



HAGSHAW HILL WIND FARM REPOWERING
ORNITHOLOGY
Appendix 8.1

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1 INTRODUCTION

MacArthur Green was commissioned by Hagshaw Hill Repowering Ltd to complete ornithological surveys at the proposed Hagshaw Hill Wind Farm Repowering site, near Douglas in South Lanarkshire (hereafter referred to as the 'Proposed Development' and the 'site'). The surveys were conducted between March and August 2018 to inform an assessment of the potential ornithological effects of the Proposed Development on the species assemblage present.

This technical report summarises the methods employed and the results of the field surveys and is supported by the following Annexes:

- Annex A: Ornithological Legal Protection;
- Annex B: Ornithological Survey Methodology;
- Annex C: Ornithological Survey Effort and General Information;
- Annex D: Ornithological Survey Results;
- Annex E: Collision Risk Assessments;
- Annex F: Review of the Effects of Artificial Light on Birds in Relation to Deployment of Obstruction Lighting on Wind Turbines; and
- Annex G: Supplementary Desk Study Information.

A range of surveys were employed to accurately record baseline conditions within the site and appropriate survey buffers (detailed in Annex B). In this Technical Appendix, associated Annexes (A – E) and Chapter 8 (Ornithology) of the Environmental Impact Assessment (EIA) Report, terms referred to are as follows:

- the site refers to the area within the red line boundary (**Figure 8.3**);
- 'survey area' is defined as the area covered by each survey type at the time of survey (**Figure 8.3**, refer to Annex B for details of various survey buffers); and
- 'study area' is defined as the area of consideration of effects on each species at the time of assessment (**Figure 8.3**).

2 LEGAL PROTECTION

With limited exceptions, all wild birds and their eggs are protected by law. Specific levels of protection are determined by a species' inclusion on certain lists. Annex A to this report details the various levels of legal protection afforded to UK bird species.

3 FIELD SURVEY METHODS

The following surveys were undertaken at the site between March and August 2018:

- Flight activity surveys (one breeding season), from one vantage point;
- Breeding bird surveys (one breeding season), within a 500m survey buffer;
- Scarce breeding bird surveys (one breeding season), within a 2km survey buffer; and

- Black grouse surveys (one breeding season), within a 1.5km survey buffer.

Survey methods followed the recommended SNH (2017¹) guidelines available at the time and methods are described in detail within Annex B. Where possible, each survey was carried out beyond the site within a buffer distance specific to that method (e.g. 2km buffer for the scarce breeding bird surveys) and these are detailed within Annex B.

The relative importance of the data collected was determined by the specific level of protection assigned to those species recorded, coupled with their perceived susceptibility to potential impacts resulting from the Proposed Development. The resulting 'target species' and 'secondary species' lists are a standard assessment tool for wind farm ornithological studies (see Annex B).

4 FIELD SURVEY RESULTS

All surveys were undertaken during suitable weather conditions (as described within Annex B – Survey Methodologies). Where weather conditions deteriorated below acceptable conditions (Annex B), surveys were either suspended or additional surveys were undertaken. In the case of flight activity surveys, any time where the visibility was <1km was excluded from total survey effort and subsequent analysis (further detail in section 4.1). Schedule 1/Annex 1 surveys were carried out by appropriately licensed surveyors. All survey data were reviewed, inputted, and analysed by MacArthur Green.

Survey effort and results of the field surveys are detailed within Annexes C & D and survey results are also illustrated within **Figure 8.5**. The following sections summarise the results from each survey undertaken.

4.1 Flight Activity

The flight activity surveys recorded all target species flight activity within the site and beyond. These data have been considered for inclusion in the collision risk modelling. The flights used in the model were those within the 'Collision Risk Analysis Area' (CRAA) (i.e. the area to be occupied by operational turbines, together with a 250m buffer to account for any surveyor inaccuracies).

Flight activity surveys across the 2018 breeding season were undertaken from one Vantage Point (VP) (**Figure 8.4**). A total of 34 hours of valid survey effort² were undertaken and full details of flight activity surveys are contained in Annex C with methodology in Annex B.

A total of six target species were recorded during the flight activity surveys (**Figure 8.5** presents observed flightlines and further details are provided in Annex D). For each species across the whole flight activity survey period, Table 8-1 details the number of flights recorded and the number of birds recorded³. The bird seconds are calculated for each observation as the product of flight duration and number of individuals. This is then summed per species to give the total bird seconds recorded across the entire surveyed period.

¹ Scottish Natural Heritage (2017) Recommended Bird Survey Methods to inform impact assessment of Onshore Windfarms.

² Hours where visibility was <1km are not considered valid for use in collision risk modelling as less than half the 2km viewshed can be seen.

³ This includes flights that would not technically be 'at-risk' of collision (e.g. recorded outwith the CRAA and/or not at rotor height).

Table 8-1 Target species recorded and total number of flights recorded during flight activity surveys, 2018

Species	Total number of flightlines recorded	Total number of birds recorded	Total bird seconds recorded*
Curlew	9	13	729
Golden plover	2	154	34,144
Herring gull	1	1	28
Lapwing	1	2	50
Osprey	1	1	90
Oystercatcher	1	1	32

*= flight duration x number of birds in flock

4.1.1 Flightlines Used in Collision Risk Modelling

Only flightlines identified to be within the CRAA and recorded within the 2km viewshed of the associated VP were considered in the collision risk modelling and Annex E provides details of the bird seconds from flights identified to be ‘at-risk’:

- ‘At-risk’ is defined as – a flight having at least part of its duration (i) at Potential Collision Height (PCH)⁴; (ii) within the CRAA; and (iii) recorded within the 2 km viewshed of the associated VP.
- PCH is defined as – the altitude between the lower and upper rotor tip height⁵ (in this case between 45m and 200m).

Curlew, herring gull and oystercatcher were recorded during flight activity surveys but no flights were ‘at-risk’⁶. Full survey results detailing the findings from each survey visit (including target species flightlines considered not ‘at-risk’ and secondary species information) can be found within Annex D. Only bird seconds for observations identified as within the CRAA and associated viewshed are considered in the following discussions. Full target species results are detailed within Annex D and the collision risk calculations are detailed in Annex E.

4.1.2 Collision Risk Model Outputs

The bird seconds for target species flights within the CRAA at PCH were then input into a Collision Risk Model (CRM) to calculate the predicted collision rates per season. The CRM calculations for each species can be found in Annex E. Table 8-2 provides the estimated collision rates and Table 8-3 the number of seasons per collision for each species.

Table 8-2 Estimated collision rate per species

Species	Collision rate
Golden plover (spring migration)	3.391
Lapwing (breeding)	0.030
Osprey (breeding)	0.015

⁴ In some cases, only part of a total flight duration was recorded at PCH, and it is assumed that this proportion is applicable for that part of the flight within the CRAA and 2km viewshed area.

⁵ Where the actual rotor blade altitude differs from the pre-defined survey height bands, the collision risk model accounts for this difference on the assumption of an even flight distribution within each particular survey height band, and an adjustment can be made to estimate total flight duration at actual rotor blade altitude.

⁶ i.e. the flights were either not within the CRAA and associated viewshed or were only recorded flying above PCH.

Table 8-3 Estimated number of seasons per collision

Species	Collision rate
Golden plover (spring migration)	0.29
Lapwing (breeding)	32.97
Osprey (breeding)	64.87

4.2 Breeding Birds

One complete breeding bird survey (comprising of four visits) was conducted in the 2018 breeding season (April to July 2018). Surveys recorded five wader species of which three were considered to be breeding (Table 8-4, wader activity is detailed on **Figure 8.6**). Full details of the breeding bird surveys are provided within Annexes C and D and survey methodology is provided within Annex B.

Table 8-4 Breeding wader territories, 2018 – (additional territories outwith the 500m study area)

Species	Number of territories
Common sandpiper	0 (1)
Curlew	1 (2)
Oystercatcher	0
Ringed plover	0
Snipe	3 (2)

4.3 Scarce Breeding Birds

Scarce breeding bird surveys were conducted during the 2018 (March to August) breeding season.

Peregrine was recorded in flight on two occasions during surveys (**Figure 8.7**), but no breeding attempts were located within the survey area.

On one survey in late August, a juvenile merlin was present within the site, but the species was absent apart from on this survey, and the observations are likely to represent a dispersing bird rather than a local breeder. On the same survey a male hen harrier and an osprey were recorded, also likely dispersing from breeding grounds elsewhere.

Buzzard, kestrel, sparrowhawk and tawny owl (secondary raptor species) were also recorded across the survey area and are likely to have bred within the wider area.

Full details of the scarce breeding bird surveys are provided within Annexes C and D, and survey methodology is provided within Annex B.

4.4 Black Grouse

Surveys to identify areas of black grouse activity, locate lek locations and establish lek size were conducted in the 2018 breeding season during April and May. No black grouse leks or black grouse themselves were recorded during targeted surveys (nor during any other surveys during the 2018 breeding season). Full details of the black grouse surveys are provided within Annex C and survey methodology is provided within Annex B.

ANNEX A ORNITHOLOGICAL LEGAL PROTECTION

In Scotland, all wild birds are protected under the Wildlife and Countryside Act 1981 (the 'Act'), as amended by the Nature Conservation (Scotland) Act 2004. This protection also extends to their eggs and nests, with it being an offence to intentionally or recklessly¹:

- Kill, injure or take any wild bird²;
- Take, damage, destroy or otherwise interfere with the nest of any wild bird while it is being built or is in use³;
- At any other time take, damage, destroy or otherwise interfere with any nest habitually used by any wild bird included in Schedule A1 (Protected Nests and Nest Sites for Birds: white-tailed eagle and golden eagle)⁴;
- Obstruct or prevent any wild bird from using its nest⁵; or
- Take or destroy an egg of any wild bird⁶.

It is also an offence to have in possession or control any live or dead wild bird or any part thereof; or any egg or part of an egg of any wild bird⁷.

Further special protection under this legislation is afforded to those species listed in Schedule 1 of the Act. For these species, it is an offence to:

- Intentionally or recklessly disturb any wild bird listed in Schedule 1 while it is nest building, or is in, on or near a nest containing eggs or young, or disturb the dependent young of such a bird⁸;
- Intentionally or recklessly disturb any wild birds included in Schedule 1 which leks, while it is doing so⁹ (capercaillie is the only bird this offence applies to in Scotland);
- Intentionally or recklessly harass any wild bird included in Schedule 1A¹⁰. Section 1, subsection 5B states, '*Subject to the provisions of this Part, any person who intentionally or recklessly harasses any wild bird included in Schedule 1A shall be guilty of an offence*'. At this time, Schedule 1A includes golden eagle, hen harrier, red kite and white-tailed eagle. This updated legislation was introduced on 16 March 2013; or

- Intentionally or recklessly take, damage, destroy or otherwise interfere with any nest and/or nest site habitually used by any bird on Schedule A1 at any time. At this time, Schedule 1A includes golden eagle and white-tailed eagle¹¹.

It is also an offence to knowingly cause or permit to be done an act which is made unlawful by any of the above provisions.

Further protection is described under the EU Birds Directive which requires member states to maintain wild bird species in favourable conservation status¹² and promote the conservation of bird species listed within Annex 1 of the Birds Directive through the protection of their habitat. This is achieved via the designation of Special Protection Areas (SPAs).

Red List bird species are those deemed to be globally threatened and to be suffering population declines within the UK. Although not legally enforceable, the conservation of Red List bird species represents a material consideration, in planning terms.

¹ Exceptions to these offences exist under various circumstances (e.g. controlling pest species; taking birds during specific season; and killing sick or injured birds etc.).

