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Nest-site selection by Golden Eagles in Scotland

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A comprehensive survey of Golden Eagles *Aquila chrysaetos* in Britain was carried out in 1982 (Dennis *et al.* 1984) and, during this, information was collected on a range of nest-site features. While these data were collected incidentally to the population survey, they nevertheless provide valuable insights into nest-site selection by Golden Eagles; they also give an opportunity to test whether variations in breeding success are linked to nest-site features.

Despite the extensive literature on Golden Eagles in Scotland (e.g. Gordon 1955; Brown & Watson 1964; Brown 1969; Everett 1971; Dennis *et al.* 1984; Watson *et al.* 1989), few quantitative data have been published describing the characteristics of nest sites used. By contrast, a number of studies have been done in Continental Europe (Jordano 1981; Tjernberg 1983; Bergo 1984; Fernandez 1989) and the United States (Mosher & White 1976), and these provide valuable comparative data.

Methods

Full details of the survey methods used in 1982 have been given elsewhere (Dennis *et al.* 1984). The principal aim was to visit all potential nesting areas and to document the numbers, distribution and breeding success of Golden Eagles throughout Britain. Observers also collected the following information on nest sites, and this forms the basis of the present paper:

(1) type of nest site used (cliff or tree);
(2) altitude of site above sea level;
(3) direction of exposure of site;
(4) distance from site to nearest public road;
(5) extent to which site was accessible to people;
(6) extent of deliberate or casual disturbance of site by people.

A pair of Golden Eagles usually has a number of alternative eyries (Brown 1976), and this was certainly true in the present study. Observers recorded information on all known alternative nests, although, for the purposes of analysis, and to retain statistical independence among the data, in this paper only one nest has been used for each pair of eagles. Analysis of additional-nest-site data within each home range will form the subject of a further paper in which we shall also investigate nest-site selection by pairs in different years. For the present study, we included nests known to contain eggs or young in 1982, but also, where eggs or young were not seen, nests which were built up and lined in that year. Only rarely was more than one nest lined within the home range of a pair, and in such cases the nest with the most recent history of occupation was used in the analysis. For pairs where no nest was built up, and therefore no preference shown for a site, the analysis was done on the site which had been used most recently. Not all nest-site variables were collected for all pairs of eagles, and, therefore, sample sizes vary.

Information on type of nest site was reported as cliff (including bank or bluff) or tree, with the species of tree recorded. Altitude above sea level was extracted from 1:50,000 maps and was expressed in metres. Distance (km) by straight line to nearest public road was measured from 1:50,000 maps, and a public road was defined as one on which vehicular access by members of the public was allowed. For each nest site, the direction of exposure was allocated to one of eight compass segments (N-NE, NE-E, etc.); where a nest was exposed to a range of directions, from, say, northwest to east, the direction of exposure was allocated to the segment which contained the bisector of the angle of the full range of exposure (in the example NW to E, this would be segment N-NE).

Objective assessments of measures of 'accessibility' and 'disturbance' were more difficult to obtain because the survey forms had been completed by a variety of observers and limited guidance had been given on criteria for recording this information. Nevertheless, we were able to place most responses into reasonably distinct categories which we believe could be used with consistency in any future survey. We considered 'accessibility' under three categories:

(1) nest site could be reached safely without the aid of a rope;
(2) a rope was advisable for safety, but not essential;
(3) it was physically impossible to reach the site without a rope.

Similarly, we interpreted the returns on 'disturbance' and placed these into three categories:

(1) no evidence of disturbance detected by the observer in 1982, nor in the recent past (previous 5-10 years);
(2) some evidence of unintentional disturbance by hill-walkers, or occasional evidence of visits by egg-collectors either in 1982 or in recent past;
(3) evidence of use of poisons within the home range, killing of adult eagles, destruction of nests and contents, or persistent egg-collecting in 1982 and/or in recent past.

Geographical variation across the Scottish highlands and islands

Dennis *et al.* (1984) reported a minimum of 424 home ranges occupied by pairs of Golden Eagles in Britain, with over 98% of these in the Scottish highlands and islands northwest of a line from Glasgow to Aberdeen (see fig. 1). This, therefore, is the area to which the nest-site data chiefly refer, although all pairs for which some nest-site data were available were included in our analysis.

