Eredine Wind Farm

An analysis of potential Golden Eagle habitat loss using the GET Model and Satellite Tracking Data

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Confidential report prepared for RWE Renewables UK Onshore Wind Limited

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Conclusion

Neither the estimated losses of range habitat, nor the proportions of tag records, within a 300m turbine exclusion buffer are close to 5%. The Revised Development will not have a significant impact on either of the two adjacent Golden Eagle home ranges.

Currently, because of the existence of the ranges, and the limited extent of good eagle habitat within a 300m turbine exclusion buffer, there will be no significant impact on habitat used by dispersing Golden Eagles.

1. Background

The impact of a development at Eredine is first assessed using the Golden Eagle Topography (GET) model (Fielding *et al.*, 2020) and extensive satellite tracking data.

Analyses are for a 17-turbine scheme provided by RWE Renewables UK Onshore Wind Ltd.

The most reliable method for assessing potential habitat loss is through the use of data from satellite tracked birds, assuming such data cover a suitable time period. However, typically, satellite tracking information is not available so alternative model-based approaches are needed.

Predicted habitat loss for range holding Golden Eagles, arising out of wind farm construction, was previously assessed using the Predicting Aquila Territories (PAT) model (McLeod *et al*., 2002) but this model is unreliable. Satellite tracking devices have been fitted to 132 range holding birds (Natural Research, unpublished data and Fielding *et al.,* 2024a) spread across Scotland representing ~20% of all occupied ranges. The PAT model's home range boundary assumptions are unsupported by data from these 132 birds so the PAT model is unreliable, as recognised by NatureScot. Consequently, if satellite tracking data are unavailable a new approach is needed. The GET model is a robust method for estimating predicted habitat losses for dispersing and range holding eagles.

The GET model is a Scotland-wide topographic model which assigns a value between 1 and 10 to every 50m pixel across Scotland. Habitat with a GET score of 6+ is a good indicator of potential Golden Eagle activity when present in large contiguous blocks. Habitat with a GET score of 5 or less is used infrequently. However, Golden Eagles also tend not to use land with a closed canopy forest cover, irrespective of the GET score. This seems to be a general property of Golden Eagle ranges across Europe[1]. Since its development the GET model has been tested with a large amount of new, independent data, including from range holding birds, and the model has performed very well (See Appendix A in Fielding *et al.,* 2023).

Analyses of Golden Eagle satellite tracking records indicate that Golden Eagles rarely approach turbines (Whitfield & Fielding, 2017; Fielding *et al*., 2022, 2021, 2023, 2024b). After turbines become operational, Golden Eagles effectively abandon inner turbine locations, and flight lines close to rotor blades are rare (Fielding *et al.*, 2021, 2024b). The main impact of a wind farm on Golden

[1] Chapters in Rodriguez, J.B. & Ellis, D.H. (eds) *The Golden Eagle Around the World A Monograph on a Holarctic Raptor.* Hancock House Publishers, Surry, BC, Canada

Eagles in Scotland is habitat loss with a very small probability of a collision. Currently, there have been at least seven Golden Eagle collision deaths in Scotland spread over more than 10 years. This collision rate may increase given recent increases in the numbers of turbines and Golden Eagles, but even if collision mortality was doubled there would be no significant impact on the Scottish population.

Open habitat is land with no closed canopy forest cover and at least 500 m from an existing or consented turbine. An appropriate baseline for an assessment of habitat loss for Golden Eagles is the current area of open GET habitat with a value of 6 or more. **All subsequent measures of good Golden Eagle habitat refer to open country with a GET score of 6+.**

Closed Golden Eagle habitat is land with extensive tree cover or within 500 m of a turbine tower. In these analyses tree cover was assessed using a 9th April 2025 Sentinel 2 image (T30VUH). A false colour composite image was constructed from the 10 m resolution bands 2, 3 and 4 while combining the 20 m resolution bands 2, 6 and 12 to enhance tree cover (Ottosen *et al.*, 2020).