² Wildlife and Countryside Act 1981, Section 1(1)(a)

³ Wildlife and Countryside Act 1981, Section 1(1)(b)

⁴ Wildlife and Countryside Act 1981, Section 1(1)(ba)

⁵ Wildlife and Countryside Act 1981, Section 1(1)(bb)

⁶ Wildlife and Countryside Act 1981, Section 1(1)(c)

⁷ Wildlife and Countryside Act 1981, Section 1(2)

⁸ Wildlife and Countryside Act 1981, Section 1(5)

⁹ Wildlife and Countryside Act 1981, Section 1(5A)

¹⁰ Wildlife and Countryside Act 1981, Section 1(5B)

¹¹ This reflects the changes introduced by the Wildlife and Countryside Act 1981 (as amended by: Variation of Schedules A1 and 1A (Scotland) Order 2013

¹² While the term 'favourable conservation status' is not used in the Birds Directive, EU court cases over recent years have progressively interpreted the concept as meaningful in a Birds Directive context (SNH, 2006).

ANNEX B ORNITHOLOGICAL SURVEY METHODOLOGY

In addition to the desk-based study undertaken for Hagshaw Hill Wind Farm Repowering (hereafter referred to as 'the Proposed Development'), ornithological surveys were undertaken in 2018. The methodologies used across all surveys are summarised in the sections below; more detailed descriptions are provided in the Scottish Natural Heritage (SNH) guidance (2017ⁱ) on which these surveys are based.

Study Area

Surveys were undertaken during the 2018 breeding season. Flight activity, black grouse, breeding and scarce breeding bird survey study areas were buffered from the proposed turbine layout (**Figure 8.3 and Figure 8.4**) provided by the client.

Delaunay Triangulation from the turbine points was used to create a wind farm area¹ and from this the Collision Risk Analysis Area (CRAA) was defined using a 250m buffer (**Figure 8.4**). Using the larger 250m area around the turbines accounts for possible inaccuracies in the recording of flightlines and ensures the assessment is precautionary. Target species flight activity within this area were used to inform the Collision Risk Analysis.

B.1 Flight Activity Survey

The aims of the flight activity (vantage point) surveys are: (1) to record flight activity within the vicinity of the site in order to identify areas of importance to birds; and (2) to quantify flight activity within 500m of the proposed turbines in order to estimate the likelihood of collision (SNH, 2017ⁱ P14-19).

Timing

- A survey period of 36 hours is recommended as the minimum level of sampling intensity at each VP for each season (breeding, non-breeding, migratory) (SNH, 2017ⁱ P17);
- Watches were spread as evenly throughout the year as possible to ensure that temporally representative data are collected (see Annex C). Specific consideration was given to the period around dawn and twilight for breeding waders/migratory geese and to changing raptor behaviour across seasons (SNH, 2017ⁱ P17);
- Watches were suspended and resumed to take account of changes in visibility (e.g. fluctuations in cloud base). Watches were undertaken in conditions of good ground visibility when the cloud base was higher than the most elevated ground being observed; and
- Watches were conducted in a range of weather conditions and were spread throughout the day (see Annexes C and D).

Field Methods

- Viewshed analysis was conducted using Arc GIS to confirm suitable Vantage Point (VP) locations and their associated visible areas²;
- Reconnaissance surveys were undertaken to refine VP locations;
- The VP location and associated viewshed is detailed in **Figure 8.4**;

¹ This was adjusted where appropriate depending on the spatial location of the turbines in relation to other turbines.

² The viewsheds are based on a 5m DTM to provide a representation of visibility from the observer locations; this is confirmed and refined through field site visits.

- Care was taken to maximize the area visible whilst minimising disturbance to birds;
- The final single VP location was selected with the aim of achieving coverage of the whole study area such that no point was greater than 2 kilometres from a VP. This objective was achieved for the majority of the CRAA, although a small area on the northern edge of the CRAA (1.7%) remained 'invisible'³;
- A maximum 180° view arc was scanned. This rule does not however apply when tracking migratory geese and waterfowl, raptors or divers across the CRAA;
- Each watch lasted a maximum of three hours but was suspended and then resumed to take account of changes in visibility (e.g. fluctuations in the cloud base).

For species of high nature conservation importance (target species) the following data were recorded (SNH, 2017ⁱ P17-18):

- The flightlines by individuals or flocks of birds;
- The time the target bird was detected and the duration (seconds) spent flying over a defined study area (the viewshed);
- The birds' flight heights (defined into prescribed height bands⁴) were recorded at the point of detection and at 15 second intervals thereafter. From this the proportion of time spent flying below, within (referred to as Potential Collision Height (PCH)) and above approximate rotor height could be estimated;
- Any difference between survey height bands and actual rotor height is accounted for within the collision risk models on the assumption of even flight distribution;
- The flight path followed was plotted in the field onto 1:25,000 scale maps;
- Observation of target species took priority over recording secondary species;
- The number of birds recorded were the minimum number of individuals that could account for the activity observed; and
- Observers only recorded perched birds and birds on water-bodies once only on arrival at the VP. Thereafter only flying birds and newly noticed perched/swimming birds were included in the activity summaries.

B.2 Moorland Breeding Bird Survey

Upland breeding bird survey methodology was employed as detailed within SNH Guidance (SNH, 2017ⁱ P11). Study areas are detailed in **Figure 8.3**. In summary, surveys involved the following:

- Open upland (including hedgerows, scrub, isolated trees and copses) was surveyed using an intensive version of the Brown and Shepherd (1993ⁱⁱ) method for upland bird survey;
- The objectives were to map the distribution of breeding bird territories and estimate the approximate size of breeding bird populations;

³ The habitat here is of sufficient similarity such that the survey data collected and subsequently assessed are considered to be representative of the whole CRAA. In addition, there were no records made during any of the BBS, breeding raptor and walkover surveys which would suggest that this area was of any importance to target species.

⁴ Flight height is defined into five height bands: 0-20m, 21-40m, 41-100m, 101-150m, >151m.

- After each survey visit one overview map was then produced showing all target species. Due to the cryptic nature of many breeding birds and the necessary assumptions made when plotting territories, a minimum and maximum number of territories was identified for each target species;
- The survey covered all areas within 500m of the site; and
- All upland wader species were recorded during the breeding bird survey.

Timing

- As recommended in Calladine *et al.* (2009ⁱⁱⁱ), four survey visits were undertaken between April and July;
- Fieldwork was undertaken between sunrise and sunrise and 1800hrs; and
- Fieldwork was not undertaken in conditions considered likely to affect bird detection rates, for example in winds greater than Beaufort Scale Force 4, persistent precipitation, poor visibility (less than 300m), or in unusually hot weather.

Field Methods

- Walk-routes which optimised ground visibility were used;
- Surveyors paused at appropriate vantage and listening points;
- Isolated trees, copses and patches of scrub were approached and examined;
- Streams, ditches and hedgerows were walked;
- All other areas were approached to within 100m; and
- Registrations were mapped at the first location that behaviour indicative of breeding was observed; and
- Standard BTO activity codes were used.

B.3 Scarce Breeding Bird Survey

The aim of the scarce breeding bird surveys was to determine the distribution of occupied nests/territories for target raptor, owl and diver species within 2km of the site and record breeding success. Secondary species such as buzzard, sparrowhawk and kestrel were also noted but location of their nests was not the key focus of the surveys. Survey areas are detailed in **Figure 8.3**.

Surveys were undertaken by experienced and licensed⁵ field ornithologists. Extreme care was taken to avoid unnecessary disturbance to breeding birds.

Guidance from SNH (SNH, 2017ⁱ P11-14), 'Bird Monitoring Methods' (Gilbert *et al.* 1998^{iv}) and 'Raptors: a field guide to survey and monitoring' (Hardey *et al.* 2013^v) were all consulted to inform survey methodology and are referenced where appropriate in the species methodologies below.

Barn Owl

- The surveys followed methodology outlined in Gilbert *et al.* (1998^{iv}), as mentioned in SNH Guidance (SNH, 2017ⁱ P12-13);
- Surveys were undertaken within 1km of the site; and

- Surveyors checked for signs of occupation (moulted feathers, pellets) in all suitable buildings within this 1km buffer.

Goshawk

Methodology outlined in Hardey *et al.* (2013^v) was used as guidance for the surveying of areas for potential goshawk breeding. Extreme care was taken not to disturb potential nests especially around the time of year when females were likely to be laying or incubating.

- Areas of suitable woodland were observed for the presence of nests. Searches for goshawk nests were focused on mature forestry blocks, although their presence was not ruled out of other wooded areas;
- Searches carried out between March and April focussed on observing territorial and nest building behaviours;
- Where nests were known to be present, scans were carried out between mid-March and May to confirm breeding. Scans were kept brief – carried out for between 5-10 minutes and from a distance; and
- When breeding was confirmed, searches for further nests were deferred until such a time as the young had hatched. Searches were then undertaken between late May and late June for evidence of provisioning young and then between late July and early August to watch for fledgling activity, this included listening for the begging calls of newly fledged young.

Hen Harrier

Methodology outlined in Hardey *et al.* (2013^v) was used as guidance for the surveying of areas for potential hen harrier breeding. Extreme care was taken not to disturb potential nests especially around the time of year when females were likely to be laying or in cold/wet weather when females were likely to be incubating or brooding. Areas of suitable habitat⁶ were visited during four time periods across the breeding season to:

- Check for territory occupancy (between March and mid-April) – this consisted of watching over suitable habitat from a good vantage point for displaying males (and females) and checking all areas of suitable habitat to within 250m (watching out for signs of kills);
- Locate incubating females (between mid-April and late May) by listening for female begging calls and watching for food passes between the male and female – surveyors watched for at least four hours as Hardey *et al.* (2013^v) notes that when the female is incubating it can be up to six hours between feeding visits from the male, but on average it is less than every four hours. Surveys were undertaken between 06:00 to 12:00 or 16:00 to 20:00;
- Check for young or breeding evidence (between late May and late June) again by listening for female begging calls and watching for food passes between male and female when the female is brooding and watching for the male and female provisioning the nest with food once brooding has ended– surveyors watched for at least two hours as Hardey *et al.* (2013^v) notes that an adult bird will visit the nest every 1-2 hours. Surveyors also watched for display behaviour which could indicate a failed breeding attempt; and
- Check for fledged young (between late June and late August).

⁶ Unsuitable habitat areas include: land above 600m; improved pasture and arable land; extensive areas of degraded land with no heather cover and low vegetation; the vicinity of cliffs, rocky outcrops, boulder fields and scree; areas within 100m of hill farms and occupied dwellings.

⁵ All surveyors hold SNH Schedule 1 Licences.

Merlin

Methodology outlined in Hardey *et al.* (2013^v) was used as guidance for the surveying of areas for potential merlin breeding.

- Areas of suitable nesting habitat (including forest edge where trees are >5m high) were closely observed between 20th March and 30th April;
- Boulders, fence lines, isolated posts, stone dykes, grouse butts, hummocks, stream banks, crags, trees and recently burnt areas of heather were checked for signs of occupation (e.g. plucked prey, moulted feathers, pellets and faeces);
- If merlin were observed, or signs found, areas were visited at least twice to verify occupation of the site; and
- Potential nest areas were watched for 4-6 hours if necessary.

Peregrine

- Potential nest sites were visited and checked for evidence of occupation between March and April;
- Sites checked included crags and steep banks identified from OS maps and searches of the study area;
- Surveyors checked for signs of occupation (e.g. faecal splash, fresh plucked prey);
- If occupied sites were found they were re-visited to verify incubation; and
- Searches were made for eyries. Where this was not possible sites were watched from a suitable vantage point for 3-4 hours or until a nest was located.