There is pronounced geographical and ecological variation across the highlands and islands, and this is most marked from west to east. The highly oceanic climate of the western seaboard contrasts markedly with the drier, more continental climate of the eastern highlands. A detailed account of the vegetation of the highlands is given by McVean & Ratcliffe (1962). One of the most conspicuous and ecologically profound changes from west to east is the increasing importance of ericaceous plants (principally heather *Calluna vulgaris*) among ground vegetation, and a consequent reduction in the importance of graminoid vegetation (grass-dominated communities). This has a bearing on the amount of prey available to Golden Eagles, which, over much of Scotland, feed extensively on two species, the mountain hare *Lepus timidus* and the Red Grouse *Lagopus lagopus* (Watson *et al.* 1987); both these animals depend heavily on heather and are consequently much more plentiful in the eastern highlands (Jenkins *et al.* 1963; Hewson 1976; Savory 1986).

There are also important topographic differences between west and east. On the western seaboard and the islands, much of the ground is generally low-lying, although there are exceptions such as the Cuillins on Skye and the Harris hills. Inland, the ground rises steeply and hills tend to be rocky, with extensive crags and sharp peaks and ridges. The mountains of the eastern highlands are more rounded, with fewer crags and extensive high-level montane plateaux; remnant Scots pine *Pinus sylvestris* woodland is more extensive in the east, and the natural tree-line is generally at a higher elevation (Nethersole-Thompson & Watson 1981).

Linked to these important differences in climate, vegetation and topography are key differences in land-use. In the western highlands, the emphasis is on hill-sheep farming, with some red deer *Cervus elaphus* management for sport, and, increasingly in recent years, conifer afforestation. In the central highlands, red deer management predominates, and in the east the land is managed for game, with deer on the higher ground and grouse moor at lower elevations (McVean & Lockie 1969; Watson *et al.* 1987; Ratcliffe 1990).

In recognition of these important west-east differences, we used longitudinal divisions based on the national grid to subdivide the eagle population and, within these bands, nest-site data were, where appropriate, pooled for analysis.