There is no current NatureScot guidance on how to assess either the significance or the area of lost good Golden Eagle habitat arising from a wind farm development. Potential impact can be estimated by assuming all habitat close to wind turbines is lost. The loss can be compared with a regional figure to assess the significance level. It is also important to assess if the wind farm may act as barrier to Golden Eagle movements creating a greater loss than that inside the wind farm.

In the absence of formal guidance, the following four step approach is used to assess the area of good Golden Eagle habitat lost following construction and its possible significance.

1. Define a turbine exclusion distance and buffer the proposed turbines to this distance. All habitat within this buffer (turbine exclusion zone) is assumed to be lost to Golden Eagles.
2. Measure the amount of good eagle habitat within the turbine exclusion buffer. This is assumed to be lost if the turbines are constructed.
3. Assess the significance of this loss of habitat by comparing it to a region-specific threshold.
4. Examine turbine positions, within the GET landscape, to assess which, if any, turbines may be particularly problematic for Golden Eagle movements.

Evidence from sufficient (defined below) satellite tracking data should always take preference over a loss estimate derived from the more general GET model.

2. Turbine exclusion distance

Analyses in Fielding *et al.* (2021, 2022, 2023, 2024b) suggest that 500 m may be a conservative displacement distance[2], a smaller distance can be justified to assess potential habitat loss, particularly if it is combined with a turbine boundary rule. Turbine diameter was not a significant predictor of how close satellite tracked birds came to the turbines (Fielding *et al.*, 2022). However,

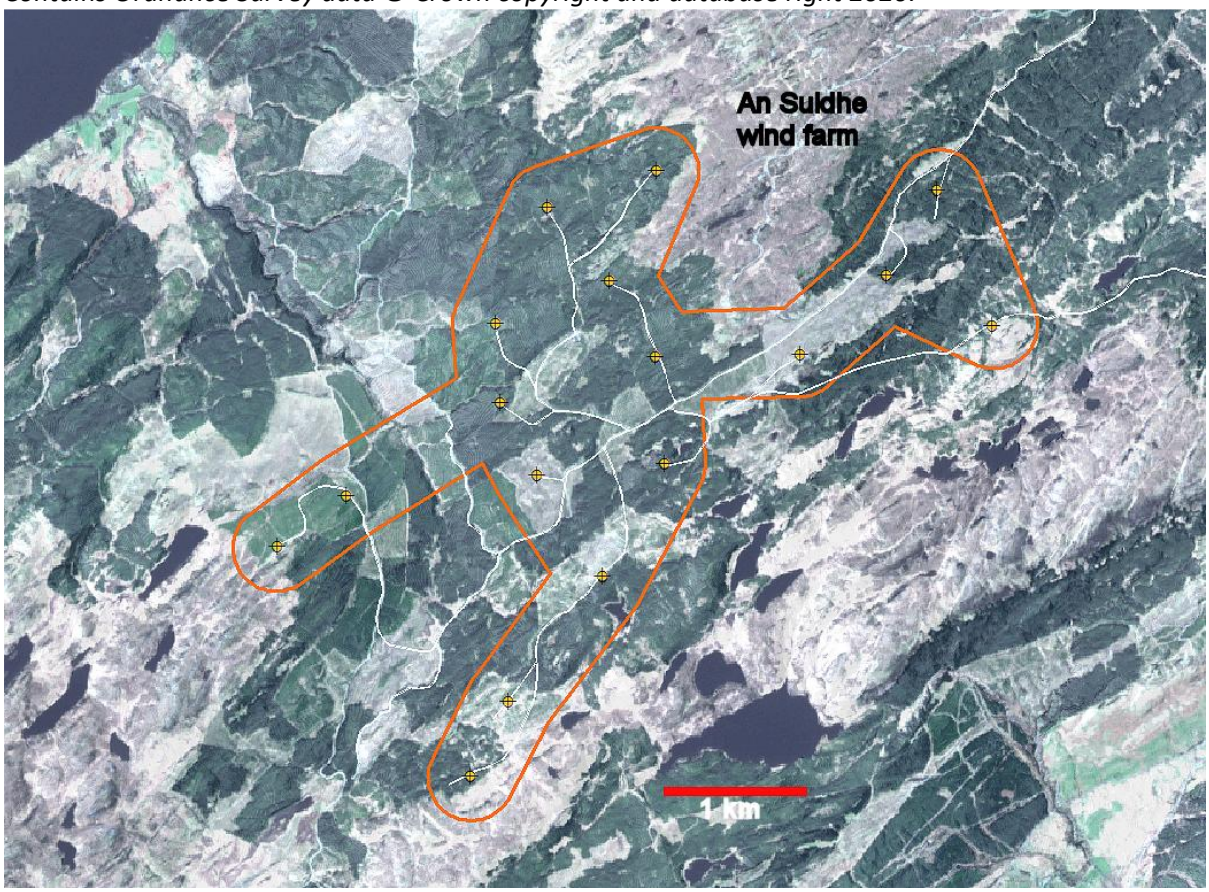
[2] 500m was introduced into wind farm assessments to deal with location inaccuracy in VP surveys when translated into collision estimates.

