (described above) except that whimbrel, golden plover, dunlin, arctic skua and great skua were treated as Target Species. Heights were recorded as one of six height bands: <10m, 10-30m, 30-50m, 50-100m, 100-150m and >150m. In addition, observers also recorded the distance to Target Species at the moment they were first detected. To facilitate accurate estimation of distance and mapping of flight lines a series of markers (white plastic fertiliser bags filled with peat) were positioned 500m from the VPs and the exact locations of notable landmarks were determined using GPS and marked on survey maps. Watches were mostly in bouts of three hours and were spread evenly throughout daylight hours. Observers also recorded the time taken to record flights, so that this could be discounted from calculations.

The 2007 watches were conducted at six VPs from late May to early August, with a total of 36 to 40 hours of watch effort at each VP. An additional 18 hours of watches were made in June and July 2008 from three VPs aimed at increasing the sample of dunlin flights.

3.7 Additional Flight Activity Study 2 (Mid Kame whimbrel)

Background to Mid Kame study

The 2010 ES Addendum identified that six wind turbines proposed for the southern part of Mid Kame ridge were in relatively close proximity to a regular concentration of breeding whimbrel in the Petta Dale valley. As a consequence of this proximity it was initially estimated that the six Mid Kame turbines posed a relatively high collision risk to whimbrel, together potentially accounting for nearly 15% of the total collision risk posed by the T127 layout. However, the 2010 ES Addendum pointed out that the large height difference (approx. 100 m) between the valley floor, where whimbrel activity is concentrated, and the ridge top where the turbines would operate may mean that collision risk from these turbines had been overestimated. At the time this potential overestimation could not be investigated further due to a lack of detailed flight activity data for whimbrel (and other species) from the Mid Kame ridge.

Following consultation with SNH, a field study was undertaken in 2011, aimed to measure flight activity by whimbrel (and other priority species) on the Mid Kame ridge and compare this with flight activity measures for the Petta Dale valley floor. The data from the Mid Kame study allow the collision risk in this part of the wind farm to be examined in detail. The data gathered by this study also supplement the data from Additional Flight Activity Study 1 (described above), increasing the sample size of flight observations from which various CRM parameters are calculated (e.g., flight height frequency, distance-related detection bias and flight duration). Parameters derived from larger data sets are likely to be more robust. CRM outputs that use these new parameter values are thus likely to give more realistic estimates of collision risk.

Mid Kame study field methods

The field methods used to collect the Mid Kame flight activity data were the same as used for the Additional Flight Activity Study 1 (described above). Watches were undertaken from six VPs. Three VPs were located on the ridge and three VPs located on the valley floor below. Heights were recorded as one of six height bands: <10m, 10-30m, 30-50m, 50-100m, 100-150m and >150m. A total of 153 hours of watches were completed approximately evenly spread between the six VPs. The watches were conducted between mid-May (by when most whimbrel have arrived back from Africa and settled on breeding territories) and the end of July (by when most whimbrel have departed Shetland).

4. SURVEY RESULTS

4.1 Moorland Breeding Surveys

The results of MBS surveys relevant to the assessment of the proposed varied development are summarised in Table 5.1.1. Results are presented in terms of the numbers of pairs (equivalent to territories) of a species breeding in the revised site area, and broken down into three sub-areas: Kergord, South Nesting and North Nesting (Table 5.1.1). For the wader and skua species of greatest conservation interest, the distribution of breeding pairs is shown in Figures 5.5 to 5.10 (dot maps). In these figures the dots indicate the location of nominal centre of territories, i.e. the central position of the records considered to be of a single breeding pair, or a pair's nest location if the nest was found. Results are presented for two time periods. The first period corresponds to MBS result for the period 2005 to 2008. These data are the same as those used in the 2010 ES Addendum assessment, but without data from the Delting and Collafirth quadrants of the original proposal, as these are no longer part of the proposed wind farm. The second period corresponds to MBS data collected in the period 2014 and 2018. In cases where within one of these time periods MBS was conducted in an area in more than one year, only the results for the most recent year of survey are used. Thus the results for each time period are the best estimate of the total numbers of breeding pairs present in one year.

Table 5.1.1. Like-for-like comparison of the numbers of pairs breeding within the revised site area derived from Moorland Bird Surveys undertaken between 2005-2008 and 2014-2018.

Species	2005-2008 surveys				2014-2018 surveys			
	Kergord	North Nesting	South Nesting	Total	Kergord	North Nesting	South Nesting	Total
Arctic skua	16	6	8	**30**	6	1	4	**11**
Arctic tern	1	1	0	**2**	1	1	0	**2**
Black-headed gull	29	2	1	**32**	0	1	0	**1**
Common gull	46	9	6	**61**	6	6	2	**14**
Common sandpiper	4	1	0	**5**	6	2	1	**9**
Curlew	89	27	44	**160**	69	15	31	**115**
Dunlin	22	18	15	**55**	19	10	14	**43**
Golden plover	41	15	17	**73**	44	16	27	**87**
Great black-backed gull	1	7	20	**28**	9	2	9	**20**
Great Skua	24	9	18	**51**	16	5	20	**41**
Greylag goose	11	8	5	**24**	21	9	29	**59**
Lapwing	36	17	7	**60**	16	9	9	**34**
Oystercatcher	53	10	22	**85**	41	10	20	**71**
Red grouse	11	6	6	**23**	6	3	14	**23**
Redshank	19	8	4	**31**	16	5	9	**30**
Ringed plover	4	7	7	**18**	1	1	7	**9**
Whimbrel	22	2	8	**32**	28	1	4	**33**

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Table 5.1. 2. Comments on the changes in abundance and distribution between the moorland breeding survey results for 2005-08 and 2014-18

Species	2005-2008 No. pairs	2014-2018 No. pairs	% change	Confidence in survey results	Magnitude of change	Distribution changes	Comparisons to changes elsewhere
Arctic skua	30	11	-63%	Very high	Large decline	Changes distributed approx. evenly	Large (ca 70%) and continuing decline in Shetland and elsewhere in Scotland over past 30 years.
Arctic tern	2	2	0%	Very high	Stable	Distribution unchanged	Trend in Scotland approx. stable over past decade
Black-headed gull	32	1	-97%	Very high	Large decline	Change dominated by the disappearance of the colony in Petta Dale in the Kergord section.	Declined across Shetland, recent trend elsewhere in Scotland uncertain
Common gull	61	14	-77%	Very high. Many non-breeding adults apparent in 2018 (excluded from count)	Large decline	Change dominated by the disappearance of the colony in Petta Dale in the Kergord section.	Approx 20% decline in Scotland over past decade.
Common sandpiper	5	9	80%	High	Moderate increase	Changes distributed approx. evenly	Trend in Shetland unknown. Numbers stable in Scotland over past 10 years.
Curlew	160	115	-28%	Moderate. Curlew territories are difficult to count accurately because of their large size.	Moderate decline, possibly an artefact of improvements to survey aimed at preventing double recording.	Reduction is most pronounced at higher elevations, where habitat quality is lower for this species.	Trend in Shetland unknown. 24% decline in Scotland over past decade.
Dunlin	55	43	-22%	Moderate, some territories likely to be over looked due to the relatively low detectability of this species.	Moderate decline	Change patchily distributed, biggest change in North Nesting section.	Unknown
Golden plover	73	87	19%	High	Small increase	Change patchily distributed, with biggest apparent change in South Nesting.	Trend in Shetland unknown. 15% decline in Scotland over past decade.
Great black-backed gull	28	20	-29%	High	Moderate decline	Change patchily distributed; increases in Kergord section and declines in Nesting section.	Approx 40% decline in Scotland over past two decades.

Species	2005-2008 No. pairs	2014-2018 No. pairs	% change	Confidence in survey results	Magnitude of change	Distribution changes	Comparisons to changes elsewhere
Great Skua	51	41	-20%	High. Counts include non-breeding territories	Small decline	Change patchily distributed, small increase in South Nesting vs declines elsewhere.	Over past two decades trends have varied between Scottish colonies.
Greylag goose	24	59	146%	Moderate, adults with goslings wander widely.	Large increase. Non-breeding adults excluded from counts.	Changes distributed approx. evenly	Large increase in Shetland. 13% increase in Scotland over past decade.
Lapwing	60	34	-43%	High. Later start date of 2014-2018 surveys may have reduced detection of pairs that fail early in the breeding season.	Moderate decline	Change patchily distributed; small increase in South Nesting vs declines elsewhere. Reduction in Petta Dale (Kergord section) may be linked to habitat change.	Trend in Shetland unknown. 39% decline in Scotland over past decade.
Oystercatcher	85	71	-16%	High	Small decline	Changes distributed approx. evenly	Trend in Shetland unknown. 19% decline in Scotland over past decade.
Red grouse	23	23	0%	Moderate, some territories likely to be over looked due to the relatively low detectability of this species.	Stable	Change patchily distributed: declines in Kergord section vs. increase in Nesting sections.	Trend in Shetland unknown. 48% increase in Scotland over past decade.
Redshank	31	30	-3%	High	Stable	Changes distributed approx. evenly	Trend in Shetland unknown. 24% decline in UK over past decade.
Ringed plover	18	9	-50%	High	Moderate decline	Change patchily distributed, stable in South Nesting section vs declines elsewhere.	Trend in Shetland unknown. 19% decline in Scotland over past decade.
Whimbrel	32	33	3%	High	Stable	Minor increase in Kergord and North Nesting, contrasts with moderate decline in South Nesting, where linked to reduced grazing.	Approx. stable on Mainland Shetland over past decade.

Changes to bird populations in Central Mainland Shetland are apparent from the bird monitoring (Table 5.1.2). The monitoring suggests that over the past decade, the numbers of golden plover have increased, that numbers of whimbrel (and perhaps curlew also) have remained approximately stable, and that numbers of Arctic skua in particular and to a lesser extent dunlin and great skua have declined.

Arctic skuas have shown a widespread serious decline across Scotland and the large declines (63% decline) observed in in the revised site area closely accord with the wider picture reported across northern Scotland (JNCC, 2016). The decline is linked to changes in the availability of marine fish prey (Table 5.1.2). Great skuas have also shown recent declines in some parts of Shetland, and this too may be linked to changes in the marine environment (JNCC, 2016).

The apparent 28% decline of curlew may be genuine, or may be due in part or in entirety to the small change to the survey field method designed to reduce the incidence of double recording (Table 5.1.2). The decline is most apparent at higher elevations, where breeding density is relatively low (presumably due to lower habitat quality). Curlews are known to be declining on mainland Scotland

4.2 Red-throated diver surveys

Distribution

4.2.1 The distribution of red-throated diver breeding sites is shown in Figure 5.3. In this figure breeding sites are shown as red dots sized according to the site's long term importance for productivity and are labelled by the site's reference code (a two- or three letter code unique to a particular breeding site).