Short-Eared Owl

- At least two visits between early April and the end of May were carried out;
- Suitable habitat was visited and checked for evidence of hunting males, territorial activity and other signs of presence; and
- If breeding was confirmed, a further visit was made in June to watch birds, locate nest-sites and confirm breeding behaviour wherever possible.

B.4 Black Grouse Survey

The survey methodology used is detailed in SNH Guidance (SNH, 2007b^{vi}; SNH, 2017ⁱ P12) and a summary is provided below. Survey areas are detailed in **Figure 8.3**. Surveys were conducted in April and May in 2018.

- Breeding Black Grouse were surveyed within 1.5km of the site by counting total numbers of males and females at leks, most lekking activity taking place at or soon after dawn in spring.
- Known lek sites and other areas of suitable habitat which can host leks were identified and visited during April within 2 hours of dawn on calm dry days with good visibility;
- Visits involved listening and scanning for lekking black grouse from strategic locations (avoiding disturbance of leks) and during walks between these locations ensuring that all potential habitat was covered;
- The maximum count of males in the 2 hours around dawn gives the standard count estimate but the maximum number of females seen was also presented; and

- Leks that were at least 200m apart within the same year were treated as separate leks.

ⁱ Scottish Natural Heritage (2017) Recommended bird survey methods to inform impact assessment of onshore windfarms.
ⁱⁱ Brown, A. F. and Shepherd, K. B. (1993) A method for censusing upland breeding waders. *Bird Study*, 40: 189-195.
ⁱⁱⁱ Calladine, J., Garner, G., Wernham, C., & Thiel, A. (2009) The influence of survey frequency on population estimates of moorland breeding birds. *Bird Study*, 56: 3, 381-388.
^{iv} Gilbert, G., Gibbons, D. W. and Evans, J. (1998) *Bird Monitoring Methods*. RSPB, Sandy.
^v Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B. and Thompson, D. (November 2013) *Raptors: a field guide for surveys and monitoring* (3rd edition). The Stationery Office, Edinburgh.
^{vi} Scottish Natural Heritage (2007) *Black grouse survey methodology*.

ANNEX C ORNITHOLOGICAL SURVEY EFFORT & GENERAL INFORMATION

Table C-1 shows the system used for recording weather conditions on all the surveys detailed in sections C.1 to C.4 below.

Table C-1 Key to meteorological conditions recorded during all surveys

Wind speed	Rain	Cloud cover	Cloud height
Calm	0	None	0
Light air	1	Drizzle/Mist	1
Light breeze	2	Light showers	2
Gentle breeze	3	Heavy showers	3
Moderate breeze	4	Heavy rain	4
Fresh breeze	5		
Strong breeze	6		
Moderate gale	7		
Fresh gale	8		
Strong gale	9		
Whole gale	10		
Storm	11		
Hurricane	12		

	Snow	Frost	Visibility
	None	0	None
	On site	1	Ground
	High ground	2	All day

	Cloud height
	In eighths
	<i>e.g.</i> 3/8
	<150m
	150-500m
	>500m

C.1 Flight Activity Surveys

Flight activity surveys were undertaken during the 2018 breeding season. Details of the flight activity surveys undertaken are supplied in Table C-2 and the associated weather data recorded is detailed in Table C-3. Refer to Annex B for survey methodology and Annex D for survey results.

Table C-2 Summary of flight activity surveys undertaken at Hagshaw Hill (sorted chronologically)

Date	Season	VP	Observer	Survey start time	Survey finish time	No. hours ¹ surveyed
27/03/2018	BR 2018	1	MW	0730	1030	2
27/03/2018	BR 2018	1	MW	1100	1300	2
23/04/2018	BR 2018	1	SP	0855	1155	3
23/04/2018	BR 2018	1	SP	1225	1525	3
15/05/2018	BR 2018	1	RD	0900	1200	3
15/05/2018	BR 2018	1	RD	1230	1530	3
11/06/2018	BR 2018	1	SP	0830	1130	3
11/06/2018	BR 2018	1	SP	1200	1500	3
23/07/2018	BR 2018	1	MW	0630	0930	3
23/07/2018	BR 2018	1	MW	1000	1300	3
16/08/2018	BR 2018	1	MW	0630	0930	3
16/08/2018	BR 2018	1	MW	1000	1300	3

¹ Note: only valid hours (i.e. where visibility was at least 1km) are presented in this column.

Table C-3 Meteorological conditions during flight activity surveys at Hagshaw Hill (sorted chronologically)

Date	VP	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
27/03/2018	1	MP	0730	1030	1	2	SSE	2	8	1	1	0	0
27/03/2018	1	MP	0730	1030	2	2	SSE	1	8	0	0	0	0
27/03/2018	1	MP	0730	1030	3	3	SSE	2	8	1	1	0	0
27/03/2018	1	MP	1030	1400	1	3	SSE	2	8	1	1	0	0
27/03/2018	1	MP	1030	1400	2	3	SSE	2	8	1	1	0	0
23/04/2018	1	SP	0855	1155	1	5	WSW	2	8	1	1	0	0
23/04/2018	1	SP	0855	1155	2	4	WSW	0	7	2	2	0	0
23/04/2018	1	SP	0855	1155	3	4	W	0	8	2	2	0	0
23/04/2018	1	SP	1225	1525	1	4	WSW	2	8	2	2	0	0
23/04/2018	1	SP	1225	1525	2	4	WSW	2	7	2	2	0	0
23/04/2018	1	SP	1225	1525	3	3	SW	3	7	2	2	0	0
15/05/2018	1	RD	0900	1230	1	3	W	0	7	2	2	0	0
15/05/2018	1	RD	0900	1230	2	3	W	0	8	2	2	0	0
15/05/2018	1	RD	0900	1230	3	3	W	0	8	2	2	0	0
15/05/2018	1	RD	1230	1530	1	3	W	0	8	2	2	0	0
15/05/2018	1	RD	1230	1530	2	3	W	0	8	2	2	0	0
15/05/2018	1	RD	1230	1530	3	3	W	0	8	2	2	0	0
11/06/2018	1	SP	0830	1130	1	2	WNW	0	8	2	2	0	0
11/06/2018	1	SP	0830	1130	2	3	NW	0	7	2	2	0	0
11/06/2018	1	SP	0830	1130	3	3	NW	0	6	2	2	0	0
11/06/2018	1	SP	1200	1500	1	2	NW	0	6	2	2	0	0
11/06/2018	1	SP	1200	1500	2	3	NE	2	6	2	2	0	0
11/06/2018	1	SP	1200	1500	3	2	NE	0	6	2	2	0	0
23/07/2018	1	MW	0630	0930	1	5	SW	0	7	2	2	0	0
23/07/2018	1	MW	0630	0930	2	6	SW	0	6	2	2	0	0
23/07/2018	1	MW	0630	0930	3	5	SW	0	6	2	2	0	0
23/07/2018	1	MW	1000	1300	1	5	SW	0	5	2	2	0	0
23/07/2018	1	MW	1000	1300	2	5	SW	0	5	2	2	0	0
23/07/2018	1	MW	1000	1300	3	5	SW	0	4	2	2	0	0
16/08/2018	1	MW	0630	0930	1	4	SSW	0	7	2	2	0	0
16/08/2018	1	MW	0630	0930	2	5	SSW	0	8	2	2	0	0
16/08/2018	1	MW	0630	0930	3	5	SSW	0	7	2	2	0	0
16/08/2018	1	MW	1000	1300	1	5	SSW	0	7	2	2	0	0
16/08/2018	1	MW	1000	1300	2	5	SSW	0	7	2	2	0	0
16/08/2018	1	MW	1000	1300	3	5	SSW	0	7	2	2	0	0

C.2 Moorland Breeding Bird Surveys

Moorland breeding bird surveys were undertaken during the 2018 breeding season. Table C-4 details survey dates and weather data recorded. Refer to Annex B for survey methodology and Annex D for survey results.

Table C-4 Meteorological conditions during breeding bird surveys at Hagshaw Hill (sorted chronologically)

Date	Survey visit	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
21/04/2018	1	SP	0715	1215	1	3	S	0	8	1	1	0	0
21/04/2018	1	SP	0715	1215	2	4	S	0	5	2	2	0	0
21/04/2018	1	SP	0715	1215	3	3	S	0	4	2	2	0	0
21/04/2018	1	SP	0715	1215	4	3	S	0	3	2	2	0	0
07/05/2018	2	RD	0915	1345	1	4	SE	0	2	2	2	0	0
07/05/2018	2	RD	0915	1345	2	4	SE	0	2	2	2	0	0
07/05/2018	2	RD	0915	1345	3	4	SE	0	2	2	2	0	0
07/05/2018	2	RD	0915	1345	4	4	SE	0	2	2	2	0	0
23/05/2018	2	SP	0645	1345	1	2	E	0	8	1	1	0	0
23/05/2018	2	SP	0645	1345	2	2	E	0	5	2	2	0	0
23/05/2018	2	SP	0645	1345	3	2	E	0	2	2	2	0	0
23/05/2018	2	SP	0645	1345	4	2	E	0	2	2	2	0	0
23/05/2018	2	SP	0645	1345	5	2	E	0	2	2	2	0	0
23/05/2018	2	SP	0645	1345	6	2	E	0	2	2	2	0	0
18/06/2018	3	SP	0500	1030	1	4	WSW	0	7	2	2	0	0
18/06/2018	3	SP	0500	1030	2	4	WSW	1	7	2	2	0	0
18/06/2018	3	SP	0500	1030	3	4	WSW	1	7	2	2	0	0
18/06/2018	3	SP	0500	1030	4	4	WSW	0	6	2	2	0	0
18/06/2018	3	SP	0500	1030	5	4	WSW	0	5	2	2	0	0
09/07/2018	4	MW	0830	1130	1	2	WNW	0	8	2	2	0	0
09/07/2018	4	MW	0830	1130	2	3	WNW	0	8	2	2	0	0
09/07/2018	4	MW	0830	1130	3	3	WNW	0	8	2	2	0	0
09/07/2018	4	MW	1200	1500	1	5	WNW	0	7	2	2	0	0
09/07/2018	4	MW	1200	1500	2	5	WNW	0	7	2	2	0	0
09/07/2018	4	MW	1200	1500	3	5	WNW	0	6	2	2	0	0

C.3 Scarce Breeding Bird Surveys

Scarce breeding bird surveys were undertaken during the 2018 breeding season. Table C-5 details survey dates and weather data recorded. Refer to Annex B for survey methodology and Annex D for survey results.