displacement distances were not the same for all turbines, even for identical turbines in the same wind farm (Fielding *et al.,* 2022, 2023, 2024b).

Unfortunately, there is insufficient evidence, on causal relationships, to incorporate such variation into current analyses. Consequently, a displacement distance of 300 m from the proposed turbine towers is suggested. The displacement distance will be less for some turbines, particularly those in or surrounded by good eagle habitat. It will be greater for others[3].

Evidence from tagging data suggests that if turbines are not in a string (a line of turbines) the outer turbines act as a barrier to the wind farm's interior (Fielding *et al.,* 2021, 2022, 2024b) and therefore displacement should be assessed with respect to a buffer around the outer turbines. To do this a 300 m buffer was drawn around each turbine and an outline constructed as a concave polygon around the outer turbines such that no point inside the polygon is <300 m from a turbine (orange lines in Fig. 1). All habitat within the concave polygon, even if >300 m from a turbine, is assumed to be lost to Golden Eagles once turbines are erected. Almost all of the Golden Eagle habitat, inside the Eredine exclusion zone, has already been lost to forest cover or turbines (Fig. 1).

Figure 1. *300m wide Golden Eagle exclusion area and putative turbine locations (orange symbols) and tracks. The red horizontal bar is 1km. Background is an April 2025 Sentinel 2 image which shows that considerable habitat in the exclusion area is already lost to Golden Eagles because of tree cover. Contains Ordnance Survey data © Crown copyright and database right 2020.*



[3] Note that a simple 500 m buffer is used to estimate losses due to existing turbines because it is computationally easier when maintaining a national database of lost habitat based on thousands of turbines. It is a conservative estimate of the existing habitat loss.

3. The current extent of good eagle habitat

Much surrounding landscape has extensive tree cover which limits the extent of good Golden Eagle habitat (Fig. 2). There is some extensive good habitat to the east. In addition to the loss of good habitat because of forest cover there are additional losses because of the 166 existing and consented turbines within 20km of the Revised Development.

- The 23 operational An Suidhe turbines are within 5 km of the Revised Development.
- Twenty one operational A'Chruach turbines, plus 14 Blarghour and eight Glasvaar consented turbines, are within 5 - 10 km.
- There are 78 operational turbines within 10-20 km: 20 Carraig Ghael; 14 Beinn Ghlass; 9 Clachan Flats; and 35 Cruach Mhor turbines. There are an additional 22 consented turbines: nine Creag Dubh and 13 at Ladyfield.

Using a false colour composite image of the 20 m resolution Sentinel 2 bands 2, 6 & 12 was used to locate the forest cover shown in Figs. 1 & 2. Using this image, and turbine buffers, the GET habitat was separated into the Open and Closed classes shown in Fig 3. **GET habitat loss is assessed only against the current extent of open habitat.**

The extent of available habitat, against which losses are assessed, was estimated in buffers of increasing distance (5, 10 and 20km) from the site (Table 1). There are several large contiguous, but isolated, blocks of good eagle habitat which tend to be associated with home ranges of resident Golden Eagles.