Changes in abundance

The diver monitoring survey results reported below are limited to the revised site area buffered to 1 km (for the period 2006 to 2018 (Table 5.1.3). Throughout this period, with the exception of 2015 when no surveys were undertaken, the diver surveys covered the whole of the revised site area buffered to 1 km and were likely to detect all breeding pairs. The monitoring from 2003 to 2005 did not achieve comprehensive coverage of some parts of this area and so were likely to miss some breeding pairs, hence they are excluded.

Since 2006 the number of pairs nesting within the revised site area buffered to 1 km has fluctuated between 16 and 26 pairs and has shown an increasing trend. The annual average number of breeding pairs in the four-year period (2006 to 2009) leading up to the 2010 ES Addendum assessment was 18 pairs (Table 5.1.3). For the most recent four-year period (2014-2018, 2015 excluded as there are no data for this year) the annual average was almost 24 pairs, an increase of nearly 32% compared to the 2006-2009 period (Table 5.1.3).

Over the period 2006 to 2018 a total of 35 water bodies within the revised site area buffered to 1 km were used for nesting divers, 27 of these were inside the revised site area (Figure 5.3). Since the 2010 ES Addendum, eight sites within the revised site area buffered to 1 km have been used as breeding sites that were not used in the 2006-2009 period. However in all cases occupancy by breeding pairs at these sites has been rather low. In Figure 5.3 these 'new' breeding sites are those with the following reference codes: EH, FJ, FM, FP, LLL, LWL, NT and NZ.

In any one year, approximately 10 % of nesting lochs that had been used in the previous year were vacant and a similar number of lochs that had been vacant in the previous year became occupied. Most of this flux occurred on lochs that had relatively poor long-term breeding success (in terms of chicks fledged per year occupied).

Table 5.1.3. The annual number of pairs of divers on breeding inside the revised site area buffered to 1 km from 2006 to 2018. No survey work was undertaken in 2015

Area	2006	2007	2008	2009	2010	2011	2012	2013	2014	2016	2017	2018
Inside revised site area buffered to 1 km												
Kergord	7	6	7	7	9	10	9	10	9	12	10	9
Nesting-Nesting	6	5	7	6	10	9	8	6	9	8	10	8
Nesting-South	7	5	4	5	6	6	6	6	5	3	6	6
Total	**20**	**16**	**18**	**18**	**25**	**25**	**23**	**22**	**23**	**23**	**26**	**23**
Inside revised site area												
Kergord	4	4	4	4	5	6	5	6	5	8	5	6
Nesting-North	6	5	7	6	10	9	8	6	9	8	10	8
Nesting-South	4	3	4	3	4	4	4	4	3	3	4	4
Total	**14**	**12**	**15**	**13**	**19**	**19**	**17**	**16**	**17**	**19**	**19**	**18**

Breeding success

Red-throated diver breeding success from 2006 to 2018 is summarised in Table 5.1.4. The pairs included in the analysis of breeding success (Table 5.1.4) include pairs breeding at sites slightly beyond the revised site area buffered to 1 km (Figure 5.3) which were monitored in some years. Over this period the average breeding success was 0.55 chicks reared per pair per year, and 43% of pairs (a pair holding territory on a breeding loch) bred successfully. The average number of chicks reared by successful pairs was 1.34.

Table 5.1.4. The breeding success of red-throated divers nesting inside or slightly beyond the revised site area buffered to 1km between 2006 and 2018 (i.e. the sites shown in Figure 5.3). No survey work was undertaken in 2015.

Parameter	2006	2007	2008	2009	2010	2011	2012	2013	2014	2016	2017	2018
No. pairs	24	21	19	18	25	25	23	22	23	24	26	25
No. chicks	18	4	9	12	12	11	13	17	12	13	17	13
% successful	54%	14%	32%	44%	36%	40%	39%	59%	39%	42%	50%	40%
Chicks per breeding pair	0.75	0.19	0.47	0.67	0.48	0.44	0.57	0.77	0.52	0.54	0.65	0.52
Chicks per successful pair	1.38	1.33	1.5	1.5	1.33	1.1	1.44	1.31	1.33	1.3	1.31	1.3

4.3 Merlin surveys

The results of merlin monitoring undertaken since 2005 are summarised in Table 5.1.5.

Table 5.1.5. The numbers of pairs and breeding success of merlin located in Central Mainland between 2005 and 2018

Year	Kergord quadrant	Nesting quadrant	Delting quadrant	Collafirth quadrant	No. of breeding pairs	No. of successful pairs	% of pairs successful
2005	1	no data	4	1	6	4	67%
2006	2	1	4	1	8	6	75%
2007	2	3	4	1	10	10	100%
2008	2	3	3	1	9	6	67%
2009	2	2	5	2	11	9	82%
2010	1	2	5	1	9	7	78%
2011	2	3	5	1	10	7	70%
2012	3	1	5	1	10	7	70%
2013	2	0	3	0	5	3	60%
2014	1	1	3	1	6	5	83%
2015	4	1	4	0	9	9	77%
2016	5	1	3	1	10	6	60%
2017	2	1	1	0	4	4	100%
2018	5	2	3	1	11	10	91%

Between 2005 and 2018 the numbers of merlin pairs breeding in Central Mainland each year fluctuated between four and 11 pairs. On average 47% of the Central Mainland pairs nested the revised site area buffered to 2km; 29% in the Kergord quadrant and 18% in the Nesting quadrant. On average 77% of pairs bred successfully (Table 5.1.5).

The distribution of merlin nest sites in the Kergord and Nesting quadrants is illustrated in Figure 5.4. In this figure nest sites are assigned to a traditional territory based on their proximity to each other and the landscape; this is denoted by a 500m buffer around clusters of nest sites judged to be within the same territory. In a few cases merlin have nested in a location in a single year only in the period examined. In these cases it is not always clear if the nest site is an alternative to regular site or represents a new territory. In most cases it is likely they are alternatives as their occupation corresponds with non-occupancy of a nearby regularly used territory. It is typically the case that a merlin territory is occupied for a number of years followed by a period of non-occupancy, which can last for up to at least five years.

4.4 Flight activity surveys for waders, skuas and merlin

Only a brief account is given here, focusing on the results that are relevant to the proposed varied development assessment.

The results of the generic flight activity surveys, the red-throated diver flight activity surveys and the Additional Flight Activity Study 1 are described in full in the 2010 ES Addendum.

The number of five-minute periods in which flight activity by a species was recorded is summarised in Table 5.1.6. The great majority of this flight activity occurred during the breeding season months.

The raw summary of the fight activity data collected for the Kergord and Nesting quadrants (Table 5.1.6) is presented here to give an indication of sample sizes of data used in the analyses of flight activity by wader and skua species discussed in (Section 5.2) and that were used to derive input parameters for collision risk modelling.

Table 5.1.6. The number of 5-minute periods in which flight activity by a species was recorded during generic flight activity surveys covering the revised site area.

Species	No 5-min periods
Arctic skua	284
Arctic tern	152
Black-headed gull	363
Common gull	1438
Curlew	2022
Dunlin	25
Fulmar	48
Golden plover	432
Great black-backed gull	2356
Great skua	1506
Grey heron	11
Greylag goose	124
Hen harrier	10
Herring gull	745
Hooded crow	1075
Lapwing	744
Lesser-black-backed gull	86
Mallard	44
Merlin	27
Oystercatcher	677
Raven	1209
Red grouse	10
Redshank	167
Red-throated diver	195
Ringed plover	42
Snipe	495
Whimbrel	143

4.5 Flight activity by red-throated diver

The number of red-throated flights detected and logged during the flight activity surveys is summarised in Table 5.1.7

Table 5.1.7. **Summary of watches for red-throated diver flights each year.**

Year	Focal point watch effort (hours)	No. of flights logged during focal point watches.	Generic flight activity watches	No. of flights logged incidentally to other fieldwork	Total flights logged
2003	170	50	177	0	227
2004[1]	178	233	0	0	233
2005	398	807	255	128	1190
2006	794	792	30	161	983
2007	20	17	0	6	23
2008-18	15	9	0	47	56
All years	**1575**	**1908**	**462**	**342**	**2712**

[1] Data from Natural Research 2004 red-throated diver study.

5. DATA ANALYSES

5.1 MBS analysis of territories

After survey work was complete MBS summary maps were compiled for each species showing the records and annotations from each visit in a different colour. These summary maps were then critically examined to identify the locations of breeding territories and breeding colonies (gulls and terns), using the most parsimonious interpretation of the data. Records considered to refer to non-breeding individuals or to breeding birds away from territory were not considered relevant to identifying breeding territories. For red grouse, Artic skua and great skua the presence of an adult or pair of adults on the ground within suitable habitat was considered sufficient to indicate the location of a breeding territory. In the case of greylag goose, the alarming single birds or pairs were assumed to be breeding birds; in many case this was confirmed by the presence of a nest of young. Groups of three or more alarming greylag geese were assumed to be non-breeding birds (approximately half the birds encountered were in such groups) unless they had goslings in attendance.

Within a visit if the distance between two records of single birds was less than 250 m apart (500 m in the case of curlew, and 200 m in the case of dunlin and small passerines) they were considered likely to be of the same pair. In such cases the location of the pair for that visit was placed centrally by convention.

Across visits, the records on the species summary maps considered most likely to represent birds of the same breeding pair (including the extent of aerial song flights) were circled. The circle including a pair's records was taken to indicate the approximate extent of that pair's territory and its centre defined as the nominal territory centre. It was not uncommon for the territory circles of adjacent pairs to show a degree of overlap. For most species, the summary maps breeding pairs/ individuals/ song flights mainly showed obvious clusters that could reasonably interpreted as the extent of the area used by a particular pair, i.e. the extent of its territory. In other cases judgement was required to decide which records could reasonably be interpreted as referring to a pair. In doing so the most parsimonious interpretation was followed bearing in mind the proximity of neighbouring pairs and the behaviour of the species (some wader species and greylag geese wander widely at the chick stage). In interpreting the maps, in cases when the nearest distance between the location of a pair/single seen on a visit-1 and the location of a pair/single seen on visit-2 records of pair exceeded 500 m (1 km in the case of curlew, 750m in the case of whimbrel and 250m in the case of dunlin and small passerines), it was not considered reasonable that the two records could refer to the same breeding pair, and it was thus assumed the two records represented different pairs. In the case of skylark, the location of singing males was taken to represent a territory centre.

The location of MBS territory centres was digitised in GIS software (ArcGIS) for use in other analysis.

5.2 Flight activity by waders, skuas and merlin

Collision risk modelling (CRM) requires as an input the expected flight activity that will occur in the areas where turbines are proposed. This is expressed as the flying time at per unit area per unit time, e.g. bird flying seconds per hectare per year.

This section explains the process used to estimate flight activity for priority wader species and skuas and merlin. The aim being to estimate flight activity in terms of flying time per unit area per unit time in the vicinity of proposed turbines, as required for CRM. The methods used to estimate flight activity by these species are the same as used for the 2010 ES Addendum. The data used for analysis have been updated in light of new survey information collected since 2010. The analysis of flight activity data for red-throated diver data were analysed by different methods, reflecting the much greater quantity of flight data collected for this species (section 4.5).