Table C-5 Meteorological conditions during scarce breeding bird surveys at Hagshaw Hill (sorted chronologically)

Date	Survey visit	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
26/03/2018	1	MW	0900	1500	1	4	WSW	0	3	2	2	1	1
26/03/2018	1	MW	0900	1500	2	4	WSW	0	3	2	2	1	1
26/03/2018	1	MW	0900	1500	3	5	WSW	0	3	2	2	1	1
26/03/2018	1	MW	0900	1500	4	5	WSW	0	4	2	2	0	1
26/03/2018	1	MW	0900	1500	5	5	WSW	0	5	2	2	0	1
26/03/2018	1	MW	0900	1500	6	5	WSW	0	6	2	2	0	1
27/03/2018	1	MW	1300	1400	1	3	SSW	1	8	0	0	0	0
18/04/2018	2	SP	0630	0830	1	3	SW	1	8	2	2	0	0
18/04/2018	2	SP	0630	0830	2	3	SW	0	8	2	2	0	0
18/04/2018	2	SP	1030	1445	3	3	SW	0	7	2	2	0	0
18/04/2018	2	SP	1030	1445	4	3	SW	0	6	2	2	0	0
18/04/2018	2	SP	1030	1445	5	3	SW	0	8	2	2	0	0
18/04/2018	2	SP	1030	1445	6	3	SW	0	8	2	2	0	0
24/04/2018	2	SP	0700	1215	1	4	SW	0	7	2	2	0	0
24/04/2018	2	SP	0700	1215	2	4	SW	2	8	2	2	0	0
24/04/2018	2	SP	0700	1215	3	3	SW	2	8	2	2	0	0
24/04/2018	2	SP	0700	1215	4	3	SW	0	7	2	2	0	0
24/04/2018	2	SP	0700	1215	5	4	SW	0	6	2	2	0	0
24/04/2018	2	SP	0700	1215	6	4	SW	0	7	2	2	0	0
28/05/2018	3	SP	0905	1205	1	1	ENE	0	3	2	2	0	0
28/05/2018	3	SP	0905	1205	2	2	NE	0	3	2	2	0	0
28/05/2018	3	SP	0905	1205	3	2	NE	0	5	2	2	0	0
28/05/2018	3	SP	1230	1530	4	2	NE	0	5	2	2	0	0
28/05/2018	3	SP	1230	1530	5	3	NE	0	5	2	2	0	0
28/05/2018	3	SP	1230	1530	6	3	NE	0	4	2	2	0	0
29/05/2018	3	SP	0645	1245	1	0	0	0	0	0	1	0	0
29/05/2018	3	SP	0645	1245	2	1	ENE	0	0	0	1	0	0
29/05/2018	3	SP	0645	1245	3	2	ENE	0	3	2	2	0	0
29/05/2018	3	SP	0645	1245	4	2	ENE	0	4	2	2	0	0
29/05/2018	3	SP	0645	1245	5	2	ENE	0	4	2	2	0	0
29/05/2018	3	SP	0645	1245	6	3	ENE	0	5	2	2	0	0
18/06/2018	4	SP	1100	1500	1	4	WSW	0	8	2	2	0	0
18/06/2018	4	SP	1100	1500	2	4	WSW	0	5	2	2	0	0
18/06/2018	4	SP	1100	1500	3	4	WSW	0	3	2	2	0	0
18/06/2018	4	SP	1100	1500	4	4	WSW	0	3	2	2	0	0
21/06/2018	4	SP	1215	1615	1	4	NW	0	4	2	2	0	0
21/06/2018	4	SP	1215	1615	2	4	NW	0	3	2	2	0	0
21/06/2018	4	SP	1215	1615	3	4	NW	0	4	2	2	0	0
21/06/2018	4	SP	1215	1615	4	5	NW	0	4	2	2	0	0

Date	Survey visit	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
27/06/2018	4	MW	0700	1000	1	2	SSW	0	1	2	2	0	0
27/06/2018	4	MW	0700	1000	2	2	SSW	0	1	2	2	0	0
27/06/2018	4	MW	0700	1000	3	2	SSW	0	1	2	2	0	0
27/06/2018	4	MW	1030	1330	4	2	SSW	0	1	2	2	0	0
27/06/2018	4	MW	1030	1330	5	2	SSW	0	1	2	2	0	0
27/06/2018	4	MW	1030	1330	6	2	SSW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	1	1	SW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	2	1	SW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	3	1	SW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	4	2	SW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	5	2	SW	0	1	2	2	0	0
28/06/2018	4	MW	0700	1000	6	2	SW	0	1	2	2	0	0
29/06/2018	4	MW	0500	0800	1	4	SE	0	0	2	2	0	0
29/06/2018	4	MW	0500	0800	2	4	SE	0	0	2	2	0	0
29/06/2018	4	MW	0500	0800	3	4	SE	0	1	2	2	0	0
29/06/2018	4	MW	0830	1130	4	3	SE	0	1	2	2	0	0
29/06/2018	4	MW	0830	1130	5	3	SE	0	1	2	2	0	0
29/06/2018	4	MW	0830	1130	6	2	SE	0	1	2	2	0	0
04/07/2018	5	MW	0630	0930	1	3	NW	0	1	2	2	0	0
04/07/2018	5	MW	0630	0930	2	4	NW	0	1	2	2	0	0
04/07/2018	5	MW	0630	0930	3	5	NW	0	3	2	2	0	0
04/07/2018	5	MW	1000	1300	1	5	S	0	4	2	2	0	0
04/07/2018	5	MW	1000	1300	2	5	S	0	4	2	2	0	0
04/07/2018	5	MW	1000	1300	3	5	SSW	0	3	2	2	0	0
05/07/2018	5	MW	0630	0930	1	4	WNW	0	4	2	2	0	0
05/07/2018	5	MW	0630	0930	2	5	WNW	0	4	2	2	0	0
05/07/2018	5	MW	0630	0930	3	5	WNW	0	5	2	2	0	0
05/07/2018	5	MW	1000	1300	1	6	WNW	0	5	2	2	0	0
05/07/2018	5	MW	1000	1300	2	5	WNW	0	6	2	2	0	0
05/07/2018	5	MW	1000	1300	3	5	WNW	0	6	2	2	0	0
24/07/2018	5	MW	0700	1000	1	3	W	0	5	2	2	0	0
24/07/2018	5	MW	0700	1000	2	4	W	0	5	2	2	0	0
24/07/2018	5	MW	0700	1000	3	5	W	0	6	2	2	0	0
24/07/2018	5	MW	1030	1330	1	5	W	0	7	2	2	0	0
24/07/2018	5	MW	1030	1330	2	5	W	0	6	2	2	0	0
24/07/2018	5	MW	1030	1330	3	5	W	0	6	2	2	0	0
25/07/2018	5	MW	0700	1000	1	6	S	0	3	2	2	0	0
25/07/2018	5	MW	0700	1000	2	6	S	0	3	2	2	0	0
25/07/2018	5	MW	0700	1000	3	6	S	0	4	2	2	0	0
25/07/2018	5	MW	1030	1330	1	6	S	0	4	2	2	0	0
25/07/2018	5	MW	1030	1330	2	6	S	0	3	2	2	0	0
25/07/2018	5	MW	1030	1330	3	6	S	0	4	2	2	0	0
17/08/2018	6	MW	0730	1330	1	6	SW	0	7	2	2	0	0
17/08/2018	6	MW	0730	1330	2	6	SW	0	8	2	2	0	0

Date	Survey visit	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
17/08/2018	6	MW	0730	1330	3	6	SW	0	8	2	2	0	0
17/08/2018	6	MW	0730	1330	4	6	SW	0	8	2	2	0	0
17/08/2018	6	MW	0730	1330	5	6	SW	0	8	2	2	0	0
17/08/2018	6	MW	0730	1330	6	7	SW	0	8	2	2	0	0
31/08/2018	7	MW	0630	1300	1	2	SE	0	1	2	2	0	0
31/08/2018	7	MW	0630	1300	2	2	SE	0	1	2	2	0	0
31/08/2018	7	MW	0630	1300	3	3	SE	0	1	2	2	0	0
31/08/2018	7	MW	0630	1300	4	4	SE	0	1	2	2	0	0
31/08/2018	7	MW	0630	1300	5	4	SE	0	2	2	2	0	0
31/08/2018	7	MW	0630	1300	6	5	SE	0	3	2	2	0	0

C.4 Black Grouse Surveys

Black grouse surveys were undertaken during the 2018 breeding season. Table C-6 details survey dates and weather data recorded. Refer to Annex B for survey methodology and Annex D for survey results.

Table C-6 Meteorological conditions during black grouse surveys at Hagshaw Hill (sorted chronologically)

Date	Survey visit	Observer	Survey start time	Survey finish time	Survey hour	Wind speed	Wind direction	Rain	Cloud cover	Cloud height	Visibility	Frost	Snow
18/04/2018	1	SP	0450	0620	1	4	SW	0	4	2	1	0	0
18/04/2018	1	SP	0450	0620	2	4	SW	2	5	2	2	0	0
21/04/2018	1	SP	0455	0630	1	4	E	0	8	0	1	0	0
21/04/2018	1	SP	0455	0630	2	4	ENE	0	7	1	1	0	0
24/04/2018	1	SP	0445	0620	1	4	SW	0	7	2	2	0	0
24/04/2018	1	SP	0445	0620	2	4	SW	0	6	2	2	0	0
24/05/2018	2	SP	0350	0635	1	2	ENE	0	8	0	1	0	0
24/05/2018	2	SP	0350	0635	2	2	ENE	0	7	1	1	0	0
29/05/2018	2	SP	0355	0630	1	0	0	0	0	2	1	0	0
29/05/2018	2	SP	0355	0630	2	0	0	0	0	2	1	0	0

ANNEX D ORNITHOLOGICAL SURVEY RESULTS

D.1 Flight Activity Records: Target Species

In accordance with SNH Guidance (2017), target species are those which may be considered to be at risk from the potential effects of wind farms. All flights of target species within the turbine area and the surrounding area were mapped and are detailed in Table D-1.

Table D-1 Details of target species recorded during flight activity surveys (sorted by species)

Date	VP	Observer	Flight start time	Species	No. of birds	Duration (s)	Seconds per height band					
							0-20m	21-40m	41-100m	101-150m	>150m	
27/03/2018	1	MW	0950	Curlew	1	25	25					
27/03/2018	1	MW	1120	Curlew	2	35	35					
23/04/2018	1	SP	1002	Curlew	1	105	75	30				
23/04/2018	1	SP	1009	Curlew	1	18	18					
23/04/2018	1	SP	1011	Curlew	2	136	30	75	31			
11/06/2018	1	SP	0834	Curlew	1	48	33	15				
11/06/2018	1	SP	1020	Curlew	1	71	26	45				
11/06/2018	1	SP	1226	Curlew	3	15		15				
11/06/2018	1	SP	1035	Curlew	1	75	30	45				
23/04/2018	1	SP	1132	Golden plover	44	196		136	60			
23/04/2018	1	SP	1311	Golden plover	110	232		112	120			
11/06/2018	1	SP	1240	Herring gull	1	28		28				
15/05/2018	1	RD	1428	Lapwing	2	25			25			
15/05/2018	1	RD	1139	Osprey	1	90			90			
11/06/2018	1	SP	1325	Oystercatcher	1	32		32				

D.2 Flight Activity Records: Secondary Species

Table D-2 details secondary species recorded per season during flight activity surveys. Secondary species were recorded to give an indication of the use of the site by these species. Refer to Annex B for survey methodology and Annex C for weather data.