[redacted] RWE purchased these data from Natural Research and these data are used later in this assessment.

Open habitat is the current area of open habitat while Full is the habitat area assuming no habitat was lost to Golden Eagles as a result of forest cover or constructed and consented turbine buffers. The key figures in Table 1 are the areas of open GET 6+ habitat within the three buffers.

The areas of good eagle habitat (Fig. 2) are 3,861 (5 km); 10,284 (10 km); and 48,626 (20 km) ha (Table 1). The areas of good habitat already lost to Golden Eagles (Full Area – Open Area), through trees and constructed or consented wind farms, are: 5,561; 15,125; and 46,730 ha respectively (Figs. 2 & 3). The percentages of GET 6+ already lost to trees and constructed or consented wind farms are 59.0 % (5 km), 59.5 % (10 km) and 49.0 % (20 km). The proportion open GET 6+ habitat is relatively constant with increasing distance from the Revised Development (Table 1, Figs. 2 & 3).

***Figure 2**. Open GET landscape in the vicinity (20 km) of the Revised Development (orange circles). Other operational and consented turbines are shown as black circles. GET score key is shown in the lower left. Contains Ordnance Survey data © Crown copyright and database right 2020.*

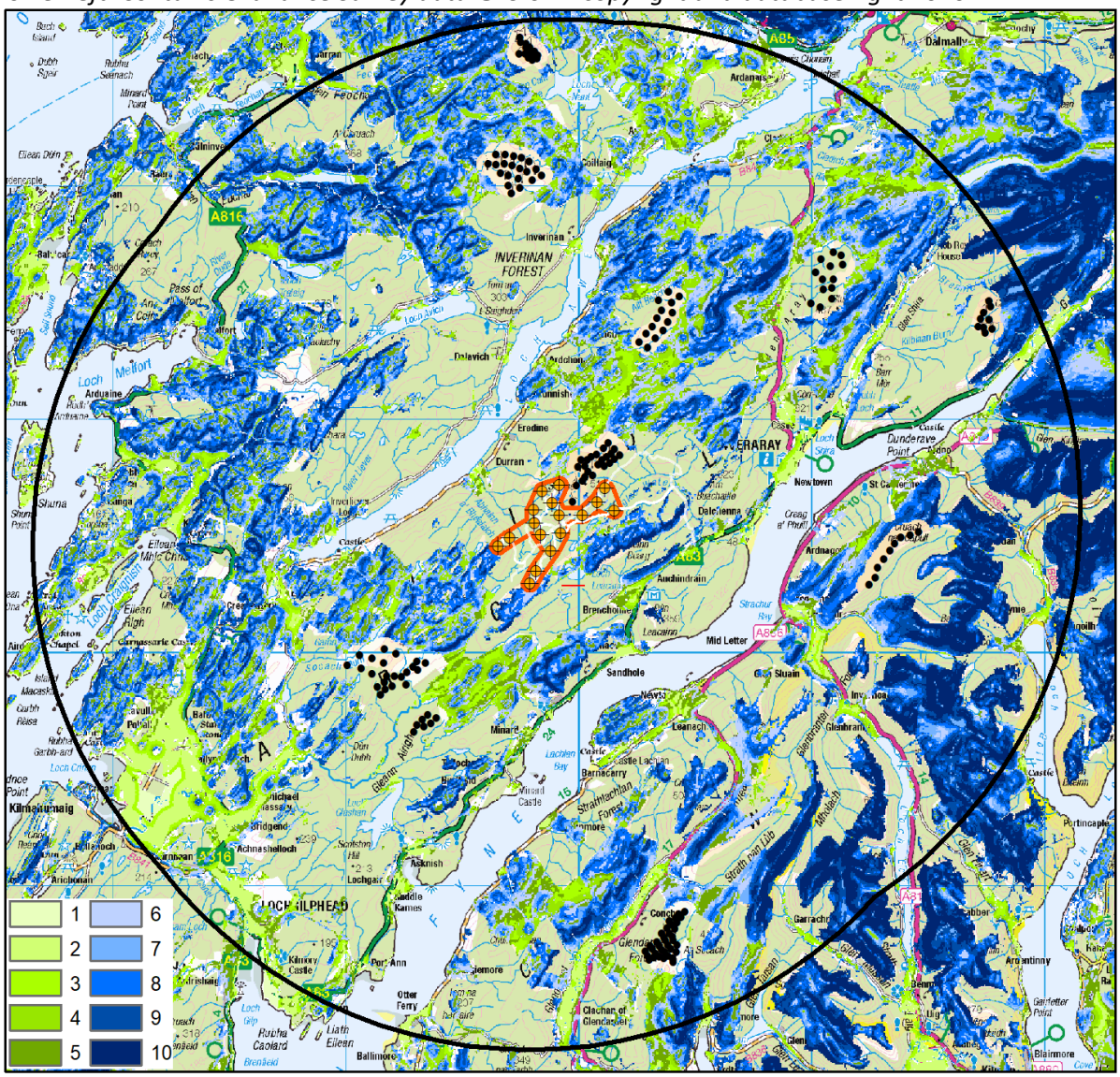