The core data available on flight activity by wader and skua species comes from the programme of generic VP flight activity survey conducted across the site between 2003 and 2006 (reported in full in 2010 ES Appendix 11.1 Birds Technical Report). For these species the occurrence of any flight activity seen was recorded for each 5-minute period through each VP watch session. The data for these species therefore describe the proportion of 5-minute intervals when flight activity by a species was recorded.

In the generic VP flight activity surveys, merlin was treated as a target species for detailed recording of flight activity, i.e. flight duration and flying heights were recorded and flight routes mapped. Thus for this species measures of flight activity per unit area per unit time are relatively easily calculated provided the visible area within the VP viewing arcs and watch duration are known.

The 5-minute-period flight activity data for wader and skua species provide high quality information on when (seasonally and time of day) flight activity occurred and the relative amount of activity occurring within the viewing arc of each VP. However these data do not provide information on the number of birds involved, flying height, flight duration, the routes followed or the amount of flight activity that occurred in the viewing arc that was likely to have gone undetected. The 5-minute-period data provide an index of flight activity only and these data require to be calibrated before they can be used to provide absolute estimates of flight activity for CRM.

The standard method described in the SNH guidance (which was developed with large species in mind such as raptors and geese) for estimating flight activity from VP watch data is to assume that all activity within the visible area of the viewing arc up to 2 km away is seen. For relatively small species this assumption is violated because there is a high likelihood that flight activity away from the VP but well within 2 km goes undetected. The consequence of overlooking a proportion of the flight activity within 2 km of the VP viewing arc is to underestimate flight activity and unless this is corrected for, collision risk will also be underestimated. The magnitude of underestimation is potentially large, e.g. underestimation by over an order of magnitude is typical for medium-sized wader species. If CRM is to produce credible results for small and medium-sized species distance-detection bias must be taken into consideration.

The generic VP data provide representative measures of flight activity at the locations where it was obtained. However, because of distance-detection effects the generic VP data is inevitably spatially biased in favour of the vicinity of VPs, as flight activity close to VPs is more likely to be seen that that further away. Whereas generic VP locations are likely to be representative of the initial area of interest they are unlikely to be representative of proposed turbine locations because the layout design was strongly influenced by ornithology sensitivities. Indeed, if the turbines layout tends to avoid sensitive areas for a species (e.g., whimbrel) it is to be expected that on average flight activity levels in the vicinity of proposed turbines will be lower than in the vicinity of the VPs. Differences in the amount of flight activity at VP locations compared to turbine locations also need to be taken into account in estimating flight activity for CRM.

Approach to deriving flight activity estimates for CRM

A three-step process is used to estimate flight activity in the vicinity of the proposed turbines from the 5- minute-period generic VP flight activity data.

- **Step 1** – calibrate the 5-minute period index values into absolute estimates of flight activity using the mean flight parameter values derived from the 2007-2008 and 2011 additional studies,

- **Step 2** – account for distance-detection effects.
- **Step 3 –** account for breeding density differences between VP locations and proposed turbine locations using MBS data.

The Additional Flight Activity Study 1 undertaken in 2007 and 2008 was designed to quantify the parameters required to calibrate the 5-minute-period data from generic flight activity surveys. In addition it collected information on flying height and on distance-from-observer differences in the detection of flight activity (Birds TR). The species studied were merlin, golden plover, dunlin, whimbrel, arctic skua, great skua. Initially curlew was also included but this species was dropped shortly into the study so that observers could concentrate on species of greater interest. The study was conducted at six selected VPs that looked across areas of the site known to hold the species of interest. They all had 180 degree viewing arcs with approaching 100% visibility up to 2 km. To aid accurate plotting of flight lines a series of distance markers were laid out in an arc 500 m from each VP.

The further study, Additional Flight Activity Study 2, undertaken in 2011 used the same methods as the 2007-2008 study and was also based on six VPs. This study examined flight behaviour near the Mid Kame ridge and provides additional calibration and distance-detection data for whimbrel and curlew.

MBS data on breeding density are available from across the wind farm site, both collected in the same year that the generic flight activity surveys were undertaken, and more recently (e.g., the 2014-2018 MBS data).

Step 1 - Calibration of 5-minute period flight activity data

For each species, the data from the two additional flight activity studies were used to quantify the following parameters:

- The mean number of birds per flight event
- The mean duration of each flight event
- The mean number of 5-minute periods straddled by each flight event
- The mean proportion of flying time in each of five height bands (<10m, 10-50m, 50-100m, 100-150m and >150m above ground level). Note, this parameter is not used in the calibration of the 5-minute-period data; it is required for CRM.

The first three parameters listed above are used to convert the 5-minute-period data into estimates of the amount of flight activity that occurred (and was likely to be detected) by a species. Put another way, the calibration provides a means to estimate the total amount of flight activity by a species that would have been recorded had an observer recorded full details of the flight activity seen during the generic flight activity surveys.

Step 1, worked example

Total number of 5-minute periods watched = 2648

- No. of flight events observed in = 177
- No. of positive 5-minute intervals = 204
- Mean no. 5-minute periods straddled per flight event = 1.15
- Mean flight event duration (seconds) = 71.4
- Mean number birds per flight event = 1.31

In this example, on average each positive 5-minute interval corresponds to:

- (1/1.15) flight events x 1.31 birds per event x 71.4 seconds = 81.3 seconds of flight activity

Thus, it is estimated that had full flight data been recorded in the generic VP watches, then for each 5-minute period when flying whimbrel were noted on average there would have been 81.3 seconds of flight activity observed.

This value can now be used to estimate the average flight activity per hour from 5-minute interval VP data. For example using the above whimbrel figure the estimate for a hypothetical VP where there were 50 positive 5-minute intervals recorded for whimbrel out of a total of 1,200 5-minute periods observed (equivalent to 100 hours VP watch effort) is 40.6 seconds of flight activity per hour of observation i.e., (81.3 x 50)/100).

Step 2 – Distance-detection effects

Step 2 involves correcting for distance-from-observer bias in the detection of flight activity.

Calculation of distance detection correction

Using the data from the two additional flight activity studies, changes in the likelihood of detection of flying birds with respect to distance from the observer were quantified by comparison of the recorded flight activity per unit of the visible area in each of a series of 250 m-wide concentric distance bands centred on the VP and up to 2km from the VP. The visible area for each band for each VP was calculated from digital terrain data in using GIS software (ArcGIS) for 20 m elevation. VPs were chosen at random with respect to bird flight activity and the location of breeding territories, and therefore there is an expectation that the actual amount of flight activity by a species per unit area, when averaged across all VPs, should be constant across all distance bands. Mapped merlin flight data collected from generic VP watches were also examined using the same method because of the small sample size of merlin flights seen in the additional flight activity studies.

For the purposes of estimating the proportion of flight activity that was seen it was assumed that all activity was observed in the first distance zone. For the two skua species and merlin flight activity levels in the second zone (250-500m) equalled or slightly exceeded that in the first distance zone and therefore it was assumed that all activity was observed in the first two distance zones. For greylag goose flight activity was similar in the first four zones and so for this species it was assumed that all activity was seen up to 1 km from VP. For each distance zone, the difference between the observed and expected activity was used to estimate the percentage of activity seen. For some smaller species this measure probably overestimates the activity seen because it is unlikely that all flight activity within the closest zone was seen.

For all species the results showed a tendency for observed flight activity per unit area to reduce successively in the further away distance bands, in most species reducing to zero well before 2 km. As would be expected, the effect was most marked in the smallest species (dunlin) and least marked in the largest species (great skua). The proportional difference between the observed flight activity per unit area in the closest distance band(s) and those bands further away from the VP gives an estimate of the proportion of flight activity that was overlooked in each distance band and thereby provides a simple means to correct for distance-detection effects (Table 5.1.8).

Table 5.1.8. Proportion of observed flight activity in each distance band from VPs, based on data collected in the two Additional Flight Activity studies.

Species	Proportion of observed flight activity in each distance band from VP (m)								
	1-125	125-250	250-500	500-750	750-1000	1000-1250	1250-1500	1500-1750	1750-2000
Dunlin	100%	19.4%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Golden plover	100%	100.0%	38.8%	32.4%	15.1%	7.1%	0.7%	0.0%	100%
Whimbrel	100%	100.0%	69.3%	37.1%	17.9%	6.5%	0.7%	0.6%	39%
Curlew	100.0%	100.0%	100.0%	50.5%	23.3%	3.7%	0.0%	0.0%	32%
Arctic skua	100.0%	100.0%	100.0%	71.2%	42.5%	14.9%	5.2%	1.9%	1.5%
Merlin	100.0%	100.0%	100.0%	57.8%	37.7%	19.9%	10.0%	5.6%	2.5%
Great skua	100.0%	100.0%	100.0%	59.6%	53.7%	42.3%	29.0%	19.4%	19.2%

The rate of decline in recorded flight activity with respect to distance was used to determine a notional distance within which the observer is assumed to detect all activity, and beyond which the observer is assumed to detect no activity. This was achieved by redistributing the observed activity was according to the activity level (flight time per ha) recorded in the closest distance zone(s). This notional distance was termed the 'Effective Total Detection Distance' (ETDD) and has valuable application in estimating the mean level of flight activity (flight time per ha per year) for each species.

There was a strong positive relationship between a species' body-size and how far away it could be seen although colour and flight height doubtless also affected detectability. The ETDD values and the derived correction factors (for a 2km view-shed) for the species examined are as follows:

- greylag goose, ETDD = 1262m, correction factor = 2.5;
- great skua, ETDD = 1156m; correction factor = 3.0;
- Arctic skua, ETDD = 883m; correction factor = 5.1;
- Merlin, ETDD = 898m; correction factor = 5.0;
- Curlew, ETDD = 723m; correction factor = 7.6;
- Whimbrel, ETDD = 643m; correction factor = 9.7;
- Golden plover, ETDD = 577m; correction factor = 12;
- Dunlin, ETDD = 193m; correction factor = 107.

Application of distance detection correction to generic flight activity data

The generic flight activity data were corrected for distance-detection bias by calculating for each generic VP the area of each 250m-distance band that would have been effectively watched if the same amount of flight activity per unit area had been observed in that band as in the distance band(s) closest to the VP. For example, if the amount of activity observed in a distance band was estimated to be 50% and the visible area of this band was 100 ha then the 'effective area' watched is estimated at 50 ha. For each generic VP, the effective areas of all the distance bands for a species were then summed to give measure of the effective total area watched.

The corrected value for flight activity per unit area at each generic VP is thus the estimated time birds were seen flying (from Step 1) divided by the sum of the effective areas of the distance band. This figure is then divided by watch effort (the number of 5-minute periods watched divided by 12) to give a measure of flight activity per hectare per hour. This figure was then averaged for all the generic VPs to give a measure of the average flight activity per hour in the vicinity of the generic VPs.

