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Golden eagles and forestry

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In association with

RSPB

Abstract

The golden eagle population in Britain is stable and found mostly in the Highlands of Scotland. Potential conflicts exist between afforestation proposals and the future of some pairs of eagles. Recent research on radio-tagged eagles in Argyll has allowed their ranging behaviour to be investigated. They prefer 'open' to 'closed' habitats, select areas dominated by heather and coarse grass and avoid low altitudes including those associated with human development. Eagles also prefer areas closer to the centre of their territory (2–3 km radius), but fly up to 9 km from that centre. The distance moved is affected by proximity of neighbouring eagles and terrain. Away from the centre, eagles avoid low ground (although coastal nesting does occur). The reasons for this are discussed.

From these data a model for golden eagle ranging behaviour was constructed. This model delineates the area over which eagle pairs range and highlights areas of particular importance. Our model is easy to use because it incorporates information already held by conservation bodies for most breeding pairs in Scotland. The model requires the locations of nesting places, plus those of neighbouring eagles and altitude. It also points to areas where conflicts between eagles and afforestation proposals are unlikely to occur. Range-specific information such as habitat details and location of prey concentrations allow the model to be refined locally to improve accuracy. Possibilities are discussed for re-designing existing forests at clear felling and the potential of semi-natural woodlands for eagles.

Background

Distribution and numbers

The golden eagle is widely distributed throughout the northern hemisphere (Cramp and Simmons, 1980; Watson, 1997). In the British Isles their breeding range has been much reduced. Today they are found primarily in the Highlands of Scotland, although a few pairs breed in south-west Scotland and northern England (Watson and Dennis, 1992; Gibbons *et al.*, 1993; Green, 1996). They are absent from Ireland.

Eagle numbers in Britain were surveyed in 1982 (Dennis *et al.*, 1984) and 1992 (Green, 1996). Results show the breeding population to be stable at about 425 pairs, although regional fluctuations have occurred during this 10-year period.

It has been suggested that declines in numbers of breeding eagles in Argyll (Watson *et al.*, 1987) and breeding success in Galloway (Marquiss *et al.*, 1985) were related to increased afforestation. Watson *et al.* (1987) predicted that forestry would have a negative effect on eagles if it exceeded 40% of the area of preferred altitudes within 4 km of the range centre.

Conservation status

The golden eagle is an 'amber list' species of medium conservation concern in the UK (Gibbons *et al.*, 1996), because it has an unfavourable conservation status in Europe due to its rarity (Tucker and Heath, 1994). The European population amounts to 5000–7200 pairs of which 6–8% are in the UK. Around 15%–20% of the world range of this species lies in Europe (Tucker and Heath, 1994).

Nesting habitat

Golden eagles build large stick nests either on crags or in trees (Cramp and Simmons, 1980). The main feature of nesting places is their relative openness, so providing easy access to nests. In Scotland, most golden eagles nest on crags (Watson and Dennis, 1992). Most are above 300 m altitude, although in western Scotland some pairs breed on rugged sea cliffs. Crag ledges need to be large enough to accommodate a substantial nest and often have an overhang that provides shelter during severe weather. When they nest in trees, these are usually old with large, open crowns (Front cover). In Britain, fewer than 5% of nests are in trees, although prior to felling of native forests, tree nesting would have been more common.

Diet

The golden eagle is capable of taking a wide range of prey, both alive and as carrion (Cramp and Simmons, 1980). In Britain, carrion is more important during the winter and live prey during the summer, especially for breeding birds (Watson *et al.*, 1993). Sheep and deer form the bulk of carrion. Live prey varies in size from nestling meadow pipits to red deer calves. However, prey the size of red and black grouse, rabbits and hares are preferred.

Diet varies with local differences in prey availability and habitat. Thus, in the Eastern Highlands diet comprises few species that occur at high density, such as red grouse and blue hares, while in the Western Highlands, eagles have a more varied diet including rabbits, hares, grouse, crows, foxes, young deer and small birds. Some coastal breeding eagles prey upon seabirds. In Scotland, the breeding density of eagles has been linked to the amount of carrion in the winter, while the number of fledglings produced is more closely associated with the abundance of live prey in spring and summer (Watson *et al.*, 1987; 1992).