***Table 1**. Areas (hectares) of good Golden Eagle habitat at various distances from the Revised Development turbines and within the turbine exclusion buffer (Within). Assessed area is the area against which the percentage of open GET 6+ habitat is calculated. These data assume no losses to the proposed Teviot wind farm*

	5 km		10 km		20 km		Within	
GET	Open	Full	Open	Full	Open	Full	Open	Full
Closed	9,838	1,032	26,774	2,566	74,535	5,413	774	0
1	9	18	68	146	483	817	-	0
2	62	136	460	958	2,935	4,455	-	0
3	429	1,053	1,060	2,688	3,616	8,072	-	66
4	658	1,583	1,591	3,815	4,800	10,012	-	111

	5 km		10 km		20 km		Within	
GET	Open	Full	Open	Full	Open	Full	Open	Full
5	754	2,396	2,048	6,148	7,255	17,217	4	166
6	937	2,752	2,299	6,697	7,993	18,604	19	224
7	784	2,294	2,503	6,848	10,613	22,953	9	119
8	1,142	2,405	2,944	6,446	12,044	23,442	29	116
9	645	1,382	1,775	4,006	10,140	18,906	11	38
10	355	590	763	1,413	7,837	11,452	4	10
Area	15,611		42,284		142,249		849	
Assessed area	5,773	14,608	15,511	39,164	67,714	135,930	75	849
GET 6+	3,861	9,422	10,284	25,409	48,626	95,356	72	507
% GET6+	66.9	64.5	66.3	64.9	71.8	70.2	95.3	59.7