Flight activity estimates from generic VP data were calculated as an annual total. To do this the data were split into three seasonal periods: winter (September to February), core breeding season (May, June and July) and 'shoulder' season (March, April and August). The mean estimated flight activity (bird seconds/ha/season) was calculated for each season from the season duration (181, 92 and 92 days respectively) and average day length for the season (8.5, 18.1 and 14.5 hours respectively). The results for the three seasons were then summed to give the estimated flight activity per year. It was assumed that there was no flight activity during the hours of darkness. Although winter flight data were included in the analysis, in practice there was either no or very low flight activity levels recorded at this time of year.

Step 3 – Estimating spatial differences in flight activity

Steps 1 and 2 estimate the mean flight activity per unit area per unit time in the vicinity of the generic VPs. Step 3 is to estimates the mean level of flight activity in the vicinity of the proposed turbines, to provide the measures of flight activity required for CRM, by accounting for the differences in breeding density between the locations of generic VPs and the locations of proposed turbines. Note this step is not required for merlin because they hunt over wide areas up to several kilometres from their nest.

It is a reasonable assumption that the amount of flight activity over an area is directly proportional to breeding density of a species in that area. On this basis, the approach taken to account for differences in the amount of flight activity at VP locations compared to turbine locations is to compare the breeding density of a species in the vicinity of the VPs with the breeding density in the vicinity of the turbines. The differences in breeding density (measured from MBS results) between VP locations and the proposed turbine locations are used to estimate flight activity at turbine locations using the calibrated 5-minute interval data from Steps 1 and 2.

The MBS results are the only spatially unbiased data available across the study area to inform variation in density. The MBS results take the forms of maps of the nominal territory centres (the average location where members of a pair were seen over successive visits) of breeding pairs in the year of survey (Figures 5.5 to 5.10). The MBS results show that the density of each species varies widely across the study area; indeed it is this variation that was used as a basis for identifying the differences in bird sensitivity that was taken into account in the windfarm design process.

Having established that MBS results can in principle give information on spatial variation in relative flight activity to use alongside absolute measures flight activity from generic VPs, the question arises of how the MBS information is best used and over what spatial scale it should be translated into a density value. This ideally requires information on how far on average the regular flight activity of a breeding pair extends from a territory centre. This is unknown but can be estimated approximately from median nearest neighbour distances (the distance between two territory centres) (Table 5.1.9). In theory, if territories were close packed across a landscape and the use of the airspace was exclusive to the territory holders, then flight activity by a pair would extend out from the territory centre to half the nearest neighbour distance and no further. In practice observations suggests there is some overlap in the airspace used by adjacent pairs, i.e. each pair's regularly used territory air space is not entirely exclusive. Furthermore, the assessment needs to err on the side of caution and recognise the inherent approximation of the MBS derived nominal territory centre locations. Therefore, it is reasonable to assume that regular flight activity by a pair extends over a somewhat greater distance. For the purposes of analyses it is assumed that it extends twice as far, i.e. to a distance from the nominal centre equal to the median nearest neighbour distance. This distance is to some extent arbitrary, however provides a reasonable basis for the analyses in the absence of better spatial data on flight activity and the estimate of density is relatively robust to the value chosen. Furthermore, it is important to realise that the choice of value for this distance has no influence on determining the amount of flight activity over the study area, rather it only affects the calculation of breeding bird density (and therefore relative flight activity) in the areas occupied by turbines. Thus although the value effects how the total risk is distributed between turbines the choice of value (within reason) has only a weak influence on CRM outputs.

Table 5.1.9. Median nearest neighbour distances of selected species breeding species based on measurement of Moorland Bird Survey results.

Species	Median nearest neighbour distance (m)
Dunlin	341
Golden plover	416
Whimbrel	508
Curlew	400
Arctic skua	817
Great skua	537

For the purposes of estimating relative flight activity in the vicinity of the proposed turbines, the density of breeding pairs of each species was calculated for a circle centred on the turbine with a radius equal to the median nearest neighbour distance for that species. The density for each turbine location was calculated from the sum of MBS nominal territory centres within the circle divided by the area of the circle, and the values for all turbines were then averaged to give a mean density at turbine locations (Table 5.1.10). The breeding density in the vicinity of the generic flight activity surveys VPs was also calculated (Table 5.1.10). GIS software was used to facilitate the counting of territories centres in the circles around turbines and VP locations. The difference between the mean density of a species in the vicinity of generic VPs and at proposed turbines locations (expressed as a percentage of the VP value) is taken to indicate the likely relative difference in flight activity.

The final part of Step 3 is to estimate the mean flight activity at the proposed turbine locations (Table 5.1.11). This is calculated from the mean estimated flight activity at the generic flight activity surveys VP locations derived from Step 2 multiplied by the relative mean breeding density at turbine locations from Table 4). The estimates of flight activity for each species in the vicinity of turbines (Table 5.1.11) is in the form required CRM. The figures in Table 5.1.11 are an estimate of the baseline flight activity in the vicinity of turbines and do not take in to consideration any reduction in flight activity that would occur due to displacement of breeding birds.

Table 5.1.10. The estimated mean density of breeding birds in the vicinity of generic VPs and proposed turbines, the percentage difference between them and the number of turbine locations where breeding density was greater than zero in the year of survey.

Species	Mean breeding density (pairs/km^2)		Density at T103 turbines *cf* VPs
	Vicinity of VPs where flight activity measured	Vicinity of T103 turbines from 2014-18 MBS surveys	
Dunlin	1.13	0.64	56.4%
Golden plover	1.2	1.27	105.7%
Whimbrel	0.46	0.25	54.3%
Curlew	2.61	1.55	59.2%
Arctic skua	0.49	0.16	32.1%
Great skua	0.79	0.70	88.2%

Table 5.1.11. The estimated mean flight activity (all heights) in the vicinity of generic VPs and proposed turbine locations.

Species	Estimated mean flight activity in vicinity of generic VPs where flight activity measured (s/ha/yr)	Density at T103 turbines *cf* VPs (from Table 5.1.10)	Estimated mean flight activity in vicinity of T103 turbines (s/ha/yr)
Merlin	50	100%	50
Dunlin	1162	56.4%	656
Golden plover	4842	105.7%	5116
Whimbrel (uses 2007 & 2011 DD data)	715	54.3%	423 [1]
Curlew (uses 2007 & 2011 DD data)	4024	59.2%	2382
Arctic skua	1247	32.1%	401
Great skua	5311	88.2%	4683
[1] Note, after adjusting for lower flight activity in the proximity of six turbines proposed along the Mid-Kame ridge this value reduces to 313 s/ha/yr			

Additional Flight Activity Study 2

GIS was used to determine the amount of flight activity by whimbrel per unit area in a series of 250m-wide distance bands centred on the six VP and in different parts of the landscape (ridge, valley side and valley floor.

After accounting for distance related bias in detection rates, the study showed that in 2011 the estimated flight activity by whimbrel over the Petta Dale valley floor averaged 1,929 seconds/hectare/year, whereas the corresponding figure for the Mid Kame ridge (where a line of turbines is proposed) was seven times lower, at an estimated 275 seconds/hectare/year. The result of this study indicated that the turbines proposed for the Mid Kame ridge pose a much lower potential collision risk to whimbrel than would be expected based on their proximity to territory centres.

The effect of taking the results of this study into consideration (i.e., lower flight activity at the locations of six of the turbines proposed for the Mid Kame ridge) is to reduce the estimated mean flight activity by whimbrel in vicinity of 103 turbines to 313 seconds per hectare per year. This adjusted value is used for evaluating collision risk.

Whimbrel flight activity measures

In light of the particular concern for collision risk to potentially impact on breeding whimbrel receptor population the question of the average amount of whimbrel flight activity in the vicinity of turbines (the key determinant of collision risk) merited additional analysis. Thus a second method was developed to estimate flight activity for this species, referred to here as Method 2. The method described above (i.e., Steps 1 -3, Method 1) provided an estimate of flight activity based on the density of nominal territory centres in the vicinity of turbines in a single year. However, the parts of the revised site area where whimbrel regularly breed have been subject to MBS surveys in multiple years since 2005 as part of the programme of monitoring priority bird species, and thus for this species there is considerably more data available. Depending on location, the parts where whimbrels regularly breed have been surveyed in at least five years and up to 12 years (Petta Dale valley) in the period 2005 to 2018. Method 2 was designed to take full advantage of this multi-year data set to derive the best long-term measure of whimbrel flight activity in the vicinity of the proposed turbines. The methods uses an essentially similar approach to Method 1, except that it undertook the calibration between measures of flight activity in the view-sheds of VPs and breeding density based on the 'raw' locations of records of breeding birds seen on survey visits rather than using nominal territory centres. This approach thus better reflects the true spatial distribution of birds in the area of interest compared to using the locations of nominal territory centres. In total the analysis was based on 591 records of whimbrel seen in the revised site area.

The average estimated flight activity by whimbrel in the vicinity of the proposed 103 turbines derived from Method 2 was 497 seconds per hectare per year. After taking into account adjustments for the six Mid Kame turbines (discussed above) this reduces to an average of 366 seconds per hectare per year, and this value was used for collision modelling.

The whimbrel flight activity estimate derived from Method 2 is approximately 17% higher than the estimate from Method 1. Given that the two estimates are derived to a large extent from different data sets the two figures are considered to be in good agreement with each other. The figure from Method 2 is considered likely to give the more reliable estimate as this is derived from a larger data-set and is derived using a more sophisticated method.

5.3 Red-throated diver flight activity

The account for red-throated diver flight activity analysis below is a shortened version of the description presented in the 2010 ES Addendum Appendix 11.1 Birds Technical Report. Since the 2010 ES Addendum no changes have been made to the analysis methods of red-throated diver flight activity. However, the estimated amount of flight activity at proposed turbine locations (i.e., the amount assumed for collision modelling purposes) has been adjusted upwards to take account of increases in the population size (both breeding birds and non-breeding birds), changes in site occupancy and new flight line data for sites that have become occupied for the first time since the 2010 ES Addendum.

Data categorisation and measurements

The amount of red-throated diver flight activity observed during flight activity watches was affected by the extent of the visible area (i.e., the view-shed), the visibility conditions (i.e. the weather) and how closely divers approach the observer (i.e. distance). These factors need to be taken into account before the data can be used in CRM.

In practice, it is reasonable to assume that nearly all flight activity within 500 m of a VP was seen, but that at greater distances an increasing proportion is missed. Beyond a distance of about 3 km very little activity was recorded. For this reason the analyses that follow are limited to within 3 km from the VP and this is termed the 'potentially visible zone' (PVZ).

Among the birds on the site, red-throated divers are unusual in that their flights must start and end on water. Furthermore, in the case of feeding flights the destination is the sea. This means that, with few exceptions (and these can be accounted for), the majority flights that enter the PVZ either start or terminate, or both, outside it, i.e. beyond 3 km. This also means that it is possible to estimate the amount of flight activity that occurred within the PVZ during watches that went unseen.