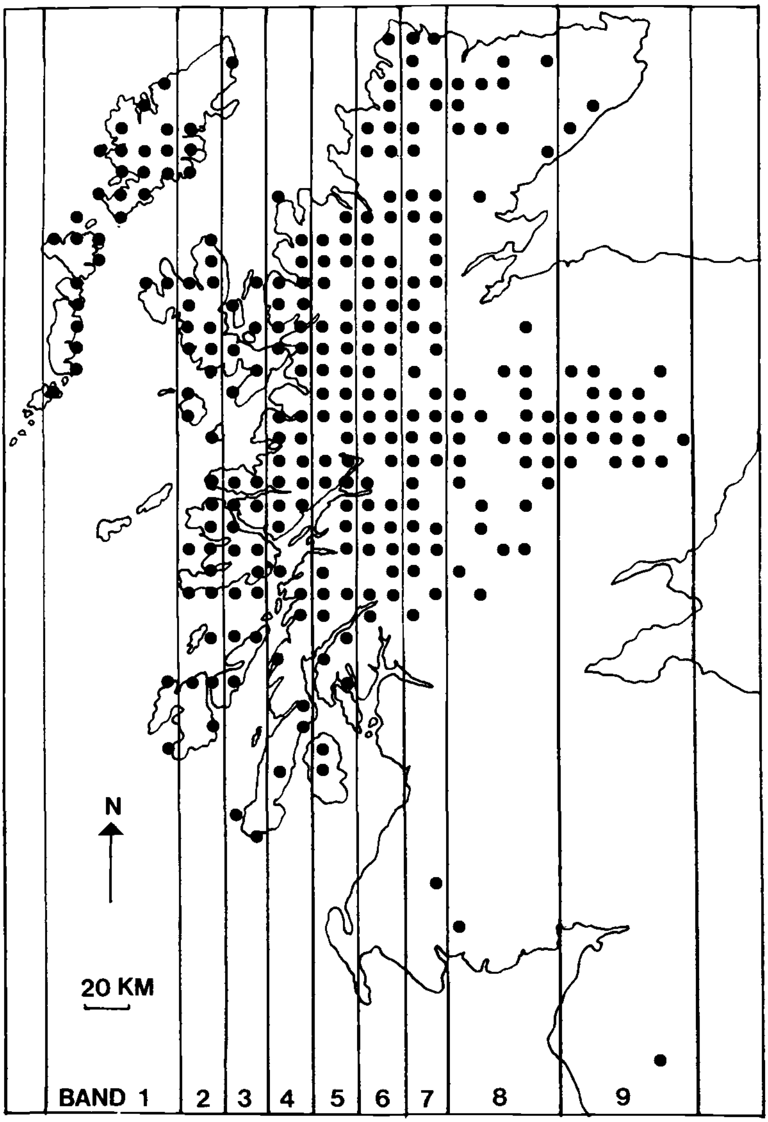

Fig. 1. Map showing distribution of 10 × 10 km squares from which nests of Golden Eagles *Aquila chrysaetos* were reported in Britain in 1982. Vertical 'bands' (1-9) indicate west-east longitudinal divisions used in subsequent analysis. Sample sizes for eagle nests located in each band are given in table 1. For reasons of confidentiality, four 10 × 10 km squares are omitted from map, although data from the sites involved are included in text

The bands used are shown in fig. 1 (the variation in band width was dictated by the need to retain roughly equal and statistically adequate sample sizes). We investigated the possibility that there might be other patterns which reflected a north-south gradation, but none was detected and we therefore restricted our geographical analysis to the west-east comparison.

Results

In the present study, nest-site information was available for around 400 pairs of eagles, although data on 'accessibility' of and 'disturbance' to nest sites were fewer. Results are presented under the six headings 'nest type', 'altitude', 'direction of exposure', 'distance to road', 'accessibility', and 'disturbance'. The first three relate to the question of nest-site selection by eagles; and the last three to the potential effect of direct or indirect human actions on the site, and thereby on the probability of successful nesting.

Nest type

Nest type was recorded for 410 pairs, of which 392 (95.6%) used cliffs and 18 (4.4%) used trees. Of the latter, all but one were in Scots pines, the other being in a larch *Larix*. Among nests not used in 1982, there were two records of sites in oaks *Quercus*. The distribution of tree nesting is heavily skewed to the east (table 1), with less than 1% of pairs using trees in the western part (bands 1-5) and nearly 10% in the eastern part (bands 6-9).

Table 1. Number of pairs of Golden Eagles *Aquila chrysaetos* using cliff or tree nests in different parts of British range in 1982

For definition of bands, see fig. 1

	BAND									
	1	2	3	4	5	6	7	8	9	Total
Cliff	45	45	33	49	55	57	53	36	19	392
Tree	0	0	1	0	0	3	1	3	10	18
TOTAL	45	45	34	49	55	60	54	39	29	410

Altitude

Altitude in metres was recorded for 410 nests and is shown for the nine longitudinal bands (table 2, fig. 2). The measure of the mean maximum altitude for land in the nine bands was derived by recording the maximum elevation in each of the 10 × 10 km squares from which eagles with nests were reported in 1982, and averaging this figure for each of the nine bands. The mean elevation of sites is given as a percentage of the mean maximum elevation of the surrounding landscape.

Table 2. Mean altitude above sea level (m ± 2s.e.) of nest sites of Golden Eagles *Aquila chrysaetos* in different sectors of population in 1982, with mean maximum altitude (m ± 2s.e.) for 10 × 10 km squares within each respective band

For definition of bands, see fig. 1

	BAND								
	1	2	3	4	5	6	7	8	9
(a) Mean nest-site elevation	154±29	211±42	208±38	281±35	372±34	442±38	402±33	474±56	460±55
(b) Mean maximum elevation	345±72	446±89	459±98	640±85	855±73	904±57	844±63	777±83	778±91
% a/b	44.6	47.3	45.3	43.9	43.5	48.9	47.6	61.0	59.1

The results show a steady rise in the mean elevation of sites from west to east, with an indication of levelling off from band 6 eastwards (this is approximately east of the line of the watershed). For bands 1-7, there is remarkable conformity in the elevation of nests in relation to maximum elevation of the surrounding land, with eagles nesting consistently at just under 50% of the maximum elevation. In the two easternmost bands, nests were located higher in relation to the maximum surrounding altitude, at around 60% of the mean maximum elevation.