4. Assess the loss of habitat with respect to a regional figure and home range areas.

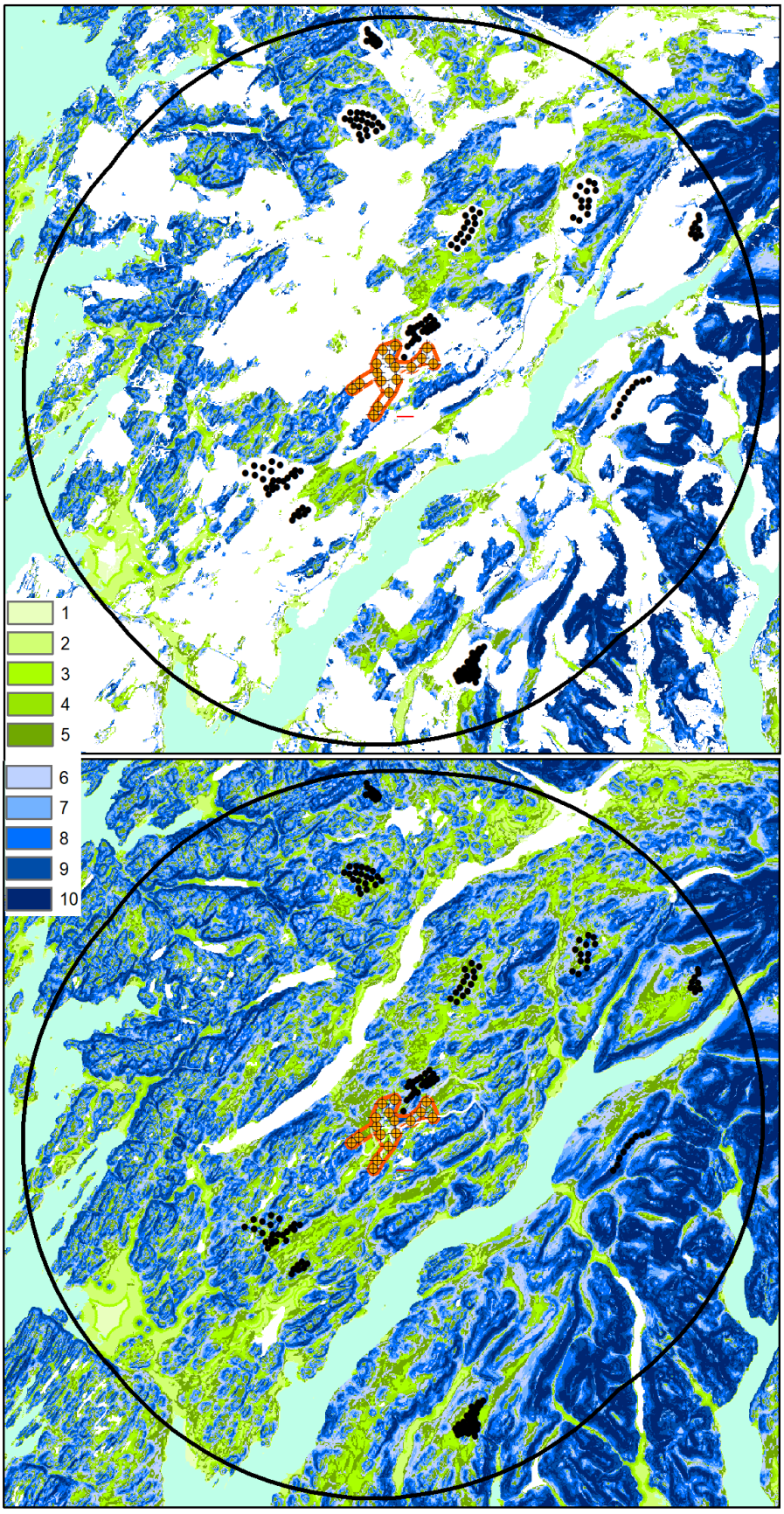
[redacted] a very robust assessment of the potential impact can be undertaken.

[redacted] Fielding *et al,* 2024a) has shown that males and females in a pair have similar home ranges. [redacted] and we can be very confident about the current home range limits.

Potential habitat loss is usually assessed by estimating the percentage loss of good eagle habitat within the home range (Box 1). But, when there are tag data, the loss can also be assessed by finding the proportion of tag records within the wind farm. The tag method has the advantage of incorporating the empirical distribution of tag records which will not be even across the home range even when there is extensive good eagle habitat.

[redacted]

***Figure 3**. Loss of open GET habitat within 20km of the Revised Development (yellow circles). Other operational and consented turbines are shown as black circles. Top – Open GET, Lower –Full GET map. Contains Ordnance Survey data © Crown copyright and database right 2020.*



Home range estimation

Home range sizes were estimated from a Utilisation Distribution (a density map of locations) of satellite tracked record locations. Isopleths are contours extracted from the UD and they are typically defined at 50% (normally called the core home range) and 95% (total home range extent) levels (Clap and Beck, 2015).

Range sizes were estimated only for records between dawn and dusk, nighttime roost sites were excluded by filtering out all records between dusk and dawn. Dusk and dawn times were obtained for each location and date using the R suncalc library (version 0.5.1).