Outgoing flights from focal lochs seen during conditions of excellent visibility provide a reference sample to compare with other flight types and visibility conditions. View-shed permitting, these outgoing flights could normally be followed to beyond 3 km (though some reached the sea before this). Comparison against a distance-exceedance frequency plot (Plot 5.1.1) for outgoing flights observed in excellent visibility provides a means of estimating the amount of flight activity that went unrecorded in different distance zones for the other flight types and in poorer visibility conditions.

To estimate how much activity within the PVZ went unseen the different types of flights seen during focal watches of diver lochs were considered separately. The five types considered are:

- Type 1: Inbound flights. Flights that end at focal loch.
- Type 2: Outgoing flights. Flights that start at focal loch.
- Type 3: Local flights. Flights that start at focal loch and end at nearby (<1km) loch or *vice versa*, or return to same loch.
- Type 4: Visiting flybys. Flights that circle or pass close to (defined as a closest approach <400 m) the focal loch but do not land.
- Type 5: Non-visiting flybys. Flights that do not visit (defined as a closest approach >400 m) the focal loch but are pass over the PVZ.

In the case of flights that were directed to or from the loch itself (flight types 1, 2, 3 and 4), the close proximity of the VP to the loch meant that it is reasonable to have assumed that all flights were detected. Thus, for these flight types any unseen activity within the PVZ was limited to those parts of flights that occurred before first detection or after poor visibility prevented further observation. 'Fly-by' flights (i.e. those that passed through the PVZ but did not come close to the focal loch) could also be potentially affected in the same way but potentially might also not be detected at all and thus go unrecorded.

Many aspects of the weather conditions affect an observer's ability to detect and watch diver flights. Weather measures recorded during watches were combined to produce a four-point ordinal visibility scale: very poor, poor, good and excellent. The definitions of these categories are shown below.

- Very poor. Fog or mist or visibility recorded as <1km, (with or without rain and wind).
- Poor. Rain or recorded as 'very dull', and/or wind >=F6, and/or cloud base <350 m.
- Good. Fine or showers, up to 100% cloud, cloud base >350 m and wind <=F5.
- Excellent. Wind <=F4 and <60% cloud and cloud base >500 m and no precipitation.

Accounting for distance-related detection bias

To investigate distance-detection relationships three distance measurements were calculated for each flight using GIS software (ArcGIS):

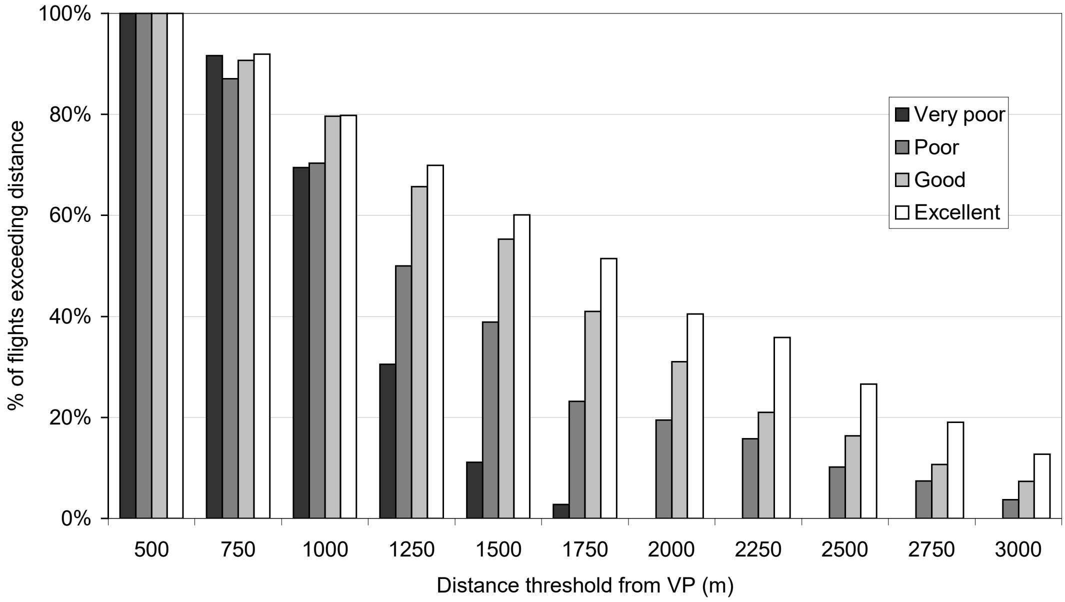
- VP to point of first detection,
- VP to closest approach point (minimum distance)
- VP to most distant observed point of flight (maximum distance)

The aim of the distance-detection analyses was to use the available data to estimate the amount of flight activity in the PVZ that went unrecorded during watches, or, put another way, the reduction in effective watch effort that occurred due to distance from VP. The analysis includes consideration of the reduction in detection caused by weather and visibility conditions.

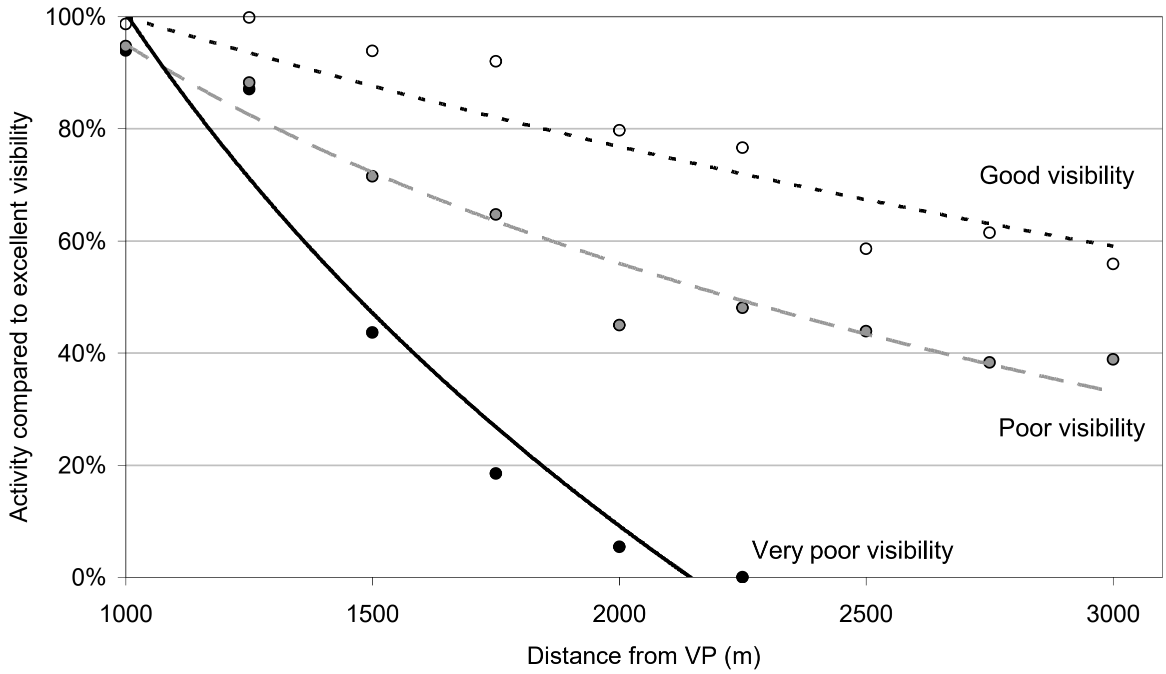
The plot of maximum distance of detection for outgoing flights under different visibility conditions (Fig. 16) gives the best indication of the amount of flight activity that was potentially visible. The fall-off with distance in the amount of activity seen in conditions of ‘excellent visibility’ is mainly due to the limitations imposed by the view shed and the fact that some flights reached the sea before 3 km. For each flight type, the differences between the curve for excellent visibility and conditions of poorer visibility are caused by unseen activity due to reduced visibility (Plot 5.1.2). For example, under conditions of ‘poor’ visibility the amount of outgoing flight activity recorded at 2 km from the VP was, on average, about half that recorded during ‘excellent’ visibility.

The differences between the distance-detection plot for outgoing flights and that for the four other types of flight indicates the average amount of unseen activity within the PVZ before these flights were detected. In the case of ‘fly-by’ flights that did not approach closer than 400 m the difference was also caused by some flights going undetected. For example, at 1000-1250 m from a VP the average inbound activity recorded was 50% of the outgoing activity and at 1500 m it was only 30% (Plot 5.1.3). The difference between the distance detection plots for inbound and outgoing flights was large (Plot 5.1.4).

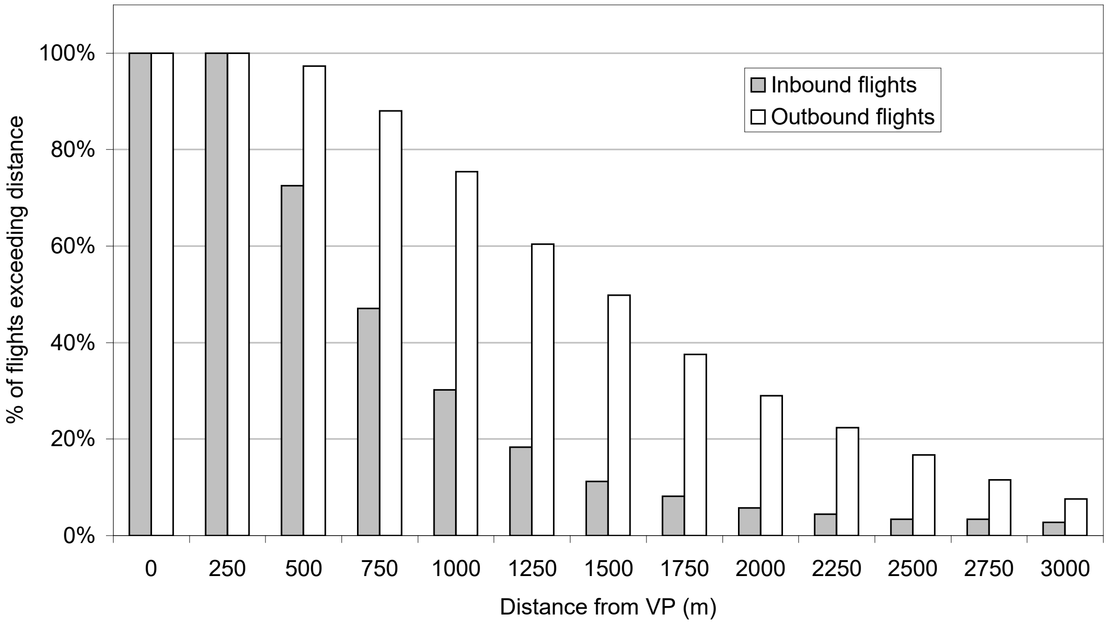
Plot 5.1.1. Maximum distance from VP that outbound flights by breeding red-throated divers were observed in different conditions of visibility (n=634).