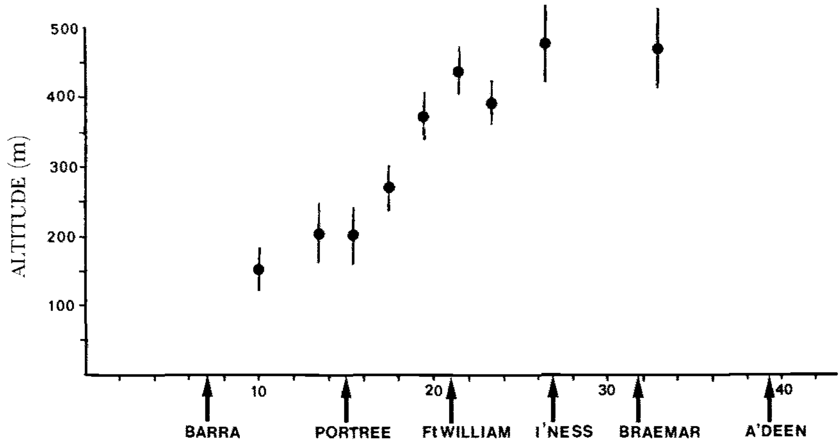

Fig. 2. Mean altitude in metres (m ± 2se) of nest sites of Golden Eagles *Aquila chrysaetos* in nine 'bands' across Scotland. See fig. 1 for explanation of 'bands'. For reference, positions of six key localities across Scotland are indicated (Barra, Portree, Fort William, Inverness, Braemar, Aberdeen). The horizontal scale is comprised of 2 × 10-km lengths passing across Scotland from west to east, starting arbitrarily at the first 100-km National Grid line west of the Hebrides

Direction of exposure

Information on direction of exposure was available for 407 nest sites. All data are presented on the basis of the number or proportion of nests with their principal direction of exposure recorded in one of eight segments (table 3, fig. 3). By our own convention, the segment N-NE included all directional-exposure records reported by observers as either N or NNE, segment NE-E included all records reported as NE or ENE, and so on. To investigate the extent to which any skewed distribution of the direction of exposure of hill slopes (and therefore potential nesting places) may have influenced the direction of exposure of nest sites, we selected a point at random within each 10 × 10 km square in which Golden Eagles were reported nesting in 1982. The exposure of the slope at each of these points was then ascribed to one of the eight segments using the same conventions as for nest sites. Results, given alongside nest-site data in fig. 3, indicate that the direction of exposure of slopes prevailing in nature across the highlands and islands is not significantly different from a null hypothesis which predicts an equal distribution among the eight segments. The direction of exposure of nest sites, however, was significantly different from the distribution expected on the same null hypothesis ($\chi^2 = 96.2$; df = 7; $p<0.001$). There were many more nests with exposures in the three segments between NW and E (58.3%) than in the three segments between SE and W (21.4%).

Table 3. Principal direction of exposure in eight compass segments of Golden Eagle *Aquila chrysaetos* nests, with exposure directions of hill slopes selected at random from 10 × 10 km squares within nesting range

		N-NE	NE-E	E-SE	SE-S	S-SW	SW-W	W-NW	NW-N	Total
Nest	no.	100	76	48	32	23	32	35	61	407
sites	(%)	(24.6)	(18.7)	(11.8)	(7.9)	(5.6)	(7.9)	(8.6)	(15.0)	
Hill	no.	42	28	39	42	40	34	34	24	283
slopes	(%)	(14.8)	(9.9)	(13.8)	(14.8)	(14.1)	(12.0)	(12.0)	(8.5)	