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Front cover. *Golden eagles regularly nest in trees in some native pinewoods in Scotland. This nest contains two large nestlings. Nest trees are usually situated in the higher parts of the forest, are old and have large, open crowns. At present fewer than 5% of eagles in Scotland nest in trees, but this could increase in the future with the provision of suitable nesting stands. (D. Dugan)*

Adult eagles can exist on carrion for most of the year. However, from late spring when chicks are being reared less carrion is available and is often too large to be carried back to the nest. This makes the successful rearing of chicks more dependent upon the availability of live prey.

Legal protection

The golden eagle is specially protected under Schedule 1 of the Wildlife and Countryside Act 1981, which makes it illegal to kill or injure golden eagles, collect individuals or eggs and to cause intentional disturbance to breeding pairs.

The golden eagle is also included on Annex 1 of the EU Directive on the Conservation of Wild Birds (79/409/EEC), requiring member states to avoid any pollution or deterioration of habitats or disturbance, especially in Special Protection Areas. This legislation is relevant to forestry expansion that might have a negative impact on golden eagle "survival and reproduction in their area of distribution". The Forestry Commission also has a statutory responsibility to achieve a reasonable balance between the development of afforestation and the conservation and enhancement of natural beauty, including fauna and flora.

Radio-tracking golden eagles in Argyll

The primary factor influencing ranging behaviour of golden eagles is the availability of prey, which itself is heavily influenced by vegetation structure. Other determining factors include the proximity of neighbouring eagles, location of nests and roosts, topography and wind flow. A better understanding of these factors was necessary to assess the impact of afforestation proposals on eagles. To achieve this, nine adult eagles were captured, fitted with radio transmitters (Plate 1) and tracked during 1992–1996 as part of a joint RSPB/Forestry Commission project.

Plate 1. Nine adult golden eagles were caught and fitted with radio transmitters to study their ranging behaviour during 1991–1996 in Argyll. The radios have a battery life of up to 4 years, and a weak-link in the harness ensures that the radios detach after 4–5 years. (M.J. McGrady)

Ranging behaviour

Throughout the year, eagle ranging activity centred around their nesting places. The mean location of nesting places used within the past 10 years is the best estimate of 'range centre' (Box 1). Using the mean of all known nesting locations was also a good estimator, but was not as good as that provided by recently used nests.

Eagles' ranging concentrated near the centre of territories (Figure 1). However, territories were not necessarily circular because their size and shape reflected topography, proximity of neighbouring eagles, habitat features and prey distribution. Territories were often centred on a distinct mountain or hill range, the shape of which influenced nest site locations and ranging behaviour. Eagle activity concentrated in areas that provided good flying conditions, particularly hillsides with updraughts. Thus, on a daily basis, weather patterns, particularly wind direction and strength, interacted with terrain to influence how eagles utilised their territories.

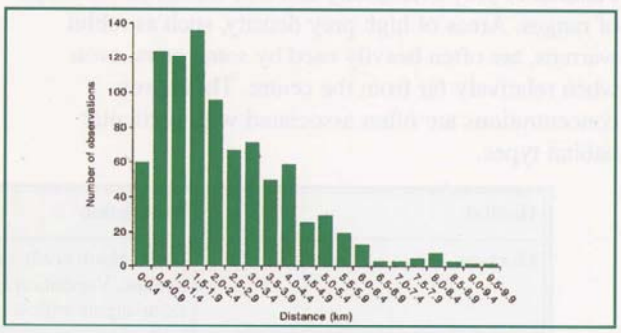

Figure 1. Radio-locations of golden eagles around a central ranging point in territories in Argyll. The horizontal axis gives distance from the central point.

In our analyses, the central core of a territory was defined as the area encompassing 50% of the ranging locations of radio-tagged eagles. Thus calculated, the mean 'core area' in Argyll was 498 ha (range 187–720 ha). The shape of the core area varied, and was sometimes split into two or more spatially distinct areas. In its simplest form, it was a circle around the range centre with a radius of 2–3 km.

The mean territory size was 6827 ha, but was variable (2604–12 853 ha). In the absence of near neighbours, eagles ranged up to 9 km from their territory centre, and roughly half-way to the centre of the neighbouring territory when the distance between these was less than 18 km. Over 98% of radio locations of eagles were within 6 km of the territory centre.