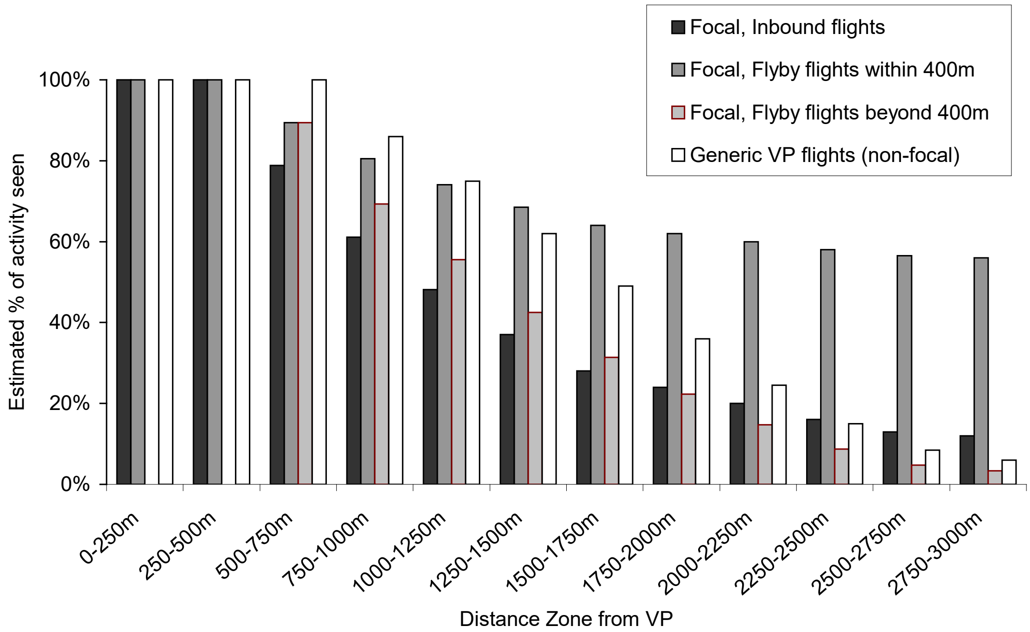
Plot 5.1.2. The effect of visibility conditions on the amount of red-throated diver outbound flight activity observed at different distances from VP relative to amount of activity observed under conditions of excellent visibility. See text for visibility definitions.



Plot 5.1.3. Comparison of the maximum distance from VP that ingoing and outgoing red-throated diver flights were observed (irrespective of visibility conditions).



Plot 5.1.4. The estimated amount of flight activity seen in 250m-wide distance intervals from vantage points for various types of red-throated diver flights. The estimates are expressed relative to outbound flight activity (i.e. outbound equals 100% in all distance zones). Based on 1670 flights recorded during focal point and generic VP watches during fieldwork conducted from 2004-2006.



Effort-corrected estimates of flight activity

In order to produce unbiased estimates of diver flight activity for CRM it was necessary to correct the raw flight activity data (essentially the mapped flight lines) for variation in observer effort, and bias caused by distance-related changes in detection and by visibility conditions. This was achieved by estimating an annual flight activity score for each cell in an array of 200 x 200 m grid squares. The corrected values were used to create a map of 200m squares, with each square coloured according to its annual flight activity score. Seven levels of score were defined, each level representing a doubling of activity. Scores were based on the estimated annual distance flown by divers in each square. Separate scores were determined for breeding and apparently non-breeding birds. For the purposes of illustrating the pattern of variation in diver flight activity across the study area (Figure 5.12), and the two values were summed. Figure 5.12 shows pattern of flight activity derived from flight activity data collected to 2007, (i.e. this is the same figure presented in the 2010 ES Addendum). The 200 x 200 m grid squares flight activity values for breeding and non-breeding birds were used as the starting point to derive estimates of flight activity at each turbine location for CRM.

The seven flight activity levels used in Figure 5.12 were as follows:

- Very Low, <3 km per year, (equivalent to *ca*. <26 passes p.a.).
- Low, 3 - 7.5 km per year, (equivalent to *ca*.26 - 50 passes).
- Medium Low, 7.5 – 15 km per year, (equivalent to *ca*. 51 - 100 passes).
- Medium High, 15 – 30 km per year, (equivalent to *ca*. 101 - 200 passes).
- High, 30 – 60 km per year, (equivalent to *ca*. 201- 400 passes).
- Very High, 60 – 120 km per year, (equivalent to *ca*. 401 - 800 passes).
- Extremely High, >120 km per year, (equivalent to *ca*.>800 passes).

The procedure to correct the raw data for biases was necessarily relatively complex because account had to be taken of the fact that the visibility from watch points varies considerably and effectively diminishes with distance (see distance detection results). It also needs to take account of the fact that flight activity is temporally uneven, both within a season and within a day, which means that watches at certain times inevitably record more activity than at others.

It was assumed that:

- The flight watch data were spatially representative of the flight routes across the areas observed.
- The temporal patterns of activity (calculated separately for breeders and non-breeders) were the same for all birds, i.e. it is fair to apply a single average temporal pattern to all areas.

Stages in Determining Observation Effort

Watch effort at each VP was translated from measurements of time (hours and minutes) and calibrated against the percentage of total annual flight activity that was theoretically observed at a particular focal breeding loch. This was achieved with reference to the analyses on temporal patterns in flight activity presented above. These analyses provide an estimate, both for breeding and for non-breeding birds, of the percentage of the total annual flight activity that occurs on average in each part of a day at each stage of the season at a particular breeding site. Thus, these analyses enable account to be taken of the variations in the 'value' of watch effort expended at different times of the day and the season. Separate calculations were made of watch effort for flight activity by breeding birds and by non-breeding birds. For ease of reference the measure of effort used is referred to here as 'percentage effort', e.g. '1% effort' means that 1% of the annual flight activity was theoretically observed.

The watch effort expended at a given VP only applies to relatively close by where the flights are witnessed. To calculate the effective watch effort beyond this the reduction in flight detectability with distance and viewing conditions (e.g. poor weather) need to be taken into account. This was done with reference to the results from the distance detection analyses. The effective effort from each VP was calculated for a series of four concentric distance zones from the VP. These were: 0-0.5 km, 0.5-1 km, 1-2 km and 2-3 km. Separate calculations were made for watch effort conducted in 'excellent', 'good', 'poor' and 'very poor' viewing conditions (defined above in 'Distance detection analyses'). For observations from focal watch VPs (but not generic VPs) separate calculations to take account of distance detection effects were required for inbound, outbound and 'fly-by' flights, because these had different distance detection functions (Fig. 18).

In addition to correcting effort for the effects of distance and weather, the area visible from each VP was also taken into account. The visible area at 20 m elevation above ground level, truncated at 3 km, was calculated using GIS software. All parts of the landscape within 3 km that were not visible from a VP (because they were hidden behind high ground) were treated as receiving zero effort as no flights could be seen in those areas.

Incidental effort, (the effort that went into recording incidental flights) was also calculated as far as possible. Incidental flights were recorded during the course of checking lochs. Whilst engaged in this fieldwork observers noted their position along their walk route every ten minutes or so. For the purposes of calculating incidental effort it was assumed that all flights within a 1 km radius of these positions were seen in that 10-minute period, and that none were seen beyond this distance. It was then a simple matter to calculate the percentage of the annual flight activity that was theoretically witnessed for the time of day and stage of season. Whilst this method is relatively unsophisticated it nevertheless gives a broadly accurate measure of the effort expended. Given that incidental flights formed only about 11% of all the flights recorded (and thus correspond to about 11% of the total watch effort) any inaccuracies will have a minor influence on the final results.

Finally, GIS software was used to calculate the effective watch effort from each watch position and each 10-minute incidental recording location for every 10x10 m square in an array covering the site. The watch effort for all locations combined was then calculated by summing the values for each 10x10 m square. These results were then converted to the mean effort for each 200x200 m square.

Determining Flight Activity

Using the mapped flight routes, GIS software was used to calculate the total observed distance flown by divers in each 200x200 m square. So that separate estimates could be made for breeding and non-breeding birds, all flights were given a probability of being by a breeding bird or non-breeding bird. In most cases this was known in which case the probability was either 1 or 0. If it was unknown (14% of flights) the probability was dependent on the prevailing ratio of breeder to non-breeder flights for the time of year the flight was seen (typically ratio was three breeding bird flights to two non-breeding bird flights).

Constructing the Effort-corrected Map of Flight Activity

Within each 200x200 m square, the observed total flight distance was divided by the estimated percentage observation effort, and then multiplied by 100 to give an estimate of annual flight distance. Results for flights by breeding birds and non-breeding birds were summed to give a figure for total annual flight distance in each square.

The scale of the analysis worked well provided the square had received a reasonable level of effort and several flights were observed there. However, in squares where effort was relatively low and/or no or few flights were observed, stochastic factors meant that the estimated flight activity values tended to be either zero or quite high. This was obviously an artefact of the combination of low effort and few flights and in these areas a 200 x 200 m resolution was too small. To overcome this problem smoothing was applied to all squares with <1.5% effort. The basis of this smoothing was to take into account in the calculation of the flight activity the values of the eight surrounding squares. Surrounding squares with zero effort were considered invalid and excluded from calculations. Also, if half or more of the surrounding square had zero effort there was considered to be too little information to calculate a reliable smoothed value and in which case the level of flight activity was classified as unknown. Where effort for a square was less than 0.5% the smoothed value of the square was taken to be the mean of the values for the square and it valid neighbours (up to eight). Where effort for a square was between 0.5% and 1.5% the smoothing was centre-weighted. The value was taken to be half the value of the square plus half the mean value of the eight surrounding squares.

These procedures effectively smoothed the geographic pattern of activity and helped highlight differences across the site (Figure 5.12). After this smoothing procedure a few cells (<20) remained that were clearly anomalous compared to their neighbours. These were individually examined and adjusted up or down (mostly down) if there was evidence that this was caused by stochastic effects, for example a single circling flight.

5.4 Collision rate modelling

The Band collision model (Band *et al.,* 2007) was used to estimate collision rates. The quantity of field data available for red-throated divers was much greater than for other species and for this reason collision estimates for red-throated diver were calculated individually for each turbine location. For all other species flight activity input data were the mean for all turbine locations, and so the collision rate was calculated for an average turbine and this was multiplied by the number of turbines to give the estimated collisions for the whole proposed development.

Red-throated Diver

Estimates of fight activity at each proposed turbine location used for CRM are presented in Table 5.1.12. In this table the flight activity values at each turbine, both for breeding and non-breeding birds, that were used in the CRM for the 2010 ES Addendum are compared with the values used in the CRM for the revised application after taken into consideration changes in population size and site occupancy.

The CRM undertaken for the 2010 Addendum took a highly precautionary approach to estimating diver annual diver flight activity across the proposed wind farm because, apart from a few then irregularly occupied sites, it was assumed that the average flight activity to and from, and in the general vicinity of, all regularly used diver breeding sites occurred at the level of intensity that occurred when these sites are occupied. In reality, in years when a site is not occupied the amount of diver flight activity associated with it will be much reduced. For breeding sites relevant to the revised application area (i.e. divers nesting in the Kergord and Nesting quadrants) the 2010 ES Addendum CRM assumed that all but two sites were occupied annually and that the other two sites were occupied in 50% and 60% of years respectively. For the purposes of the CRM for the revised application, it is assumed that these two sites are occupied in all years as in recent years occupancy rates have been very high.