Table D-2 Summary of secondary species recorded during flight activity surveys

Date	Observer	Species	Number recorded	Notes
27/03/2018	MW	Buzzard	2	Flew across site at 1233 for 77seconds
27/03/2018	MW	Common gull	1	
27/03/2018	MW	Kestrel	1	
23/04/2018	SP	Buzzard	1	Flew through survey area at 1046 for 113 seconds
23/04/2018	SP	Buzzard	1	Flew through survey area at 1428 for 90 seconds
23/04/2018	SP	Raven	1	Flew through survey area at 1023 for 45 seconds
23/04/2018	SP	Sparrowhawk	1	Recorded on-route to VP
15/05/2018	RD	Buzzard	1	
15/05/2018	RD	Buzzard	1	
15/05/2018	RD	Buzzard	1	
15/05/2018	RD	Buzzard	1	
15/05/2018	RD	Kestrel	1	
15/05/2018	RD	Kestrel	1	Female hunting
15/05/2018	RD	Raven	2	
11/06/2018	SP	Black-headed gull	1	Flying west to east
11/06/2018	SP	Buzzard	1	Circling north of High Broomerside until lost from view
11/06/2018	SP	Buzzard	1	South from Smithy Burn
11/06/2018	SP	Buzzard	2	Second buzzard joined buzzard previously recorded alone during same survey
11/06/2018	SP	Buzzard	3	Third buzzard joined two buzzards previously recorded together during same survey from east, all circled south over VP
11/06/2018	SP	Buzzard	1	Perched on fence post east of High Broomerside
11/06/2018	SP	Buzzard	1	Flying west towards Smithy Burn
11/06/2018	SP	Raven	1	Heard west of VP
11/06/2018	SP	Raven	1	Flying south west to north east
11/06/2018	SP	Raven	2	Flying from High Broomerside to Smithy Burn
11/06/2018	SP	Raven	5	Family group
11/06/2018	SP	Raven	3	Constant activity around High Broomerside
23/07/2018	MW	Buzzard	1	
23/07/2018	MW	Buzzard	1	
23/07/2018	MW	Kestrel	1	Hunting
23/07/2018	MW	Kestrel	1	Hunting
23/07/2018	MW	Kestrel	1	Hunting
23/07/2018	MW	Raven	3	
16/08/2018	MW	Raven	6	
16/08/2018	MW	Buzzard	2	
16/08/2018	MW	Kestrel	1	

D.3 Moorland Breeding Bird Records

Moorland breeding bird surveys were undertaken during the 2018 breeding seasons and focussed on recording activity of upland wader species within the survey area (Table D-3). Survey methodology is detailed in Annex B and survey timing/weather conditions in Annex C.

Table D-3 Wader activity recorded during moorland breeding bird surveys

Date	Observer	Species	Number recorded	Notes
21/04/2018	SP	Curlew	1	Display flight
21/04/2018	SP	Curlew	1	Calling
21/04/2018	SP	Curlew	1	Flew away calling
21/04/2018	SP	Snipe	1	In song
07/05/2018	RD	Curlew	1	
07/05/2018	RD	Curlew	1	
07/05/2018	RD	Curlew	2	
07/05/2018	RD	Snipe	1	Calling
23/05/2018	SP	Curlew	1	Display flight
23/05/2018	SP	Curlew	1	Alarm calling in flight
23/05/2018	SP	Curlew	1	Perched at a potential nest then flew away alarm calling
23/05/2018	SP	Curlew	1	Display flight moving between two places
23/05/2018	SP	Curlew	1	Display flight
23/05/2018	SP	Curlew	2	Flying over
23/05/2018	SP	Curlew	1	Alarm calling, potential nest
23/05/2018	SP	Curlew	1	Moving between two places
23/05/2018	SP	Curlew	1	Alarm calling in flight
23/05/2018	SP	Curlew	1	Calling in flight
23/05/2018	SP	Curlew	1	Flew away calling
23/05/2018	SP	Curlew	1	Flying over
23/05/2018	SP	Curlew	1	Flying over alarm calling
23/05/2018	SP	Curlew	2	
23/05/2018	SP	Oystercatcher	1	
18/06/2018	SP	Common sandpiper	1	Alarm calling
18/06/2018	SP	Oystercatcher	1	Flying over
09/07/2018	MW	Snipe	1	
09/07/2018	MW	Snipe	1	

D.4 Scarce Breeding Bird Records

Table D-5 details all records of raptors and owls recording during surveys, however only Annex 1¹ or Schedule 1² species are considered to be scarce breeding birds (i.e. target species). Refer to Annex B for survey methodology, Annex C for weather data.

Table D-4 Raptor records: 2018

Date	Species	Protection status	Number recorded	Notes
26/03/2018	Buzzard	BoCC ³ Green	1	
26/03/2018	Kestrel	BoCC Amber	1	Not mapped
21/04/2018	Buzzard	BoCC Green	2	Potentially two flying over at the same time
21/04/2018	Peregrine falcon	Annex 1, Schedule 1, BoCC Green	1	Flying over
07/05/2018	Kestrel	BoCC Amber	1	Hunting
07/05/2018	Peregrine	Annex 1, Schedule 1, BoCC Green	2	Unsexed
23/05/2018	Buzzard	BoCC Green	1	Flying over
23/05/2018	Kestrel	BoCC Amber	1	Flying over
23/05/2018	Sparrowhawk	BoCC Green	1	
23/05/2018	Sparrowhawk	BoCC Green	1	Flying over
28/05/2018	Buzzard	BoCC Green	3	At Cumberhead Forest (north east part)
28/05/2018	Buzzard	BoCC Green	1	At Long Plantation
28/05/2018	Buzzard	BoCC Green	1	At Cumberhead Forest (north east part)
29/05/2018	Buzzard	BoCC Green	1	At High Broomerside
18/06/2018	Tawny owl	BoCC Amber	1	At Cumberhead Forest (South) in location NS 78333 32401
28/06/2018	Buzzard	BoCC Green	1	
29/06/2018	Buzzard	BoCC Green	1	
29/06/2018	Kestrel	BoCC Amber	1	
09/07/2018	Kestrel	BoCC Amber	1	
24/07/2018	Buzzard	BoCC Green	1	
24/07/2018	Kestrel	BoCC Amber	1	
24/07/2018	Sparrowhawk	BoCC Green	1	
25/07/2018	Buzzard	BoCC Green	1	
17/08/2018	Buzzard	BoCC Green	1	
17/08/2018	Kestrel	BoCC Amber	1	
31/08/2018	Merlin	Annex 1, Schedule 1, BoCC Red	1	Juvenile
31/08/2018	Merlin	Annex 1, Schedule 1, BoCC Red	1	Juvenile
31/08/2018	Hen harrier	Annex 1, Schedule 1, BoCC Red	1	Male
31/08/2018	Osprey	Annex 1, Schedule 1, BoCC Amber	1	
31/08/2018	Merlin	Annex 1, Schedule 1, BoCC Red	1	

¹ Annex 1 of the EU Bird Directive

² Schedule 1 of the Wildlife and Countryside Act 1981, as amended by the Nature Conservation Act (Scotland) 2004

³ BoCC – Birds of Conservation Concern (Eaton *et al.* 2015)

Date	Species	Protection status	Number recorded	Notes
31/08/2018	Buzzard	BoCC Green	1	
31/08/2018	Buzzard	BoCC Green	1	
31/08/2018	Kestrel	BoCC Amber	1	
31/08/2018	Kestrel	BoCC Amber	1	
31/08/2018	Buzzard	BoCC Green	4	
31/08/2018	Kestrel	BoCC Amber	1	

D.5 Black Grouse Records

Table D-6 details all black grouse records with lek numbers indicated where appropriate. Refer to Annex B for survey methodology and Annex C for weather data.

Table D-5 Black grouse activity records: 2018

Date	Observer	Survey visit	Lek no.	No. males	No. Females
18/04/2018	SP	1		No black grouse/signs of black grouse recorded	
21/04/2018	SP	1		No black grouse/signs of black grouse recorded	
24/04/2018	SP	1		No black grouse/signs of black grouse recorded	
24/05/2018	SP	2		No black grouse/signs of black grouse recorded	
29/05/2018	SP	2		No black grouse/signs of black grouse recorded	

D.6 Bird Species Index

A total of 64 bird species or signs were recorded at, or adjacent, to the site during the ornithological surveys. Table D-9 comprises a list of all these species along with their conservation status.

Table D-6 All bird species recorded at Hagshaw Hill (March to August 2018)

Species	Conservation status	Species	Conservation status
Blackbird	BoCC Green	Meadow pipit	BoCC Amber
Black-headed gull	BoCC Amber	Mistle thrush	BoCC Red
Blue tit	BoCC Green	Moorhen	BoCC Green
Bullfinch	BoCC Amber	Mute swan	BoCC Amber
Buzzard	BoCC Green	Nuthatch	BoCC Green
Carrion crow	BoCC Green	Oystercatcher	BoCC Amber
Chaffinch	BoCC Green	Peregrine	Annex 1, Schedule 1, BoCC Green
Chiffchaff	BoCC Green	Pied wagtail	BoCC Green
Coal tit	BoCC Green	Raven	BoCC Green
Common crossbill	Schedule 1, BoCC Green	Red grouse	BoCC Amber
Common gull	BoCC Amber	Redwing	Schedule 1, BoCC Red
Common sandpiper	BoCC Amber	Reed bunting	BoCC Amber
Cuckoo	BoCC Red	Ringed plover	BoCC Red
Curlew	BoCC Red	Robin	BoCC Green
Duncock	BoCC Amber	Rook	BoCC Green
Fieldfare	Schedule 1, BoCC Red	Sand martin	BoCC Green
Goldcrest	BoCC Green	Sedge warbler	BoCC Green
Goldfinch	BoCC Green	Siskin	BoCC Green
Grasshopper warbler	BoCC Red	Skylark	BoCC Red
Great tit	BoCC Green	Snipe	BoCC Amber
Grey wagtail	BoCC Red	Song thrush	BoCC Red
House martin	BoCC Amber	Sparrowhawk	BoCC Green
Jackdaw	BoCC Green	Starling	BoCC Red
Jay	BoCC Green	Swallow	BoCC Green
Kestrel	BoCC Amber	Swift	BoCC Amber
Lapwing	BoCC Red	Tawny owl	BoCC Amber
Lesser black-backed gull	BoCC Amber	Tufted duck	BoCC Green
Lesser redpoll	BoCC Red	Wheatear	BoCC Green
Linnet	BoCC Red	Whinchat	BoCC Red
Little grebe	BoCC Green	Willow warbler	BoCC Amber
Magpie	BoCC Green	Woodpigeon	BoCC Green
Mallard	BoCC Amber	Wren	BoCC Green

ANNEX E COLLISION RISK ASSESSMENTS

Table E-1, Table E-2 and Table E-3 present the parameters which apply to each Collision Risk Model (CRM).

Table E-1 Wind farm parameters

Parameter	Value	Unit
Wind farm envelope	164.2	hectares (ha)
Number of turbines	8	turbines
Rotor diameter	155	metres (m)
Hub height	122.5	m
Max. rotor depth	0.826	m (at 15° pitch angle)
Max. chord	3.4	m
Pitch	15	degrees (°)
Rotation period	3.158	seconds (secs)
Turbine operation time	0.85	percent (%)
Risk height: lowest	45	m
Rick height: highest	200	m
Flight risk volume	254477451.3	m ³

Table E-2 CRM parameters per species

Species	Length (m)	Wingspan (m)	Assumed flight speed, v (ms ⁻¹)	Avoidance rate	Probability of collision	Bird transit times (secs)
Golden plover	0.28	0.72	17.9	0.98	0.0484	0.0618
Lapwing	0.31	0.87	11.9	0.98	0.0706	0.0955
Osprey	0.58	1.7	11.4	0.98	0.0965	0.1234

Table E-3 Visible area within the CRAA per vantage point

VP	Area (ha)
1	161.3160

Birds are assumed to be active during all the daylight hours and this is estimated by calculating the number of hours per day between sunrise and sunset (adjusting for correct latitude) for the survey seasons as defined in Table E-4 below.

Table E-4 Season definitions per species/species group

Species	Breeding season			Non-breeding season		
	Start date	End date	Hours presumed present	Start date	End date	Hours presumed present
Golden plover ¹	-	-	-	1 st March	30 th April	789
Raptors	15 th March	31 st August	2,647	1 st September	14 th March	1,849
Waders	15 th March	31 st August	2,647	1 st September	14 th March	1,849

Outputs for the CRM for the following species are presented in the following order below:

- Golden plover;
- Lapwing; and
- Osprey.