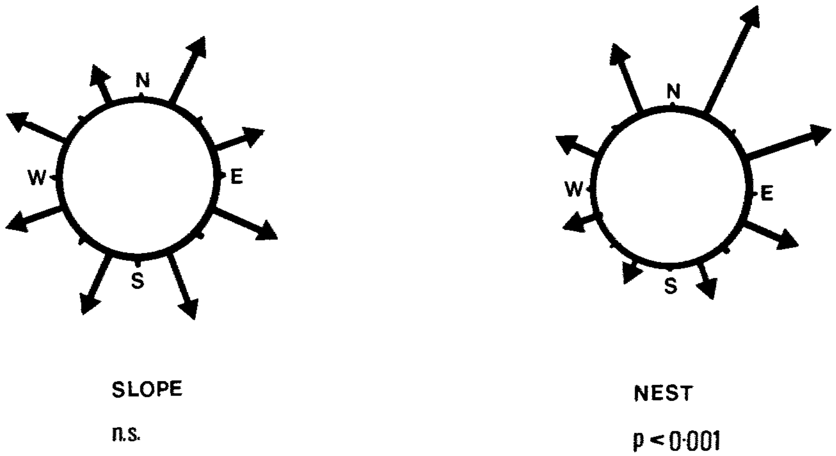

Fig. 3. Direction of exposure of 407 nest sites and of hill slopes at 283 localities (stratified random sample, see text) across range of Golden Eagle *Aquila chrysaetos*. Length of each arrow indicates proportion of nests/slopes recorded in each compass segment (for numerical data see table 3)

Distance to road

It might be expected that Golden Eagles, which are considered particularly vulnerable to human disturbance, would abandon active nest sites situated close to public roads more readily than those farther away. If this hypothesis is correct, then the proportion of nesting attempts which fail altogether should be highest close to public roads and decrease progressively as distance to nearest road increases. Distance to nearest public road was recorded for 406 nest sites, and for analytical purposes the numbers of nests were pooled for distance intervals of 1-km width; all nests more than 8 km from a road were pooled in order to avoid small samples. Table 4 gives the proportion of nests which failed to produce any young in 1982 in relation to distance from public road. There was no significant relationship ($r = 0.116$; n.s.), indicating that probability of nesting failure was not related to distance between nest site and public road.

Table 4. Number of Golden Eagle *Aquila chrysaetos* nest sites located at different distances from public roads, with respective percentages of 1982 nesting attempts which failed

	DISTANCE TO PUBLIC ROAD (km)								
	0.1-1	1.1-2	2.1-3	3.1-4	4.1-5	5.1-6	6.1-7	7.1-8	>8
No. of nests	31	66	76	57	49	44	28	25	30
% failed	51.6	62.1	56.6	57.9	59.1	52.3	64.3	64.0	43.3

Accessibility

Are eagles which use nest sites that are more accessible to people more prone to failure than those at sites that are difficult to reach? Table 5 shows the incidence of nesting failure at sites which were classified as easy (1), moderate (2) and difficult (3) in terms of accessibility. Pairs using class 3 sites were significantly more likely to fledge young successfully than were those using sites classified as 1 ($\chi^2 = 6.37$; df = 1; $p<0.05$); sites classified as 2 were intermediate, as would be expected. Interestingly, the eagles using class 1 sites, if they were successful at all, raised broods of two chicks more frequently than did those at class 3 sites, although the difference was not statistically significant ($\chi^2 = 2.81$; df = 1; $p<0.1$); again, class 2 sites were intermediate.

Table 5. Incidence of breeding failures together with fledging success at Golden Eagle *Aquila chrysaetos* nest sites classified as easy (1), moderate (2) or difficult (3) in terms of accessibility

See text for definition of terms 1-3

	Failed	(%)	NO. OF YOUNG FLEDGED 1	2	(% 1+2)	Total
Easy	47	(69.1)	15	6	(30.9)	68
Moderate	73	(54.9)	47	13	(45.1)	133
Difficult	73	(49.7)	66	8	(50.3)	147

Disturbance

Data on disturbance were available for 335 pairs in 1982 (table 6). These show that, while breeding failure was reported for 46.2% of pairs which were not considered subject to disturbance (class 1), this figure rose to 74.3% for class 2 (some threat identified) and to 93.1% for class 3 (serious persecution reported). The incidence of class 3 disturbance among the population as a whole was comparatively low, at 8.7%, and class 2 was higher, at 20.9%, leaving 70.4% with no serious disturbance reported in 1982.