Only two of the ‘new’ breeding sites (i.e., those where breeding was not recorded before 2010) are in locations where associated flight activity by breeding birds is likely to cross areas where turbines are proposed. These are the two sites with reference codes ‘FJ’ and ‘FM’ in Figure 5.3. The increase in flight activity in the vicinity of the three turbines that would potentially pose a risk to birds nesting at these two sites has been taken into consideration (Table 5.1.12).

The changes to the size of the non-breeding red-throated diver population using the revised site area and environs since the 2010 ES Addendum are unknown. For the purposes of CRM and evaluating the significance of potential collision mortality it is caustiously assumed that the non-breeding population has increased in line with the breeding population. It is thus assumed that flight activity by non-breeding birds that could be subject to collision risk has increased by 32% since compared to the level of flight activity assumed in the CRM presented in the 2010 ES Addendum.

The net effect of the above adjustments to diver flight activity values made to account for population and occupancy changes that have occurred since the 2010 ES Addendum is to increase the assumed flight activity at turbine locations by 22.5% and 32% for breeding birds and non-breeding birds respectively.

The calculation for Stage 2 of the Band Model for red-throated diver is presented in Table 5.1.13. The Band Stage 1 calculation for the proposed project is presented in Table 5.1.14.

Table 5.1.12. Estimated flight activity by breeding and non-breeding red-throated divers in the vicinity of proposed turbines used in collision rate modelling. Annual flight activity was calculated for 200 x 200 m cells centred on each proposed turbine. Values were converted from kilometres flown per year to hours flown per year using a mean flight speed of 17.5 m/s.

Quadrant	Turbine	Flight activity in 200 x 200 m grid cells (hours/year)			
		Values for 2010 ES Addendum CRM		Values for 2018 revised application CRM	
		Breeding birds	Non-breeders	Breeding birds	Non-breeders
Kergord	42	0.000	0.000	0.000	0.000
Kergord	43	0.000	0.000	0.000	0.000
Kergord	44	0.000	0.000	0.000	0.000
Kergord	45	0.000	0.000	0.000	0.000
Kergord	46	0.241	0.241	0.241	0.318
Kergord	47	0.032	0.032	0.032	0.043
Kergord	48	0.076	0.076	0.076	0.100
Kergord	49	0.667	0.216	0.667	0.285
Kergord	50	0.000	0.000	0.000	0.000
Kergord	51	0.000	0.000	0.000	0.000
Kergord	52	0.000	0.000	0.000	0.000
Kergord	53	0.000	0.000	0.000	0.000
Kergord	54	0.000	0.000	0.000	0.000
Kergord	55	0.000	0.000	0.000	0.000
Kergord	56	0.008	0.008	0.008	0.010
Kergord	57	0.000	0.000	0.000	0.000
Kergord	58	0.000	0.000	0.000	0.000
Kergord	59	0.000	0.000	0.000	0.000
Kergord	60	0.000	0.000	0.000	0.000
Kergord	61	0.000	0.000	0.000	0.000
Kergord	62	0.063	0.063	0.063	0.084
Kergord	63	0.031	0.018	0.031	0.023
Kergord	64	0.072	0.092	0.072	0.122
Kergord	66	0.048	0.197	0.080	0.259
Kergord	67	0.236	0.144	0.393	0.190
Kergord	68	0.167	0.105	0.167	0.138
Kergord	69	0.049	0.035	0.049	0.046
Kergord	70	0.061	0.060	0.061	0.080
Kergord	71	0.025	0.036	0.025	0.048
Kergord	72	0.090	0.368	0.090	0.486
Kergord	73	0.005	0.008	0.005	0.011
Kergord	74	0.000	0.000	0.000	0.000
Kergord	75	0.231	0.062	0.231	0.082
Kergord	76	0.452	0.487	0.452	0.643
Kergord	77	0.291	0.211	0.291	0.278
Kergord	78	0.040	0.141	0.040	0.187
Kergord	79	0.018	0.026	0.018	0.034
Kergord	80	0.000	0.000	0.000	0.000
Kergord	81	0.000	0.000	0.000	0.000
Kergord	82	0.000	0.000	0.000	0.000
Kergord	83	0.010	0.010	0.010	0.014
Kergord	84	0.000	0.000	0.000	0.000
Kergord	85	0.000	0.000	0.000	0.000

Quadrant	Turbine	Flight activity in 200 x 200 m grid cells (hours/year)			
		Values for 2010 ES Addendum CRM		Values for 2018 revised application CRM	
		Breeding birds	Non-breeders	Breeding birds	Non-breeders
Kergord	86	0.000	0.000	0.000	0.000
Kergord	87	0.000	0.000	0.000	0.000
Kergord	88	0.000	0.000	0.000	0.000
Nesting	89	0.083	0.470	0.083	0.621
Nesting	90	0.044	0.044	0.044	0.059
Nesting	91	0.000	0.000	0.000	0.000
Nesting	92	0.140	0.054	0.279	0.071
Nesting	93	0.017	0.060	0.034	0.080
Nesting	94	0.091	0.153	0.183	0.202
Nesting	95	0.000	0.000	0.000	0.000
Nesting	96	0.098	0.051	0.195	0.067
Nesting	97	0.124	0.044	0.248	0.059
Nesting	98	0.416	0.295	0.416	0.390
Nesting	99	0.149	0.097	0.149	0.128
Nesting	100	0.055	1.044	0.600	1.378
Nesting	101	0.078	1.156	0.600	1.525
Nesting	102	0.022	0.379	0.022	0.501
Nesting	103	0.054	0.301	0.054	0.397
Nesting	104	0.013	0.100	0.013	0.132
Nesting	105	0.224	0.502	0.224	0.663
Nesting	106	0.073	0.063	0.073	0.084
Nesting	107	0.048	0.417	0.048	0.550
Nesting	108	0.191	0.270	0.191	0.356
Nesting	109	0.043	0.694	0.043	0.916
Nesting	110	0.137	0.343	0.137	0.453
Nesting	111	0.044	0.141	0.044	0.186
Nesting	112	0.076	0.132	0.076	0.174
Nesting	113	0.102	0.726	0.102	0.958
Nesting	114	0.067	1.200	0.067	1.584
Nesting	115	0.287	0.168	0.287	0.221
Nesting	116	0.230	1.275	0.230	1.683
Nesting	117	0.157	0.948	0.157	1.251
Nesting	118	0.192	0.216	0.192	0.285
Nesting	119	0.152	0.133	0.152	0.175
Nesting	120	0.450	0.470	0.450	0.620
Nesting	121	0.278	0.275	0.278	0.362
Nesting	122	0.647	0.770	0.647	1.016
Nesting	123	0.046	0.084	0.046	0.111
Nesting	124	0.037	0.031	0.037	0.041
Nesting	125	0.192	0.824	0.192	1.088
Nesting	126	0.002	0.002	0.002	0.002
Nesting	127	0.183	0.349	0.600	0.460
Nesting	128	0.003	0.007	0.003	0.010
Nesting	129	0.279	0.234	0.279	0.309
Nesting	130	0.058	0.031	0.058	0.041
Nesting	131	0.265	0.170	0.265	0.224
Nesting	132	0.118	0.352	0.118	0.464

Quadrant	Turbine	Flight activity in 200 x 200 m grid cells (hours/year)			
		Values for 2010 ES Addendum CRM		Values for 2018 revised application CRM	
		Breeding birds	Non-breeders	Breeding birds	Non-breeders
Nesting	137	0.178	0.060	0.178	0.080
Nesting	138	0.000	0.000	0.000	0.000
Nesting	139	0.099	0.278	0.099	0.367
Nesting	140	0.041	0.041	0.041	0.054
Nesting	141	0.000	0.000	0.000	0.000
Nesting	142	0.032	0.032	0.032	0.043
Nesting	143	0.008	0.008	0.008	0.010
Nesting	144	0.020	0.113	0.020	0.149
Nesting	145	0.026	0.151	0.026	0.199
Nesting	147	0.000	0.000	0.000	0.000
Nesting	148	0.035	0.092	0.035	0.121
Nesting	149	0.079	0.297	0.079	0.392
Nesting	150	0.127	0.086	0.127	0.114
Average turbine		**0.092**	**0.183**	**0.113**	**0.242**

Table 5.1.13. Band Model Stage 2 calculation for the probability of collision by red-throated divers.

Stage 2 Collision risk											
K: [1D or [3D] (0 or 1)	1		Calculation of alpha and p(collision) as a function of radius								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.20	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	13.0		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.71	m	0.025	0.575	8.34	29.42	1.00	0.00125	28.33	1.00	0.00125
Wingspan	1.1	m	0.075	0.575	2.78	10.17	0.39	0.00291	9.08	0.35	0.00260
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.67	7.30	0.28	0.00348	5.97	0.23	0.00285
			0.175	0.860	1.19	6.33	0.24	0.00423	4.70	0.18	0.00314
Bird speed	17.5	m/sec	0.225	0.994	0.93	5.74	0.22	0.00493	3.86	0.15	0.00331
RotorDiam	120	m	0.275	0.947	0.76	4.67	0.18	0.00491	2.88	0.11	0.00303
RotationPeriod	4.49	sec	0.325	0.899	0.64	3.92	0.15	0.00486	2.22	0.08	0.00276
			0.375	0.851	0.56	3.45	0.13	0.00494	1.84	0.07	0.00264
			0.425	0.804	0.49	3.08	0.12	0.00500	1.56	0.06	0.00254
			0.475	0.756	0.44	2.78	0.11	0.00504	1.35	0.05	0.00245
Bird aspect ratioo: β	0.64		0.525	0.708	0.40	2.53	0.10	0.00507	1.19	0.05	0.00239
			0.575	0.660	0.36	2.31	0.09	0.00508	1.07	0.04	0.00234
			0.625	0.613	0.33	2.13	0.08	0.00507	0.97	0.04	0.00231
			0.675	0.565	0.31	1.96	0.07	0.00505	0.89	0.03	0.00229
			0.725	0.517	0.29	1.81	0.07	0.00500	0.83	0.03	0.00230
			0.775	0.470	0.27	1.67	0.06	0.00494	0.78	0.03	0.00232
			0.825	0.422	0.25	1.54	0.06	0.00487	0.75	0.03	0.00235
			0.875	0.374	0.24	1.43	0.05	0.00477	0.72	0.03	0.00241
			0.925	0.327	0.23	1.32	0.05	0.00466	0.72	0.03	0.00253
			0.975	0.279	0.21	1.22	0.05	0.00453	0.73	0.03	0.00272
				Overall p(collision) =		Upwind		9.1%		Downwind	5.1%
							Average	7.06%			

Table 5.1.14. Collision calculation for red-throated diver based on mean flight activity estimates for the 200 x 200 m grid cells surrounding turbines.