E.1 Golden Plover

Spring Migration 2018

Table E-5 Golden plover flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr ⁻¹)
1	4827.1	1613.1	0.0008

Table E-6 Golden plover mortality estimates

Mean activity in wind farm at rotor height	0.136	hr ⁻¹
Total Combined rotor swept volume	167002.3	m ³
Bird occupancy	107.69	hrs/season
Bird occupancy of rotor swept volume	254.43	bird-sec
No. of transits through rotors	4116.57	per season
Estimated collisions	199.456	per season
Estimated collisions after correction for operation	169.54	per season
Estimated collisions after avoidance factor	3.391	per season
Equivalent to 1 bird every	0.295	seasons

¹ Spring migration period.

E.2 Lapwing*Breeding Season 2018***Table E-7 Lapwing flight activity**

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr ⁻¹)
1	23.597	5484.74	1.19509E-06

Table E-8 Lapwing mortality estimates

Mean activity in wind farm at rotor height	0.0002	hr ⁻¹
Total Combined rotor swept volume	171531.0	m ³
Bird occupancy	0.519	hrs/season
Bird occupancy of rotor swept volume	1.260	bird-sec
No. of transits through rotors	13.198	per season
Estimated collisions	0.907	per season
Estimated collisions after correction for operation	0.771	per season
Estimated collisions after avoidance factor	0.015	per season
Equivalent to 1 bird every	64.875	seasons

E.3 Osprey*Breeding Season 2018***Table E-9 Osprey flight activity**

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr ⁻¹)
1	35.29	5484.74	0.000002

Table E-10 Osprey mortality estimates

Mean activity in wind farm at rotor height	0.0003	hr ⁻¹
Total Combined rotor swept volume	212288.4	m ³
Bird occupancy	0.777	hrs/season
Bird occupancy of rotor swept volume	2.333	bird-sec
No. of transits through rotors	18.908	per season
Estimated collisions	1.784	per season
Estimated collisions after correction for operation	1.517	per season
Estimated collisions after avoidance factor	0.030	per season
Equivalent to 1 bird every	32.969	seasons

ANNEX F REVIEW OF THE EFFECTS OF ARTIFICIAL LIGHT ON BIRDS IN RELATION TO DEPLOYMENT OF OBSTRUCTION LIGHTING ON WIND TURBINES

F.1 Introduction

With the increase in height of wind turbines, it is now a requirement for obstruction lighting to be added to tall turbines (>150m) to make the structures more visible to pilots of aircraft. This review summarises the impacts of artificial light on birds and considers whether any of the known impacts might arise in birds as a consequence of deployment of aviation lighting on wind turbines. This review was undertaken by Professor Bob Furness in September 2017.

F.2 Methods

A literature search was carried out, using tools such as Web of Knowledge and Google scholar, to identify relevant published work. Identified publications were obtained and read, in order to prepare this review paper.

F.3 Results Obtained from Literature Search

There is a large literature identifying a wide range of impacts of artificial lights on birds. The identified impacts all relate to effects occurring at night. These include:

- Disruption of photoperiod physiology of birds due to artificial light;
- Extension of daytime activity (earlier start at dawn, later end at dusk);
- Phototaxis of seabirds (birds attracted to light sources and grounded on land);
- Phototaxis of nocturnal migrants (birds attracted to light sources and grounded or killed);
- Ability of some birds to use nocturnal feeding assisted by artificial light;
- Increased predation risk for nocturnal birds resulting from artificial lighting;
- Birds better able to avoid collision when structures are illuminated; and
- Displacement of birds due to avoidance of lights.

These impacts are considered in turn below.

Disruption of photoperiod physiology of birds due to artificial light

In theory, low levels of artificial light have the potential to affect the physiological photoperiod experienced by birds, and thereby to affect the timing of their onset of activity in the morning and end of activity in the evening, as well as potentially affecting the seasonal triggers for activities such as deposition or shedding of fat stores, moult, breeding and migration (Titulaer et al. 2012, Gaston et al. 2013, 2015, De Jong et al. 2017, Da Silva et al. 2017). However, there are no published studies or observations reporting clear examples of any seasonal activities of birds being affected by exposure to artificial light. There are a few anecdotal examples of urban birds starting to nest in winter, and this could possibly be interpreted as birds coming into breeding condition early because their photoperiod had been affected by artificial light. However, such early breeding is generally seen only in a few bird species that are often able to breed successfully in winter if weather conditions permit. That suggests that such cases represent opportunistic breeding in urban environments rather than disruption of natural photoperiod responses. De Jong et al. (2017) experimented with birds in captivity, exposing them to different colours of light at night. Birds advanced their onset of activity in the morning when exposed to light at

night, and advanced timing more in response to red and white light than to green light. Birds advanced timing more in response to higher intensity of artificial light. However, there have not been similar experiments with free-living wild birds, so it is uncertain if such effects occur in wild birds. Since such effects have not been reported, it seems more likely that there is very little, if any, effect of artificial light on photoperiod responses of wild birds.

Extension of daytime activity

Da Silva et al. (2017) used an experimental approach with wild birds, exposing the area around an automated feeding station in a forest to artificial light at night. They found a small response in some bird species, with blue tit and great tit starting to forage earlier during experimentally lighted mornings. However, no response was shown by willow/marsh tit, nuthatch, jay or blackbird, and the response of great tits was weak. The authors concluded that *'our results suggest that artificial light during winter has only small effects on timing of foraging'*. Da Silva et al. (2017) used an experimental approach to test whether birds start singing earlier in the morning when their forest habitat was illuminated with artificial light. They found no effect of artificial light (testing a variety of different light colours) on the timing of the dawn chorus. These results suggest that artificial light has very little, if any, impact on the available daylength for day-active birds, possibly because the natural variation in light levels is so large that artificial light makes very little difference to the natural diurnal cycle of light levels.

Phototaxis of seabirds

Most burrow-nesting shearwaters and petrels are nocturnally active. Adults rear a single chick, and 'desert' the fully-grown chick to leave it to fledge independently. Chicks fledge at night, usually just after dark, and show strong positive phototaxis; they are attracted to light. This allows them to navigate from the dark burrows at the colony to the sea, as light intensity is naturally higher over the sea than onshore. This phototactic response is therefore important to allow fledglings to find the sea when they first leave their burrow (especially important for those petrel species that breed at colonies some distance inland from the sea). This phototaxis behavioural response is also seen, for example, in hatchling sea turtles and has the same function. Puffins also show this same response as petrels. There are numerous examples of shearwater, petrel, and puffin chicks being attracted to artificial lights at fledging, and being grounded (Wilhelm et al. 2013, Rodriguez et al. 2014, Gineste et al. 2017). This is well known, for example, at colonies in the Hawaii, Balearic islands, Canary Islands and Azores where fledglings will collide with street lights and car headlights (Fontaine et al. 2011, Troy et al. 2011, 2013, Rodriguez et al. 2012a,b,c, 2015a,b). It also occurs in Scotland, for example at the islands of Rum and St Kilda (Miles et al. 2010) where Manx shearwaters, European storm-petrels, Leach's storm-petrels and Atlantic puffin fledglings are grounded at street lights and illuminated windows. In virtually all of these examples, only fledglings are attracted and grounded, during the short period in late summer when chicks are departing from nesting burrows. Adults appear to be unaffected by artificial lights. Although for most colonies the numbers of fledglings distracted by artificial lights is trivial, the impact on survival of fledglings can be significant in a few cases where large colonies are close to extensive artificial lighting. In Reunion Island, 13,200 tropical shearwater fledglings were found grounded due to artificial lights, with numbers increasing from 1996 to 2015 (Gineste et al. 2017). At Phillip Island, Australia, 8,871 short-tailed shearwater fledglings were found grounded by lights along the roadsides, with at least 40% of these dead or dying (Rodriguez et al. 2014). Turning off the street lights mitigated this mortality (Rodriguez et al. 2014). In Kauai, Hawaii, more than 30,000 grounded fledglings of the federally threatened Newell's shearwater have been collected under lights, an impact that may be contributing to the decline of this population (Troy et al. 2011).

Lights on wind farm turbines in Scotland are unlikely to affect fledging puffins, shearwaters or petrels from Scottish colonies, as most of those colonies are on offshore islands immediately overlooking the sea. Fledglings are likely to disperse over the sea without seeing lights on wind turbines. Exceptions to this might be puffins from Isle of May fledging past offshore wind farms in the Forth and Tay area, Manx shearwaters and European storm petrels fledging from Sanda Islands, Kintyre, past terrestrial wind farms on the Kintyre peninsula, puffins fledging from the Shiant Islands passing terrestrial wind farms in the Western Isles, Manx shearwaters fledging from the small isles (especially Rum) and the Treshnish Isles passing terrestrial wind farms on Skye or Mull.

However, the lights involved on wind turbines would be likely to represent a trivial amount of lighting relative to the street lights and house lights of local towns, villages, lighthouses, ships and fishing vessels. These fledglings are also thought to tend to fly low rather than at high altitudes, and so would not be likely to be particularly close to lights at the tops of turbines. Phototaxis of fledging seabirds in Scotland is, therefore, very unlikely to be a problem in relation to obstruction lighting on wind turbines.

Phototaxis of nocturnal migrants

It has been recognised for a very long time that nocturnal migrant birds are attracted to artificial light while migrating (Harvie Brown et al. 1881, Horring 1926, Mehlum 1977, Jones and Francis 2003). This topic has recently received considerable attention specifically in relation to lighting at communication towers (Longcore et al. 2008, Gehring et al. 2009), wind farms (Kerlinger et al. 2010, Hüppop and Hilgerloh 2012), oil and gas production platforms (Day et al. 2015, Ronconi et al. 2015), cruise ships (Bocetti 2011), and in general in relation to bird ecology (Zhao et al. 2014, Watson et al. 2016).

The strongest and most dramatic examples of phototaxis in nocturnal migration birds are the ‘falls’ of migrants that can occur at lighthouses and lightships, especially during foggy weather in autumn. These were studied in detail in the 1880s to 1920s. For example, Harvie Brown and Alfred Newton established a committee of the British Association for the Advancement of Science in the 1870s and sent questionnaires to lighthouse keepers throughout the British Isles to obtain data on nocturnal bird migration and the numbers of birds killed by collision with lights. As long ago as 1881, they reported that *‘the brightest, whitest, fixed lights attract the most birds’*, that most collisions occurred during autumn migration rather than during spring migration, and that most collisions occurred when the weather was foggy and windy (as also concluded over 100 years later by Mehlum 1977). These same factors were identified as affecting collision rates in a study by Zhao et al. (2014). The British association annual reports show the large numbers of birds that can be killed; for example, 600 thrushes killed by collision with Skerryvore lighthouse in October 1877. A high proportion of the birds killed were juveniles, which probably at least in part explains why numbers killed tended to be much higher in autumn than in spring. Similar surveys were conducted around the same period in many different European countries. For example, the 41st annual report on birds at Danish lighthouses, for the year 1923, was published in 1926 (Horring 1926). That report mentions that at least 4,600 birds, mostly thrushes and starlings, were killed by collision at Danish lighthouses and lightships in 1923. Study of birds at lighthouses fell out of favour around the 1930s, and there is very little literature on this topic after that period, although it was recognised that large numbers of migrating birds were still being killed by collision at lighthouses (e.g. Mehlum 1977, Jones and Francis 2003). Jones and Francis (2003) reported that from 1960-1989 there were kills of up to 2,000 birds in a single night in autumn at Long Point lighthouse (Ontario, Canada). However, this light was fitted with a new beam in 1989, which was narrower and less powerful, and this resulted in a huge decrease in numbers of migrant birds killed. From 1990 to 2002 the mean numbers known to be killed were reduced to only about 30 birds per year. The authors point out that this highlights the *‘effectiveness of simple changes in light signatures in reducing avian light attraction and mortality during migration’*.