Table 6. Assessments of level of disturbance according to three classes (low, moderate or severe) at nest sites of 335 pairs of Golden Eagles *Aquila chrysaetos* in 1982, together with respective fledging success

See text for definition of classes of disturbance

Disturbance	0	(%)	NO. OF YOUNG FLEDGED 1	2	(% 1+2)	Total	%
Low	109	(46.2)	107	20	(53.8)	236	(70.4)
Moderate	52	(74.3)	14	4	(25.7)	70	(20.9)
Severe	27	(93.1)	2	0	(6.9)	29	(8.7)
TOTAL	188		123	24		335	

Table 7. Number of nests subject to disturbance according to three classes (low, moderate or severe) in different parts of Golden Eagle's *Aquila chrysaetos* range across Scotland in 1982

See text for definition of classes of disturbance, and fig. 1 for definition of bands

Disturbance	BAND 1	2	3	4	5	(% 1-5)	6	7	8	9	(% 6-9)
Low	21	23	21	32	42	(74.3)	44	28	13	12	(65.6)
Moderate	10	7	2	15	9	(23.0)	8	9	7	3	(18.2)
Severe	2	2	0	1	0	(2.7)	0	4	13	7	(16.2)
Totals	33	32	23	48	51		52	41	33	22	

TOTAL NO. OF NESTS 335

The distribution of each level of persecution across the range of the species is shown in table 7. The number of sites subject to moderate disturbance (class 2) was not significantly different between the western and eastern segments of the population (bands 1-5, 23.0%; bands 6-9, 18.2%). The frequency of occurrence of serious persecution, however, was significantly higher in the east than in the west (bands 6-9, 16.2%; bands 1-5, 2.7%: $\chi^2 = 17.49$; df = 1; $p<0.001$). Much the highest incidence of serious disturbance was among sites in the two bands farthest east (8 and 9), where the combined figure was 36.4%.

These data allowed us to estimate the number of young which might have been reared to fledging in the absence of moderate or severe disturbance. Assuming that the 99 pairs reported to experience either moderate or severe disturbance were allowed to produce at least as many young as the pairs reportedly suffering no disturbance, then the figures for young fledged per pair should match the 0.62 per pair for undisturbed nests. This would suggest that a minimum of 22 chicks failed to fledge from 70 nests in disturbance class 2 and another 16 from 29 nests in class 3: giving an estimated loss of 38 chicks from a potential annual production figure of 209 from the 335 pairs for which the disturbance level was documented, or an annual loss through disturbance of 18%. This is undoubtedly an underestimate since most losses from disturbance occurred in the eastern half of the range, where breeding performance in the absence of persecution was significantly higher than in the west, mainly because food in the form of live prey is much more plentiful on the eastern moors (Watson *et al.* 1987, 1989).

Discussion

Nest-site selection

Typically, Golden Eagles in Scotland nest on cliffs, at elevations between 150 and 450 m above sea level and with the principal direction of exposure lying between northwest and east. The frequency of tree nesting is higher in the eastern half of the range, where nesting is also at higher elevations compared with the 'oceanic' west. Judging by the distribution of the directions of exposure of hill slopes, there is a clear preference for nesting with a northerly rather than a southerly exposure. Eagles were most likely to nest at elevations of just under half the maximum altitude of the surrounding landscape, although in the most easterly part of the range nests were at around 60% of the maximum elevation.

Throughout most of Europe, tree nests make up less than 10% of the total (e.g. Bulgaria—Michev *et al.* 1989; Spain—Fernandez 1989; Italy—Fasce & Fasce 1984; Switzerland—Haller 1982; France—Mathieu & Choisy 1982; Yugoslavia—Grubac 1988), and the results from Scotland are therefore typical. Nests in trees are in the majority in Sweden (Tjernberg 1983), Finland (Sulkava *in litt.*) and Czechoslovakia (Voskar *et al.* 1969); in Estonia and Belarus, Golden Eagles are exclusively tree-nesting (T. Randla *in litt.*; V. V. Ivanovsky *in litt.*). In the Baltic States and eastern Fennoscandia, the species inhabits mainly relatively flat wooded-bog landscapes, where there is simply no option but to nest in trees. Most mountain landscapes offer an abundance of cliff nest sites, and it would appear that, where cliffs are available, they are the preferred choice (Haller 1982). The relatively high proportion of tree nesting in eastern Scotland is consistent with this, since the rounded hillsides offer many fewer crag-nesting options than do the rocky hills of the west. Indeed, since most of the original forest of Britain has been lost, and given a lack of suitable cliffs in many eastern areas, it is likely that nest-site availability is one factor limiting Golden Eagle distribution in parts of eastern and southern Scotland and northeast England where otherwise there would appear to be abundant food.