In order to reduce autocorrelation records were restricted to one per 30 minutes. The spatial autocorrelation that is problematic for animals, such as relatively slow-moving mammals, is much less of a problem for a Golden Eagle which could easily move from one end of its range to the other in 10 minutes. Also, restricting records to one per 30-minute period helps overcome differences in record frequencies between winter and summer when the fix rate is dependent on the state of the solar charged batteries.

The record time stamp was converted to a decimal value between 0 and 24 and rounded to the nearest 0.5. Duplicate records, which had the same date and rounded time stamp, were filtered out leaving a single record for each 30-minute period.

Home range sizes were estimated from the track files for the two isopleth levels (50% & 95%) using the amt hr_akde function which takes account of the possible autocorrelation between sequential records (Singer and Fieberg, 2021). Home range isopleths have 95% confidence intervals but they are effectively identical, and indistinguishable when mapped, so only the central estimate is used.

Analyses (Fielding *et al.*, 2024a) suggest that 12 months of range-use data are needed for a robust assessment of the range. There are at least seven years of range holding data for both birds so the estimated range boundaries will be robust, particularly given the volume of data, essentially one record every 30 minutes for more than seven years.

Many Scottish Golden Eagle ranges have experienced historic loss of habitat, mainly from the planting of closed canopy forests or other more recent anthropogenic structures such as wind farms. If there are historic habitat losses for a currently occupied range there is no way of knowing what a range boundary was prior to these losses. This is relevant to the analyses presented below as the [redacted] boundaries prior to the planting of extensive forests and the construction on the wind farms cannot be known or estimated.

Roost and Perch locations

Although most emphasis is typically placed on assessing the risk to flying birds Golden Eagle spend at least half of the daytime stationary on the ground on in a tree and they roost during the night meaning that time spent flying in the air represents a minority of their use of their home range.

A **perch site** is a location where a Golden Eagle is stationary on the ground or in a tree during day time. Perches tend to be transient, many lasting only a few minutes but the average is around 60 minutes and the maximum is the whole of the day time, i.e. the bird does not fly that day. On average Golden Eagles appear to spend 40% - 60% of daylight hours perching although this is very variable day to day (Natural Research unpublished data and Sur *et al*., 2021).

Downloaded tag data contain a speed field. If it is day time and the speed is 0 the bird is not moving and it can be assumed to be on the ground or in a tree, i.e. perching. It might be assumed that if sequential speed records are 0 the individual has continued to perch in the same location. However, depending on the time interval between sequential records the bird may have moved, undetected, between records so it is necessary to compare the coordinates of sequential records with a speed of 0. In order to prevent the same perch being treated as different perch locations, partly driven by the tag's location accuracy, it is necessary to apply a movement threshold. Deciding on an appropriate value for this threshold is an active research area. For the purposes of these analyses if the bird has moved <100 m it is assumed to be at the same perch location.

[redacted]

A **roost site** is a place where a Golden Eagle spends the night; this may be a tree, crag or a sheltered patch of land. Golden Eagles rarely move more than a few meters overnight. Golden Eagles have a surprisingly large number of roosts in their home range. The most frequently used roost sites may not be identifiable from bird signs on the ground, i.e. there may be no or very few field signs of use (C. Chandler and B. Urqhart, independent *pers comms*).

Roost sites are used during the night between dusk and dawn. A bird could begin roosting before dusk, in which case a perch becomes a roost or it could continue roosting after dawn when the roost would become a perch. It is assumed that the bird does not move significantly (<50 m) during the night and there is very robust evidence from night time location data to support this assumption.

Dusk and dawn times were obtained for each tag location and date using the R suncalc library. A record's time stamp can be compared with the dawn and dusk times at that place and date to decide if it is day or night time record. Records after midnight but before dawn the next day are assigned to the previous date. A median roost location is estimated from all night time records during the night (dusk to dawn).

Finally, to simplify the data and to deal with the spatial error in GPS records, all roosts were assigned to the centre of the 50 m pixel containing the record. It is not obvious how far apart roost sites need to be to be considered as separate sites. It is possible to have roosts in adjacent 50 m pixels which stretch in a line for 500 m or more with no gaps. Are the roosts at each end of the 500 m string of pixels the same roost site? This is another topic of active research. In these analyses all 50 m pixels, with at least one record, are treated as separate roost sites. Frequency of use (number of separate nights) was calculated for each roost site.