Ronconi et al. (2015) and Day et al. (2015) both report that poor weather (e.g. fog, rain, low cloud cover) exacerbate nocturnal attraction of bird migrants to lights at oil and gas production platforms, with on occasions thousands of birds being killed in a night, especially where gas is being flared. Kerlinger et al. (2010) report that bright artificial lighting may have caused *‘multi-bird fatality events’* at wind farms in North America, but that obstruction lighting at turbines as recommended by the Federal Aviation Administration (FAA) (flashing red lights) had no influence on bird collisions compared with turbines at the same wind farm, where there was no obstruction lighting (see also this same conclusion in Manville 2009). Gehring et al. (2009) reported that communication towers equipped with non-flashing/steady-burning lights in addition to red or white flashing obstruction lights were responsible for much higher numbers of bird collisions; towers with fixed lights and flashing lights were responsible for 13 bird fatalities per season, whereas towers with only flashing obstruction lights were responsible for 3.7 bird fatalities per season. They concluded that having only flashing obstruction

lights reduced bird collisions significantly, a conclusion supported by Patterson (2012). Longcore et al. (2008) reported that steady-burning lights increased the numbers of birds colliding with communication towers.

Watson et al. (2016) report that more nocturnal flight calls can be detected over artificially lit areas than over dark areas. They conclude that artificial lighting changes behaviour of nocturnal migrant birds, either by changing their flight paths to pass over lit areas, by flying at lower altitudes over lit areas, by increasing their call rates over lit areas, or by remaining longer over lit areas. Hüppop and Hilgerloh (2012) suggest that nocturnal migrants are more vocal when conditions are adverse, so that vocalisations do not indicate bird numbers but rather the stress levels of the birds. Bocetti (2011) identified that cruise ships, which often have bright external lighting during the night, also represent a collision hazard for nocturnal migrant birds, although it seems likely that the numbers of birds killed at cruise ships are rather small compared to numbers killed at lighthouses.

The evidence indicates that lights on wind turbines are likely to increase numbers of nocturnal migrant birds that collide. However, that increase is mainly seen if lights are steady-burning, whereas there is very little increase in collisions when lights are flashing. Obstruction lighting on wind turbines appears to be several orders of magnitude less effective than the light from lighthouses and lightships in attracting nocturnal migrant birds. Survival rates of small birds are low, and it is recognised that many birds die during migration, especially juvenile birds during autumn migration (Newton 2008). Birds that are attracted by artificial light are likely to be birds that are already at high risk of mortality because they are facing adverse weather conditions and are lost or exhausted (Newton 2008). Furthermore, Welcker et al. (2017) reported that, despite the apparent attraction of nocturnal migrating birds to lights, nocturnal migrants represented only 8.6% of all fatalities at a sample of German wind farms. They concluded that *‘nocturnal migrants do not have a higher risk of collision with wind energy facilities than do diurnally active species, but rather appear to circumvent collision more effectively’*.

Phototaxis of other birds

Attraction of fledgling shearwaters, petrels and puffins, and attraction of nocturnal migrating birds to lights is well established and has been studied in detail. In contrast, there is no clear evidence from research studies or observations to suggest that other kinds of birds show attraction to lights. There seems to be little or no phototaxis shown by adult shearwaters, petrels or puffins around the British Isles, despite the strong response seen in fledglings. There is some evidence of adult petrels being attracted to bright artificial lights at night at colonies in the sub-Antarctic (e.g. Furness, pers. obs.), but that may simply be a disorientation and grounding of birds that fly into strong beams of light such that they are unable to see where they are going. There is little evidence to suggest that those birds are attracted towards artificial light. There is little or no evidence to suggest that birds that are not undertaking migration are attracted to artificial light. While nocturnal migrants are found as collision casualties at lighthouses during the migration seasons, resident birds in summer or winter, wintering birds in winter or breeding birds in summer are not found as collision casualties in summer or winter. Seabirds breeding close to lighthouses are not found as collision casualties at lighthouses. The evidence strongly indicates that resident, breeding and wintering birds do not show phototaxis. Therefore, there is no risk due to phototaxis for resident birds, breeding or wintering birds in the vicinity of wind farms as a direct consequence of deployment of obstruction lighting on wind turbines.

Ability of some birds to use nocturnal feeding assisted by artificial light

Birds that are visual feeders and feed only during the day may benefit from artificial light that allows them to feed visually at night. This has been reported, for example, in intertidal waders. Santos et al. (2010) found that visual feeding shorebirds fed at night in areas of the Tagus Estuary (Portugal) where artificial light allowed them to see prey. Tactile-feeding waders did not show any change in distribution attributable to the distribution of artificial light. Similarly, Da Silva et al. (2017) found that blue tits and great tits started foraging earlier in the morning when artificial light was available. The availability of artificial light did not alter feeding times of willow/marsh tits, nuthatches, jays or blackbirds, and the effect on great tits was weak and only evident during nights when weather was poor. There are anecdotal observations of birds such as robins feeding under street lights during winter darkness in urban environments.

In the context of obstruction lighting on wind turbines, it is highly unlikely that the amount of light provided would allow birds to feed at times when natural light levels were low, so this effect is very unlikely to be seen at wind farms.

Increased predation risk for nocturnal birds resulting from artificial lighting

Canario et al. (2012) observed short-eared owls and long-eared owls catching migrating songbirds that had been attracted to artificial lights. Oro et al. (2005) found significantly lower survival rates of breeding adult European storm-petrels at a colony in Benidorm Island (Spain) that was illuminated by artificial lighting shining across the sea from Benidorm city compared to a control colony on the dark side of Benidorm Island. The low survival of the population exposed to artificial light was due to yellow-legged gull predation on the storm petrels which was facilitated by the artificial light allowing gulls to see, and catch, storm petrels attending the colony at night.

Amounts of light produced by obstruction lighting at the top of wind turbines will be far less than produced by the lights in the studies reported above. It is, therefore, extremely unlikely that the lighting on wind turbines would affect predation risk for nocturnal birds in the vicinity of wind farms.

Ability to avoid collision when structures are illuminated

Blackwell et al. (2012) showed that artificial lights on aircraft reduced the risk of bird strike because lights made the aircraft more detectable to birds so allowed earlier avoidance behaviour. A study of bat collisions at wind farms in Texas found that bat fatalities were more frequent at turbines without aviation lights compared with turbines with synchronised red flashing aviation lights. The lower mortality at turbines with lights applied for only one species of bat, the other species showing no difference in mortality between turbines with or without aviation lights. However, the study suggests that at least one of the bat species avoided turbines more successfully when the turbine was equipped with obstruction lighting.

Displacement of birds due to avoidance of lights

Day et al. (2017) reported that migrating eiders showed higher avoidance at night of an oil-production facility in Alaska when it was illuminated with a hazing light system. However, this seems to be a rare example of birds being displaced by artificial lights, and there seem to be more examples of birds using artificial lights to their benefit, such as the use by shorebirds of artificial lights to allow them to feed visually at night.

Cumulative assessment

Loss et al. (2015) assessed the scale of anthropogenic mortality of birds in the United States and concluded that cause-specific annual mortality was billions due to predation by domestic cats, hundreds of millions due to collisions with buildings (mainly windows) and vehicles, tens of millions due to collisions with power lines, millions due to collisions with communication towers and electrocution at power lines, and hundreds of thousands due to collisions with wind turbines. These relative impacts are likely to be in a similar ranking in Scotland, and indeed throughout most of Europe.

F.4 REFERENCES

Bennett, V.J. and Hale, A.M. 2014. Red aviation lights on wind turbines do not increase bat-turbine collisions. *Animal Conservation*, 17, 354-358.

Blackwell, B.F., DeVault, T.L., Seamans, T.W., Lima, S.L., Baumhardt, P. and Fernandez-Juricic, E. 2012. Exploiting avian vision with aircraft lighting to reduce bird strikes. *Journal of Applied Ecology*, 49, 758-766.

Bocetti, C.I. 2011. Cruise ships as a source of avian mortality during fall migration. *Wilson Journal of Ornithology*, 123, 176-178.

Canario, F., Leitão, A.H. and Tomé, R. 2012. Predation attempts by short-eared and long-eared owls on migrating songbirds attracted to artificial lights. *Journal of Raptor Research*, 46, 232-234.

Day, R.H., Rose, J.R., Prichard, A.K. and Streever, B. 2015. Effects of gas flaring on the behaviour of night-migrating birds at an artificial oil-production island, Arctic Alaska. *Arctic*, 68, 367-379.

Day, R.H., Prichard, A.K., Rose, J.R., Streever, B. and Swem, T. 2017. Effects of a hazing-light system on migration and collision avoidance of eiders at an artificial oil-production island, Arctic Alaska. *Arctic*, 70, 13-24.

Fontaine, R., Gimenez, O. and Bried, J. 2011. The impact of introduced predators, light-induced mortality of fledglings and poaching on the dynamics of the Cory's shearwater (*Calonectris diomedea*) population from the Azores, northeastern subtropical Atlantic. *Biological Conservation*, 144, 1998-2011.

Gaston, K.J., Davies, T.W., Bennie, J. and Hopkins, J. 2012. Reducing the ecological consequences of night-time light pollution: options and developments. *Journal of Applied Ecology*, 49, 1256-1266.

Gaston, K.J., Bennie, J., Davies, T.W. and Hopkins, J. 2013. The ecological impacts of nighttime light pollution: a mechanistic appraisal. *Biological Reviews*, 88, 912-927.

Gaston, K.J., Visser, M.E. and Hölker, F. 2015. The biological impacts of artificial light at night: the research challenge. *Philosophical Transactions of the Royal Society B*, 370, 20140133.

Gehring, J., Kerlinger, P. and Manville, A.M. 2009. Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions. *Ecological Applications*, 19, 505-514.

Gineste, B., Souquet, M., Couzi, F.X., Giloux, Y., Philippe, J.S., Hoarau, C., Tourmetz, J., Potin, G. and le Corré, M. 2017. Tropical shearwater population stability at Reunion Island, despite light pollution. *Journal of Ornithology*, 158, 385-394.

Harvie Brown, J.A., Cordeaux, J. and Newton, A. 1881. Report of the Committee for obtaining observations on the migrations of birds at lighthouses and lightships. *Report of the British Association for the Advancement of Science*, 51, 189-194.

Horring, R. 1926. The birds at the Danish lighthouses in 1923; 41st yearly report on Danish birds. *Vidensk Meddel Dansk Naturhist for Kobenhavn*, 80, 453-516.

Hüppop, O. and Hilgerloh, G. 2012. Flight call rates of migrating thrushes: effects of wind conditions, humidity and time of day at an illuminated offshore platform. *Journal of Avian Biology*, 43, 85-90.

Jones, J. and Francis, C.M. 2003. The effects of light characteristics on avian mortality at lighthouses. *Journal of Avian Biology*, 34, 328-333.

de Jong, M., Caro, S.P., Gienapp, P., Spoelstra, K. and Visser, M.E. 2017. Early birds by light at night: Effects of light color and intensity on daily activity patterns in blue tits. *Journal of Biological Rhythms*, 32, 323-333.