Habitat preference and prey

Land cover details were taken from Macaulay Land Use Research Institute LCS88 (MLURI, 1993) and forestry stock maps. In general, eagles chose open habitats. The order of relative preference was; *montane > heather > coarse grassland > bracken > smooth grassland with scrub > bog > broadleaved forest > pre-thicket forest/*

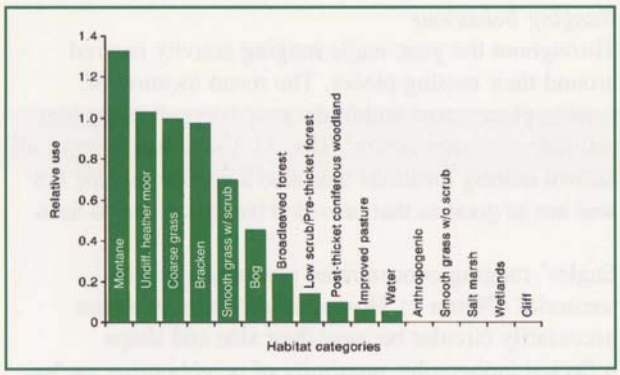

Figure 2. Selection of habitat by golden eagles in Argyll using 16 habitats found within eagle ranges. Open upland habitats are preferred. The vertical axis shows the relative importance of habitats to eagles. The last five categories have values too small to appear on the graph.

low scrub > *post-thicket forest* > *improved pasture* > *water* > *anthropogenic* > *smooth grassland without scrub* > *salt marsh* > *wetlands* > *cliff* (Figures 2 and 3). Patterns of prey availability can also influence the shape of ranges. Areas of high prey density, such as rabbit warrens, are often heavily used by some pairs, even when relatively far from the centre. These prey concentrations are often associated with particular habitat types.

Altitude

Eagles in Argyll preferred altitudes between 150–500 m (Figure 4). The avoidance of low altitudes was probably linked to higher levels of human activity, the presence of less preferred habitats and lack of updraughts needed for soaring. None of the radio-tagged eagles occupied low-lying territories, so we lacked data on the use of such areas. Observations from low-lying territories on the Isle of Mull suggested that eagles there use some lower altitudes (P. Howarth and A. Fielding *personal communication*).

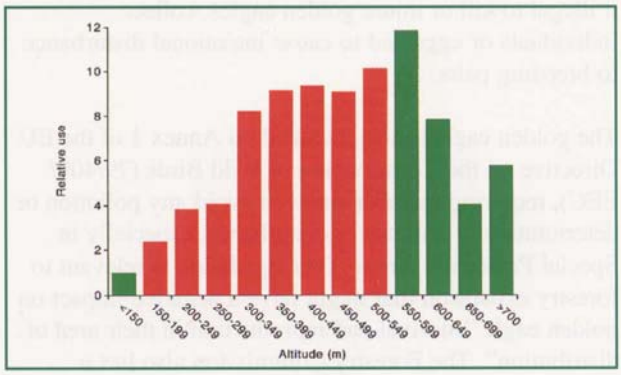

Figure 4. Selection of altitudes by golden eagles in Argyll. The vertical axis shows the relative importance of altitudes to eagles, a significant preference is shown for altitudes of 150–550 m (red).

Habitat	Description
Montane	Dwarf shrub heath, moss heath and grassland. Often found above the natural treeline. Vegetation sparse, windblown. Taller herb assemblages and arctic-alpine willow in seepages. Also areas of blanket bog.
Undifferentiated Heather	All dry and wet heather moorland. All mosaics dominated by heather / blaeberry heath.
Coarse Grass	Mosaics dominated by flying bent grass, bog myrtle.
Bracken	Bracken dominated, often mosaic with grass.
Smooth Grass with Scrub	Grassland dominated by bent grasses, fescues, sweet vernal grass. May contain rushes. Also contains gorse or broom covering less than 50%.
Bog	Exposed peat with associated heather, cotton grasses, deer grass, flying bent and *Sphagnum*.
Broadleaved Woodland	Forest and forest mosaics dominated by broadleaved species.
Low Scrub / Pre thicket Coniferous Forest	Forest mosaics showing signs of afforestation < 10 years of age. Include areas fenced for forestry or recently ploughed. Also, young conifers mixed with alder and willow. Regenerated heather stands are often a feature.
Post-thicket Coniferous Forest	Forest and forest mosaics dominated by coniferous forest > 10 years of age.
Improved Pasture	Well-drained grassland, usually at lower altitudes, dominated by species of grass and clover of high grazing value.
Water	Rivers, standing fresh or salt water.
Anthropogenic Features	Houses, farm buildings, roads, etc.
Smooth Grass	Grassland dominated by bent grasses, fescues, sweet vernal and Yorkshire fog grass. May contain rushes. Intergrades with improved pasture.
Salt Marsh	Marsh areas in estuaries dominated by sea-water tolerant plants.
Wetlands	Often occurring in low lying valley bottoms where the water table is at or near the surface for most of the year. Can be dominated by rushes, reed grass, reed or yellow flag.
Cliffs	Cliff areas > 2ha.