[redacted]

[redacted]

[redacted]

[redacted] **This represents a loss of 0.7%** (16/2,319) **of the open GET 6+ habitat from the 95%** [redacted] **This small loss,** [redacted]**, will not be significant.** Note that the loss of open GET 6+ habitat [redacted], has already been included in [redacted]

[redacted]

[redacted] **it is reasonable to conclude that there would not be a significant loss to the** [redacted] **following the construction of the Revised Development.**

[redacted]

[redacted] **This small loss,** [redacted] **will not be significant.** [redacted]

[redacted]

[redacted] **it is reasonable to conclude that there would not be a significant loss to the** [redacted] **following the construction of the Revised Development.**

Note that despite being almost 30% larger, the [redacted] emphasising the need to concentrate on the area of good eagle habitat rather than the total range area.

[redacted]

A qualitative assessment of a development's impact should also look at the Revised Development in relation to the surrounding landscape and likely Golden Eagle movement patterns. Golden Eagles have clear movement patterns along extensive contiguous GET 6+ areas, [redacted]. Connectivity can be disrupted by wind farms [redacted] resulting in a larger loss of habitat than that within the turbine exclusion area. In this assessment the empirical movement data demonstrates that the Revised Development in unlikely to have a significant impact on important movement corridors.

[redacted]

the Proposed Developed will not create a barrier for Golden Eagle movements.

[redacted]

4.3 Dispersing young birds

Wind farms can also result in a loss of habitat used by dispersing Golden Eagles. Generally, dispersing Golden Eagles stay outside of occupied home ranges so if a wind farm is within an existing Golden Eagle range, as in this case, any losses for dispersing young eagles should be small because the range holding birds will be restricting use of the range habitat by dispersing Golden Eagles.

Assessing the impact on dispersing Golden Eagle habitat at the natural heritage zone level will inevitably result in a trivial loss of habitat. For example, the 20 km buffer around the Revised Development currently has more ~48,600 ha of open eagle habitat (Table 1) and the exclusion zone around the Revised Development would result in a very small ~0.15 % loss of this open GET 6+ habitat (72 ha from 48,626 ha). Because dispersing Golden Eagles cover enormous areas, assessing loss at the scale of an individual's dispersal area would also lead to an inevitable trivial loss estimate.

Instead, habitat loss can be estimated regionally using a buffer (distance from Revised Development) which is appropriate for the region; in which case the question becomes what buffer size is appropriate? Clearly, estimated percentage losses will be larger for small buffers and vice versa. The estimated adult range size could be an appropriate lower limit for the buffer size. However, this is not a fixed planar area and the size of a buffer required to include a particular area of open eagle habitat depends on many factors but mainly topography, forestry and wind farms. Although the area of open GET 6+ habitat might be expected to scale in a non-linear manner with increasing buffer size (simple buffer area is non-linear with increasing buffer distances[4]), the rate of increase in good eagle habitat is unpredictable.

It is suggested that the upper limit for assessing the impact of a Revised Development on dispersing Golden Eagle habitat should be EITHER a buffer with a <u>maximum</u> [redacted]

The area of good eagle habitat within 10 km of the Revised Development is 10,284ha (Table 1) [redacted] A loss of 72 ha from 10,284 ha is ~0.7%, which would normally be considered an insignificant loss. However, as most [redacted] **and it is clear that the Revised Development would not result in a significant loss of good eagle habitat used by dispersing birds.**

Also, based on the extent of open GET 6+ habitat (Fig. 2), the Revised Development would not create movement barriers for dispersing Golden Eagles.

[4] For example, for a point, buffer areas of increasing distances between 1 and 5 units are 3.1, 12.6, 28.3, 50.3 & 78.5 units^2. So, the area for a buffer with a radius of 5 units is not five times larger but 25.3 times larger than one with a buffer radius of 1 unit.

[5] Note, this is a regional specific value and is expected to vary across Scotland.

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