Kerlinger, P., Gehring, J.L., Erikson, W.P., Curry, R., Jain, A. and Guarnaccia, J. 2010. Night migrant fatalities and obstruction lighting at wind turbines in North America. *Wilson Journal of Ornithology*, 122, 744-754.

Longcore, T., Rich, C. and Gauthreaux, S.A. 2008. Height, guy wires, and steady-burning lights increase hazard of communication towers to nocturnal migrants: A review and meta-analysis. *Auk*, 125, 485-492.

Loss, S.R., Will, T. and Marra, P. 2015. Direct mortality of birds from anthropogenic causes. *Annual Review of Ecology, Evolution, and Systematics*, 46, 99-120.

Manville, A.M. 2009. Towers, turbines, power lines, and buildings – steps being taken by the U.S. Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. In C.J. Ralph and T.D. Rich (editors). *Proceedings 4th International Partners in Flight Conference*, February 2008, McAllen, Texas.

Mehlum, F. 1977. Birds killed at the lighthouse Faerder Fyr Outer Oslo Fjord and some possible explanations of bird kills by illuminating constructions. *Fauna (Oslo)*, 30, 191-194.

Miles, W., Money, S., Luxmoore, R. and Furness, R.W. 2010. Effects of artificial lights and moonlight on petrels at St Kilda. *Bird Study*, 57, 244-251.

Newton, I. 2008. *The Migration Ecology of Birds*. Academic Press, London.

Oro, D., de Leon, A., Minguéz, E. and Furness, R.W. 2005. Estimating predation on breeding European storm-petrels (*Hydrobates pelagicus*) by yellow-legged gulls (*Larus michahellis*). *Journal of Zoology*, 265, 421-429.

Patterson, J.W. 2012. *Evaluation of new obstruction lighting techniques to reduce avian fatalities*. National Technical Information services (NTIS) Springfield, Virginia. US Department of Transportation Document DOT/FAA/TC-TN 12/9.

Rodrigues, P., Aubrecht, C., Gil, A., Longcore, T. and Elvidge, C. 2012a. Remote sensing to map influence of light pollution on Cory's shearwater in Saõ Miguel Island, Azores Archipelago. *European Journal of Wildlife Research*, 58, 147-155.

Rodriguez, A., Rodriguez, B. and Lucas, M.P. 2012b. Trends in numbers of petrels attracted to artificial lights suggest population declines in Tenerife, Canary Islands. *Ibis*, 154, 167-172.

Rodriguez, A., Rodriguez, B., Curbelo, A.J., Perez, A., Marrero, S. and Negro, J.J. 2012c. Factors affecting mortality of shearwaters stranded by light pollution. *Animal Conservation*, 15, 519-526.

Rodriguez, A., Burgan, G., Dann, P., Jessop, R., Negro, J.J. and Chiaradia, A. 2014. Fatal attraction of short-tailed shearwaters to artificial lights. *PLoS ONE*, 9, e110114.

Rodriguez, A., Rodriguez, B. and Negro, J.J. 2015a. GPS tracking for mapping seabird mortality induced by light pollution. *Scientific Reports*, 5, 10670.

Rodriguez, A., Garcia, D., Rodriguez, B., Cardona, E., Parpal, L. and Pons, P. 2015b. Artificial lights and seabirds: is light pollution a threat for the threatened Balearic petrels? *Journal of Ornithology*, 156, 893-902.

Ronconi, R.A., Allard, K.A. and Taylor, P.D. 2015. Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. *Journal of Environmental Management*, 147, 34-45.

Santos, C.D., Miranda, A.C., Granadeiro, J.P., Lourenço, P.M., Saraiva, S. and Palmeirim, J.M. 2010. Effects of artificial illumination on the nocturnal foraging of waders. *Acta Oecologica*, 36, 166-172.

da Silva, A., Diez-Mendez, D. and Kempenaers, B. 2017. Effects of experimental night lighting on the daily timing of winter foraging in common European songbirds. *Journal of Avian Biology*, 48, 862-871.

da Silva, A., de Jong, M., van Grunsven, R.H.A., Visser, M.E., Kempenaers, B. and Spoelstra, K. 2017. Experimental illumination of a forest: no effects of lights of different colours on the onset of the dawn chorus in songbirds. *Royal Society Open Science*, 4, 160638.

Titulaer, M., Spoelstra, K., Lange, C.Y.M.J.G. and Visser, M.E. 2012. Activity patterns during food provisioning are affected by artificial light in free living great tits (*Parus major*). *PLoS ONE*, 7, e37377.

Troy, J.R., Holmes, N.D. and Green, M.C. 2011. Modeling artificial light viewed by fledgling seabirds. *Ecosphere*, 2 (10), 109.

Troy, J.R., Holmes, N.D., Veech, J.A. and Green, M.C. 2013. Using observed seabird fallout records to infer patterns of attraction to artificial light. *Endangered Species Research*, 22, 225-234.

Watson, M.J., Wilson, D.R. and Mennill, D.J. 2016. Anthropogenic light is associated with increased vocal activity by nocturnally migrating birds. *Condor*, 118, 338-344.

Welcker, J., Liesenjohann, M., Blew, J., Nehls, G. and Grünkorn, T. 2017. Nocturnal migrants do not incur higher collision risk at wind turbines than diurnally active species. *Ibis*, 159, 366-373.

Wilhelm, S.I., Schau, J.J., Schau, E., Dooley, S.M., Wiseman, D.L. and Hogan, H.A. 2013. Atlantic puffins are attracted to coastal communities in eastern Newfoundland. *Northeastern Naturalist*, 20, 624-630.

Zhao, X.B., Chen, M.Y., Wu, Z.L. and Wang, Z.J. 2014. Factors influencing phototaxis in nocturnal migrating birds. *Zoological Science*, 31, 781-788.

ANNEX G SUPPLEMENTARY DESK STUDY INFORMATION**Table G-1 Collision estimates at other wind farms within 2 km of Proposed Development**

Wind Farm site and Target Species	Breeding / Non-breeding season/Annual ¹	Number of collisions per year	Number of years per collision
Hagshaw Hill Extension (2003 & 2004)			
Black grouse	One flight line outside of rotor height (below 10m) was recorded within 100m of proposed turbines.		
Hen harrier	Out of 88hrs of observation time, hen harrier spent 0.004% of time at rotor height. Four out of a total of five flights were recorded within 500m of proposed turbines.		
Peregrine	Out of 88hrs of observation time, peregrine spent 0.05% of time at rotor height. Two flights were recorded within 500m of proposed turbines, one flight was recorded within 250m.		
Nutberry (2004 to 2006): 95% avoidance rate			
Curlew	Breeding (2005)	0.1779	5.6
Golden plover	Breeding (2005)	0.0579 None recorded in 2006	17.3 None recorded in 2006
	Non-breeding (2005)	0.1039	9.6
Hen harrier	Breeding (2004 & 2005)	0.0148 (2004) – 0.0187 (2005), None recorded in 2006	67.6 (2004) – 53.6 (2005) None recorded in 2006
	Non-breeding (2004/05)	0.0039	257.5
Merlin	Breeding (2004 & 2005)	0.0016 (2004) – 0.0037 (2005) None recorded in 2006	637.2 (2004) – 271.4 (2005) None recorded in 2006
	Non-breeding (2004/05)	0.0036	274.4
Galawhistle (2007 to 2009):			
Curlew	Breeding (2008 & 2009)	0.127	7.9
	Non-breeding (2007/08 & 2008/09)	0.164	6.1
Greylag goose	Non-breeding (2007/08 & 2008/09)	0.82	1.2
Golden plover	Breeding (2008 & 2009)	0.021	47.6
	Non-breeding (2007/08 & 2008/09)	0.027	37.0
Hen Harrier	Breeding (2008 & 2009)	0.016	62.5
	Non-breeding (2007/08 & 2008/09)	0.006	166.7
Lapwing	Breeding (2008 & 2009)	0.017	58.8
Peregrine	Breeding (2008 & 2009)	0.029	34.5
	Non-breeding (2007/08 & 2008/09)	0.032	31.3
Pink-footed goose	Non-breeding (2007/08 & 2008/09)	1.70	0.6
Red kite	Breeding (2008 & 2009)	0.015	66
	Non-breeding (2007/08 & 2008/09)	0.001	885
Snipe	Breeding (2008 & 2009)	0.011	87
	Non-breeding (2007/08 & 2008/09)	0.003	393
DWCW² (2009 to 2010):			
Curlew	Breeding (2010)	0.0641	15.6
Greylag goose	Breeding (2010)	0.0007	1386.6
Lapwing	Breeding (2010)	0.0029	348.3
Merlin	Breeding (2010)	0.0043	232.5
Osprey	Breeding (2010)	0.0229	43.7
Peregrine	Non-breeding (2010/2011)	0.004	227.1
Snipe	Non-breeding (2010/2011)	0.0008	1280.0
Dalquhandy (2011 to 2012):³			
Curlew	Breeding (2011 & 2012)	0.0034863	286.8
Golden plover	Annual ⁴ (2011 & 2012)	0.0222494	44.9
Greylag goose	Non-breeding (2011 & 2012)	0.05	18.6

¹ Annual CRM results are presented if breeding and non-breeding data are not analysed separately.

² CRM data taken from Ornithology Technical Appendix 8.1 Annex E for the Douglas West Wind Farm ES

³ Greylag goose and pink-footed goose CRM is calculated at 99% avoidance

⁴ Annual = October to May

Wind Farm site and Target Species	Breeding / Non-breeding season/Annual ¹	Number of collisions per year	Number of years per collision
Lapwing	Annual ⁵ (2011 & 2012)	0.00000105	948231.2
Pink-footed goose	Non-breeding (2011 & 2012)	0.90	1.11
Snipe	Annual ⁶ (2011 & 2012)	0.0158	62.9
Cumberhead (2013 to 2004):⁵			
Curlew	Annual ⁷ (2013 & 2014)	0.013	77.9
Golden plover	Breeding (2013 & 2014)	0.016	64.0
	Non-breeding (2013)	0.612	1.6
Goshawk	Annual ⁹ (2013 & 2014)	0.007	147.5
Greylag goose	Non-breeding (2013 & 2014)	0.013	78.6
Herring gull	Annual ⁹ (2013 & 2014)	0.059	17.0
Peregrine	Annual ⁹ (2013 & 2014)	0.018	56.0
Pink-footed goose	Non-breeding (2013 & 2014)	0.025	40.5
Whooper swan	Non-breeding (2013 & 2014)	0.016	61.7
Douglas West (2014 to 2015):			
Common sandpiper	Breeding (2015)	0.0007	1460.55
Curlew	Breeding (2015)	0.0543	18.42
	Non-breeding (2014/2015)	0.0558	17.92
Greylag goose	Breeding (2015)	0.0297	33.69
	Non-breeding (2014/2015)	0.1686	5.93
Hen harrier	Breeding (2015)	0.0118	84.50
	Non-breeding (2014/2015)	0.1136	8.80
Lapwing	Breeding (2015)	0.0206	48.55
	Non-breeding (2014/2015)	0.0076	131.13
Merlin	Non-breeding (2014/2015)	0.0014	694.97
Oystercatcher	Breeding (2015)	0.0023	431.36
	Non-breeding (2014/2015)	0.0015	653.47
Pink-footed goose	Breeding (2015)	0.0362	27.62
	Non-breeding (2014/2015)	0.2179	4.59
Snipe	Breeding (2015)	0.0890	11.24
	Non-breeding (2014/2015)	0.0092	108.5
Whooper swan	Non-breeding (2014/2015)	0.0129	77.47

⁵ Annual = July, October to November, February to August and November

⁶ Annual = November, March to June and September

⁷ Annual = May to August