Figure 3. Habitats found within golden eagles ranges in Argyll (aggregated from MLURI LCS88 and forest stock maps).

Eagles in Argyll avoided the highest areas. This was probably prey-related, and may not hold true for montane habitats in the Eastern Highlands where ptarmigan and mountain hare are more plentiful.

Model of golden eagle ranging behaviour

Analysis of radio-tracking data led to the development of a relatively simple model of eagle ranging (Box 1). It provides a framework for evaluating the impact on eagles of afforestation proposals and design plans for existing forests. It should be used on a site-by-site basis incorporating locally-available knowledge.

The model requires information about the location of nests, use of nests (optional), location of nests of neighbouring pairs, and elements of altitude and distance from the territory centre. It estimates the outer boundary of a territory and the size and shape of the core area. Relative values of land cover and altitude can then be incorporated to help identify preferred areas within the territory.

The model is based on information from territorial eagles in Argyll and is therefore only applicable to the ranging behaviour of territorial eagles. Little is known about the requirements or ranging behaviour of eagles in the non-breeding sector of the population (Grant and McGrady, in press).

Box 1. Determining the shape of an eagle territory

*Step 1. Finding the **range centre**.*

The **range centre** is best calculated from the mean position of nests used in the past 10 years, but lacking these data use the mean position of all nests. For example, the **range centre** for three nests located at NL205602, NL209610 and NL204605 is calculated from the mean northing (205+209+204)/3 = 206, and the mean easting (602+610+605)/3 = 606, to give the **range centre** at NL206606. If the same nest is used on three occasions, enter its grid reference three times into the calculation of the mean. In some territories, geographical features cause nests to fall into separate clusters. In these, the mean position of each nest cluster should be calculated, and if their centres are more than 2 km apart, then the range will contain more than one centre. The following steps should be applied to each centre.

*Step 2. Determining the **core area***

The **core area** (where eagles spend 50% of their time) can be estimated by a circle around the **range centre** with a radius of 2 to 3 km. The distance which best estimates the **core area** is a function of territory quality, prey distribution, and geographical features. In general, one would expect territories with abundant prey to have smaller **core areas**, and those with much unsuitable habitat (including plantation forest) or low prey densities to have larger **core areas** (Box 2).

*Step 3. Determining the **territory boundary** with neighbouring eagles*

To estimate the **territory boundaries** between two neighbouring pairs of eagles: (1) draw a straight line joining the two range centres, (2) find a point on this line half-way between centres, (3) draw a line through the half-way point at right angles to the first line. This is an estimate of the boundary between these two pairs. To estimate the boundary with other neighbours repeat these steps until the line drawn forms a polygon around the **range centre**. The strength with which this boundary is defended decreases as one moves away from **range centre**. The exact position of this boundary may vary with topographical features and windflow which combine to produce favourable flying conditions.

*Step 4. Determining the **territory boundary** where there are no neighbouring eagles*

Most eagle territories extend 6 km from the **range centre**. However, some will use areas up to 9 km from their **range centre** in the absence of neighbours or geographical boundaries. To determine the boundary, draw a curved line at 6 km radius from the **range centre** to connect adjacent boundary lines drawn in Step 3. Eagles travelling farther are usually making use of a reliable source of food, such as a rabbit warren or a carcass, in areas not occupied by neighbouring eagles or interacting with other eagles.

*Step 5. Using an **altitude cut-off***

Eagle territories can be grouped as high altitude (e.g. Cairngorms), medium altitude (e.g. mainland Argyll) or low altitude (e.g. Isle of Mull). Eagles in medium and high altitude territories avoid low ground. For medium altitude territories use an **altitude cut-off** at 150 m outside the **core area**, but include all altitudes within the **core area**. Use this rule in conjunction with steps 3 and 4 to delineate the outer edge of the eagle territory. High altitude territories exhibit an **altitude cut-off** outside the **core area** of 150–200 m above the valley floor. In low-lying coastal territories, eagles can use all altitudes except areas with a high level of human activity. In high and low altitude territories, local information is crucial to decide what **altitude cut-off** to use.