The steady rise in the altitude of nest sites from the western seaboard eastwards indicates that eagles are choosing sites in relation to some environmental variable which changes across this part of Scotland. The most likely variable is food, and more particularly where that food occurs. In western Scotland, the amount of prey, in particular Red Grouse and mountain hare, available in mountain and moorland habitats is a fraction of that available farther east (Watson *et al.* 1987), and eagles must therefore hunt more low-ground prey such as rabbits *Oryctolagus cuniculus* and seabirds. The need to minimise the transportation of such prey 'up the hill' to nests probably dictates the preferred elevation of sites here. While eagles in the central and eastern highlands have nests at a similar mean elevation of around 450 m, there are subtle differences: those in the central highlands nest at around 48% of the maximum surrounding elevation, while eastern birds are at 60% of the maximum. Again, we believe this to be food-related and suggest that the high numbers of Ptarmigan *Lagopus mutus*, Red Grouse and mountain hares on the extensive rounded summits and mountain plateaux are sufficient to allow successful breeding at these relatively high elevations, even though there is comparatively less hunting ground above the nesting sites. It may also be that levels of persecution in the eastern highlands (see below) have favoured the selection of nesting sites at higher elevations which may be more secure, but which may not be optimal in terms of providing food for nestlings.

The average altitude of nest sites varies widely across Europe and is certainly related to the availability of suitable hunting ground and food. In Norway and Sweden, the mean elevation is around 500-600 m (Bergo 1984; Tjernberg 1983) and coincides closely with the natural tree-line; here, eagles hunt extensive open land above the tree-line and are therefore almost always able to transport prey downhill to nests, giving potential energy savings (Glutz von Blotzheim *et al.* 1971; Haller 1982). In Spain, there are populations at two distinct altitudinal levels, with eagles nesting in some parts of the peninsula at around 600 m (Jordano 1981) and in the Pirineos (Pyrénées) at nearer 1,500 m (Fernandez 1989); a similar dichotomy is reported in France (Mathieu & Choisy 1982) and Italy (Fasce & Fasce 1987; Magrini *et al.* 1987). In each case, the explanation is related to availability of food and suitable hunting ground. In the arid landscapes of the Iberian peninsula, Provence in France and the Appennines in Italy, fire combined with pastoral activity has provided open ground for hunting at comparatively low elevations, and with it prey such as rabbits, brown hares *Lepus capensis* and Red-legged Partridges *Alectoris rufa* (Watson 1991). By contrast, in the truly alpine mountains (the Alps and Pyrenees), dense forest cover over low and intermediate slopes excludes Golden Eagles, and they reappear at about the tree-line (1,500-1,800 m), where they nest, transporting their favoured prey of marmots *Marmota marmota* downhill from alpine meadows. One final example of food and hunting habitat dictating nesting altitude comes from Estonia, where virtually the whole landmass, and therefore each nest site, is situated below 200 m altitude. And yet, here again, the Golden Eagle is occupying a 'tree-line'-like habitat with patchy woodland interspersed with open bog (Zastrov 1946; Randla *in litt.*). Here, it is the high watertable, rather than low temperatures, the effects of grazing, fire or drought, that prevents tree growth and thereby offers suitable terrain for eagles to hunt; this time, their favoured prey is the Capercaillie *Tetrao urogallus* (Zastrov 1946). Given the evidence from Continental Europe, it is interesting to speculate that the extant variation in mean elevation of nesting sites across Scotland may reflect an ancestral tree-line.

Despite the availability of slopes facing equally all segments of the compass, Golden Eagles in Scotland appear to choose nests with a northerly rather than a southerly exposure. There are several possible reasons for this and we offer two explanations, both of which invoke the effects of weather:

(1) Golden Eagles in Scotland may prefer sites facing north by east to provide maximum protection from prevailing inclement weather, which comes mainly from the southwest;
(2) they could prefer north-facing sites to avoid excessive exposure to sun, and thereby reduce risks to nestlings of overheating.