WIND FARM PARAMETERS		
Size of activity envelope	4	ha
Number of turbines	103	
Rotor diameter	120	m
Hub height	95	m
Rotor tip height (max)	155	m
Ground clearance (min)	35	m
Max. rotor depth in metres	4.4	m
Max. chord	4.2	m
Pitch	13.0	degrees
RPM	13.4	rpm
Rotation period	4.49	s
Turbine operation time	85	percent
BIRD PARAMETERS		
Length	0.71	m
Wingspan	1.1	m
Assumed flight speed	17.5	m/s
% flight activity at RSH	61.4%	
Stage 1 Collision risk		
Mortality estimate		
Flight risk volume (Vw)	4800000	m^3
Rotor swept area (Ar)	11310	m^2
Rotor swept volume (Vr) = Ar*(d+l)	57793	m^3
Bird transit time (t)	0.29	secs
Breeding adults		
Average turbine, 200mSq breeder occupancy (n)	0.113	hr/yr
Average turbine, 200mSq breeder occupancy at RSH (n)	0.069	hr/yr
Average turbine, breeder occupancy of rotor swept vol (b)	3.01	bird-secs
Average turbine, no. breeder rotor transits	10.30	transits/yr
Average turbine, no avoidance breeder collisions	0.62	deaths/yr
103 turbines, no avoidance	63.6	deaths/yr
103 windfarm breeder collisions, 99.5% avoidance	**0.32**	**deaths/yr**
Non-breeding birds		
Average turbine, 200mSq non-breeder occupancy (n)	0.242	hr/yr
Average turbine, 200mSq non-brd occupancy at RSH (n)	0.149	hr/yr
Average turbine, non-breeder occ of rotor swept volume (b)	6.44	bird-secs
Average turbine, no. non-breeder rotor transits	22.05	transits/yr
Average turbine, no avoidance non-breeder collisions	1.32	deaths/yr
103 turbines, no avoidance	136.2	deaths/yr
103 windfarm non-breeder collisions, 99.5% avoidance	**0.68**	**deaths/yr**

Other species

The turbine parameters used for CRM for other species are the same as for red-throated diver. Species-specific parameters are presented in Table 5.1.16. The size of activity envelope considered in the CRMs for other species is a single hectare. The CRM for whimbrel is presented in Table 5.1.15, by way of example.

Table 5.1.15. Collision calculation for proposed varied development for whimbrel. This example is based on flight activity derived from using Method 2.

WIND FARM PARAMETERS		
Size of activity envelope	1	ha
Number of turbines	103	
Rotor diameter	120	m
Hub height	95	m
Rotor tip height (max)	155	m
Ground clearance (min)	35	m
Max. rotor depth in metres	4.4	m
Max. chord	4.2	m
Pitch	13.0	degrees
RPM	13.4	rpm
Rotation period	4.49	s
Turbine operation time	85	percent
BIRD PARAMETERS		
Length	0.45	m
Wingspan	0.8	m
Assumed flight speed	13	m/s
Number of days birds potentially present	96	days
Number of hours birds potentially present	18	hours
Mean flight activity in vicinity of turbines (corrected for detection bias) (based on Method 2, see text)	366	sec/ha/yr
% flight activity at RSH	32.0	%
Stage 2 collision risk	6.72	%
Stage 1 Collision risk		
Flight risk volume (Vw)	1,200,000	m^3
Rotor swept area (Ar) (for 1 turbine)	11310	m^2
Combined rotor areas (Vr) (for 103 turbines)	1,164,903	m^2
Risk volume for all turbines (Vr * (d + l))	5,643,953	m^3
Average bird occupancy at rotor height (includes adjustment for Mid Kame turbines)	117.1	secs/year/ha
Average bird occupancy of rotor swept volume	550.6	bird-secs
Bird transit time (t)	0.37	secs
No. of transits through rotors	1,477	per year
Estimated no. of ‘no avoidance’ collisions	84.4	per year
After applying a 98% avoidance rate	1.69	deaths per year

Table 5.1.16. Input parameters for Band collision models for all species other than red-throated diver.

Input parameters	Merlin	Golden plover	Dunlin	Curlew	Whimbrel	Arctic skua	Great skua
Mean flight activity in vicinity of turbines (sec/ha/yr) (corrected for detection bias)	50	5116	656	2382	313, Method 1 366, Method 2	401	4683
% of flight activity at rotor height	31.0%	62.4%	22%	30%	32.0%	32.4%	53.5%
Bird length (m)	0.28	0.28	0.18	0.55	0.45	0.6	0.56
Bird wingspan (m)	0.56	0.72	0.41	0.90	0.80	1.10	1.33
Assumed flight speed (m/sec)	14	14	13	13	13	12	12
Stage 2 Collision probability (from Band Model)	5.7%	5.8%	5.3%	7.3%	6.7%	7.9%	7.8%

5.5 Analysis of displacement and disturbance

The methods used to estimate the potential for displacement and disturbance of breeding birds during the operational stage are based on those used for the 2010 ES Addendum and are summarised in Table 5.1.17.

For wader and skua species it is assumed that the larger size of the proposed project's turbines (120m diameter with a maximum tip height of 155m compared to the original proposal of 110m diameter turbines with a maximum tip height of 145m) could increase the potential for displacement of these species. The threshold distance between a pair's territory centre and a wind turbine for it to be considered at risk of displacement is increased from 200m to 250m, a linear increase of 25% and resulting in an area-at-risk increase of approximately 28%. This increase more than reflects the increase in the turbine rotor swept area (19%). The previous choice of threshold (200m) was informed by review of the literature considering the impacts of wind farms on the distribution of upland breeding waders (2010 ES Addendum). For the purposes of assessment it is assumed that 50% of pairs with a nominal territory centres closer than 250m from a proposed turbine location or 100m from a wind farm road would be displaced (Table 5.1.17).

For merlin and red-throated diver it is considered that proximity thresholds between breeding sites and wind turbines that were used in the 2010 ES Addendum were highly cautious and do not need to be increased to reflect the propose increased in turbine diameter and height. For merlin it is assumed that pairs nesting within 500m of a turbine could be potentially vulnerable to displacement.

Table 5.1.17. Method used to determine the potential magnitude of displacement of breeding birds during the operational stage of the proposed project

Species	2010 ES Addendum assessment for consented Viking Wind Farm (110m diameter turbines)	2018 Variation assessment (120m diameter turbines)	Change
Wader & skua species	50% of MBS nominal territory centres within either 200m of a turbines or 100m of wind farm road	50% of MBS nominal territory centres within either 250m of a turbine or 100m of wind farm road	Distance-from-turbines used to identify pairs at risk of displacement increased by 25% (from 200 to 250m)
Merlin	Nest sites within 500m of turbines	Nest sites within 500m of turbines	No change to method
Red-throated diver	Vulnerability Index based on proximity <500m to roads and turbines	Vulnerability Index based on proximity <500m to roads and turbines	No change to method

For red-throated diver the potential for displacement was estimated by calculating a disturbance vulnerability index (DVI) for each breeding site, in the same way as was done for the 2010 ES Addendum. The DVI is designed to take into consideration that susceptibility of this species to disturbance and displacement is strongly affected by the size of the breeding site; pairs on small lochans are more susceptible than those on larger sites. The severity of potential disturbance and displacement associated with access roads, turbine bases and turbine rotors was assumed to be correlated with proximity (distance from lochan), potential visibility from a lochan and lochan size (access roads and turbine bases only). These assumptions are based on experience of how breeding divers react to disturbance gained during baseline surveys. DVI values were calculated for each of these potential sources and then summed to give a Total DVI score (i.e., Total DVI score = DVI for access roads + DVI for turbine base + DVI for turbine rotors).

For access roads and turbine bases potential visibility (visible =1, not visible = 0) was determined for 2m elevation above access road/base level. This was undertaken in a GIS environment using Topos software (43D Ltd) and an Ordnance Survey Profile DTM (10m post spacing) elevation model. Two metres above ground level was chosen as it approximates to the maximum height above ground level of pedestrians and maintenance vehicles

Divers nesting on small lochans (<50m long) are more susceptible to disturbance from ground-based human activity than those at larger lochs. Birds are more likely to fly off and temporarily leave small lochans in response to being disturbed and less likely to ‘sit tight’ than birds at larger lochans. The DVI was weighted for lochan size according to three size categories: small (<50m maximum length) weighting score = 3; medium, (50-250m) weighting score = 2; and large (>250m) weighting score = 1. Although somewhat arbitrary this weighting system is designed to reflect the differences, albeit not quantified, in the average responses of birds observed during baseline fieldwork. Distances in metres between infrastructure and lochans were measured to the nearest shore, or in the case of larger sites (>100m) to the traditional nest site.

Thus the DVI calculations were as follows:

- DVI for access roads = (500 – closest distance) x visibility x lochan size weighting.
- DVI for turbine bases = (500 – distance from base) x visibility x lochan size weighting.
- DVI for turbine rotors = (500 – distance from base) x visibility.

An total DVI score was calculated for each breeding loch by adding together the individual DVI values for access roads, turbine bases and turbine rotors.

The use of DVI scores enabled the potential vulnerability of sites to disturbance to be assessed in a standard way and summarised as a single measure, the benefits of possible layout changes to be evaluated and the need for mitigation measures to be identified.

For the assessment of the proposed project the potential for disturbance to lead to displacement or breeding failure was determined according to the categories in Table 5.18. The DVI scores for diver breeding sites within the revised site area are shown in Table 5.1.19 for all breeding sites where the total DVI score is greater than zero (i.e. breeding sites within 500m of proposed wind farm infrastructure).

Table 5.1.18. Assumed changes in site occupancy and breeding success at by red-throated diver breeding lochs in response to different levels of potential disturbance as estimated by the total disturbance vulnerability index (DVI) score for a site.

Total DVI score	Assumed reduction in occupancy	Assumed reduction in breeding success
0	None	None
1 - 499	None	25%
500 - 999	None	50%
1000 - 1499	50%	50%
>1500	100%	100%

Table 5.1.19. Red-throated diver breeding lochans potentially affected by operational disturbance/displacement based on total disturbance vulnerability index (DVI) score for a site. Breeding sites with a total DVI score of zero are not shown.

Loch code	Breeding importance category	Closest visible access road (m)	Closest turbine (m)	Turbine base visible	Lochan size	Total DVI score
AX	High	>500	415	No	Medium	170
AY	Low	>500	490	No	Medium	10
BA	V. High	495	495	Yes	Medium	30
BB	Medium	400	400	Yes	Medium	600
BD	V. High	>500	440	No	Medium	120
BX	Low	>500	430	No	Small	210
DU	Medium	342	342	No	Small	1088
LBE	Low	485	485	Yes	Large	45
FJ	Low	210	215	Yes	Small	2010
FM	Very low	265	265	Yes	Medium	1175

The total DVI scores in Table 5.1.19 are used in the assessment of the proposed varied development to evaluate potential red-throated diver disturbance and displacement effects (Variation ES Chapter 5, paragraphs 5.4.33 to 5.5.38) based on the categories defined in Table 5.1.18.

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