Because the model is derived from a small sample of eagles in one area in Scotland, caution is needed in its application, though the model predicted territorial boundaries fairly accurately when tested in south-west Scotland, the central Highlands and the Isle of Mull. However, it is essential that eagle density and productivity continue to be monitored in areas where land-use changes are occurring, to confirm that our predictions are valid.

Planting and management of forests within eagle territories

Forestry has the potential to come into conflict with golden eagles. Under EU and British law, the loss of even a single pair due to human activities is usually considered to be unacceptable. Thus, proposals to expand the area of forest within eagle territories must take account of possible impacts on the eagle population. The following sections provide advice on assessing the likely impact on eagles if afforestation occurs, and ways of improving the value to eagles of existing forests.

Where to plant

When considering the impact of afforestation on golden eagles, use Box 1 to estimate the extent of an eagle pairs territory and Box 2 to assess the importance to eagles of land within that territory. In general, changes in land use might have the greatest negative effect upon breeding eagles if these occur in the core area or adjacent hunting habitat. Outside these areas a balance needs to be struck over the location of plantations, because eagles may still use distant open habitats, even though their importance to the survival of the breeding pair is usually less critical. These outer areas may be more important when much of the core has already been planted.

Plate 2. Afforestation of Highland glens can potentially reduce foraging areas for eagles, with subsequent declines in the viability of the territories. Here the forest covers only the lower glen, part of the landscape least used by eagles. (M.J. McGrady)

Box 2. Assessing the potential for afforestation within an eagle territory

Some areas within the territory will be preferred by eagles. Identifying these is important in evaluating the impact of any afforestation proposals. The following interpretation often depends upon habitat and prey information.

Distance considerations

Areas close to the territory centre are used more by eagles, so avoid planting in the core area (Figure 1). Clear felling gives the opportunity to increase the extent of open areas close to the centre. Watson *et al.* (1987) suggested that forests should not exceed 40% of the area in preferred altitudes within 4 km of the range centre.

Altitude considerations

Eagles prefer intermediate altitudes (Figure 4). Therefore, planting proposals below the altitude cut-off should be favoured.

Habitat and prey considerations

The size and shape of eagle territories are intimately connected with the density and distribution of prey, which in turn are linked to habitat quality. Open habitats supporting live prey are important. Avoid planting areas of high prey abundance, such as rabbit warrens. Management can sometimes enhance live prey abundance, for instance, by reducing grazing on large moorland patches within or adjacent to the forest.

Barriers

Certain landscape features create barriers to eagles because they generate poor soaring conditions or poor hunting. These include large water bodies, wide valleys and extensive plantations. The impact of these on the ranging behaviour of eagles depends on their size and location. Large barriers furthest from the range centre are avoided, while smaller barriers close to the centre will be over-flown. So avoid planting large new forests or extending existing ones when they increase the separation between major hunting areas.

Planting should be directed away from the range centre towards lower elevations and areas covering less-favoured habitat types (Plate 2). However, *all proposals should be dealt with on a case-by-case basis so that important local information can be incorporated*. For example, in some territories uneven prey distribution, such as the existence of rabbit warrens, might enhance the importance of certain open or low-elevation areas.

Eagles use montane and open upland habitats more than others. Such habitats are often unsuitable for tree planting because of poor soils and exposure, both of which can lead to uneconomic growth rates and increased risk of windthrow.

It seems likely that in many areas eagles can adapt to some changes in land use, as long as they are sensibly located and scaled. To a certain extent eagle territories are flexible, but the extent to which they can change their shape in the face of changing land-use is probably limited by geography, the nearness of neighbours, the availability and location of nesting places and the amount of food which will vary seasonally and annually.

Forest design

Eagles are found in open habitats. Their wingspan of almost 2 m is an adaptation for soaring on updraughts rather than close manoeuvring through forests. Most spruce plantations are only open enough to permit access by eagles for 7–10 years after planting and for a similar period after felling and restocking.

Following afforestation, the removal of sheep and the control of deer allows vegetation to recover. This often leads to an increase of live prey, such as red grouse. Despite this, there is no evidence from radio-tagged birds in Argyll to suggest that young forests are preferentially used by eagles (Figure 2). Additionally, although the removal of sheep may coincide with an increase in live prey, it also leads to a decline in the amount of carrion available (Petty, 1996; in press). Overall, this may result in a net loss of food for eagles, particularly during winter.