Evidence from elsewhere in Europe is revealing. In Norway and Sweden, where eagles nest at higher elevations (500-600 m) than in Scotland and yet receive inclement weather on the same southwesterly airstream, the principal direction of exposure in both cases is southerly (Bergo 1984; Tjernberg 1983). In southern Europe, the high-altitude (1,500-1,800 m) nesting populations in the Alps and Pyrénées both show preference for south-facing sites (Fernandez 1989; Henninger *et al.* 1987), while comparatively low-altitude populations at 600-900 m in Spain, Italy, Sicily and Yugoslavia all avoid southerly aspects (Jordano 1981; Magrini *et al.* 1987; Seminara *et al.* 1987; Grubac 1988). Thus, populations at similar latitudes but differing altitudes show a complete shift in direction of exposure; these results are consistent with the second explanation (above). The sites at higher elevations, where temperatures are cooler, may, we suggest, gain from increased insolation, while eagles nesting at low-level sites which risk overheating must take avoiding action. These findings support a similar analysis of nest-site exposure in the USA (Mosher & White 1976).

Nest-site characteristics and breeding success

We found no evidence that proximity to public roads increased the probability of nesting failure. Similar findings have been reported from Sweden (Tjernberg 1983). In Norway (Bergo 1984), there was a reported dearth of nests situated less than 500 m from public roads, and this was interpreted as avoidance of such locations on account of disturbance. In Scotland, a number of nest sites very close to public roads have been abandoned over the past 40 years (J. Watson, unpublished data). It may, therefore, be that any detrimental effect caused by road-users leads relatively quickly to the abandonment of a site, and thereby precludes the detection of suppressed breeding performance linked to proximity to roads. If abandonment of such sites is the Golden Eagle's response to disturbance from road-users, then this may ultimately be detectable during subsequent surveys, when the mean distance between sites and public roads should increase.

Our analysis showed that pairs using nest sites judged to be easily accessible to people were more likely to fail completely than were pairs using inaccessible eyries. There was no detectable pattern across the species' range in the distribution of nests of a particular ease or difficulty of access. Clearly, nests which are accessible without the aid of a rope would be more likely to receive the attentions of egg-collectors and others with a desire illegally to destroy the contents of the eyrie. Such nests might also be vulnerable to pine martens *Martes martes*, red foxes *Vulpes vulpes* or to the risk of trampling by wild goats *Capra*, although it is unlikely that the impact of any of these is as marked as that of people. We have found no equivalent analysis of breeding failure in relation to nest-site accessibility in the European literature.

The key finding of the disturbance analysis related to the distribution of the most serious type of disturbance (severe persecution). The vast majority of sites subject to severe persecution, which was defined as frequent destruction of eggs and young, killing of adults and/or use of poisons, were in the eastern one-third of the range. Specifically, there was substantial evidence of such persecution in Caithness, east Sutherland, Speyside, Deeside and Perthshire, and in each case this coincided with areas managed principally for Red Grouse.

There were isolated instances of severe persecution in sheep-farming areas on the western seaboard, but these amounted to a small fraction of the cases linked to grouse moors. The frequency and extent of this phenomenon will be documented during the course of future national surveys of Golden Eagles and, as such, may indicate whether the problem is receding or increasing. So far, we have evidence that, since 1982, the locations suffering severe persecution have changed (J. Watson and R. H. Dennis, unpublished data; A. G. Payne *in litt.*), although there is still no evidence that levels of persecution generally have declined (RSPB & NCC 1991).

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Summary

In 1982, the population of Golden Eagles *Aquila chrysaetos* in Britain was surveyed and this provided an opportunity to document a range of nest-site features. Information was collected on type of site (cliff or tree), altitude, direction of exposure, distance to nearest public road, accessibility of the site to people, and extent of human disturbance. Variation in a number of these features was assessed along west-east climatic and ecological gradients across Scotland. Less than 5% of pairs used tree sites, and these were mainly towards the east of the range. Mean elevation of sites ranged from around 150 m in the west to over 450 m in the east. The majority of nests were orientated between NW and E, and the greatest percentage lay between N and NE. There was no significant relationship between the incidence of nesting failure and distance to public road; nests judged to be more accessible to people, however, failed more frequently than those in inaccessible sites. The incidence of disturbance attributable to people was highest in the eastern half of the range and generally coincided with moorland areas which were managed for Red Grouse *Lagopus lagopus*. Results are discussed with the benefit of comparable studies of nest-site features throughout Continental Europe.

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