There appears to be little prey (grouse, rabbit and hares) for eagles on restocked sites, and what prey there is may have more cover from eagles than on moorland areas (Petty, 1996) (Plate 3). Radio-tracking information suggested that eagles used newly restocked areas as infrequently as mature forest.

When restructuring, there is little that can be done in the short- to medium-term which would enhance the quality of existing forest plantations for eagles. In the long-term restructuring could enhance the value of a forest for eagles by:

- Leaving higher elevation areas unplanted after felling. Areas of most value to eagles are those adjacent to existing moorland where the recovery of ericaceous vegetation and broadleaved scrub would lead to an increase in live prey. Such areas would need to be large (100 ha or more).
- Establishing stands of widely-spaced trees in suitable locations as future nest sites. The Southern Uplands provide an example of where eagles may be able to expand their current breeding range if an effort was made to provide trees in suitable locations (Box 3).

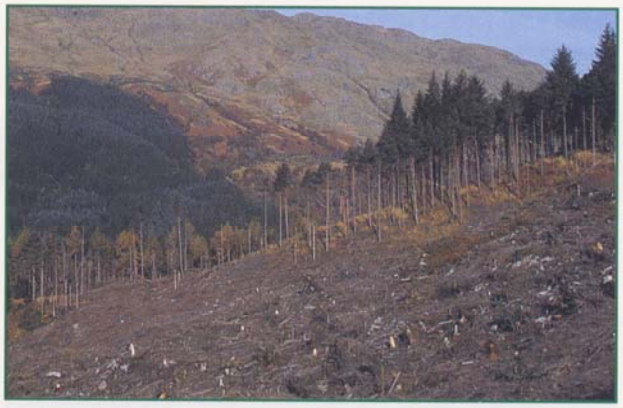

Plate 3. Felled patches within forests are open enough for eagles to hunt over, but contain little prey because the ground vegetation has little time to develop before being shaded out by the next tree crop. (S.J. Petty)

Box 3. Criteria for selecting and creating nesting stands for golden eagles

- Adjacent to or within a mountain/hill range that provides at least 5000 ha of suitable foraging habitat for eagles.
- Situated near to or at the forest/moorland edge where, (1) prevailing winds and topography generate good soaring conditions and (2) there is little human disturbance (for example, no habitation closer than 1.5 km and no forest roads within 0.5 km).
- Stands should be a minimum size of 10 ha, located on well-drained soils where the risk of windthrow is low, and should be part of a network of stand retentions.
- Aim to create stands with less than 100 trees per ha at around 100 years of age. Wide initial spacing will in time provide wind-firm trees with good crown development. Eagles can breed in stands of conifers from around 80 years of age.
- Include tree species that will provide a suitable crown structure for eagles to build their substantial nest. Evergreen conifers are preferred, because their canopy gives better protection during severe weather. Eagles have well-grown chicks before broadleaves come into leaf. Scots pines probably provide the best crown structure, but are slow growing, so outwith native pinewood areas include other conifer species that are suited to the site.
- The provision of man-made platforms in trees can sometimes encourage eagles to nest in them (Saurola, 1978).

In the long-term it is likely that the establishment of large areas of semi-natural forest may have less of a negative impact on eagles than close-grown forests of spruce, because these incorporate more open ground, allow for the better development of ground vegetation (and associated live prey) and aim to produce some patches of older trees (Plate 4).

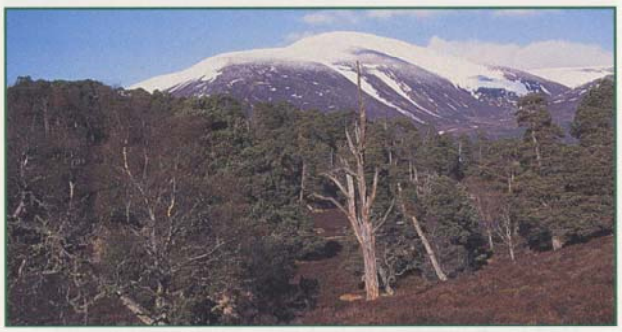

Plate 4. Semi-natural pinewoods can provide open-structured woodland that eagles use. There is ample space for such large birds to hunt, the ground vegetation creates ideal habitat for eagle prey such as black grouse and capercaillie, and large open-crowned trees provide numerous nest sites. (S.J. Petty)

Forestry operations and disturbance

Establishment, maintenance, and harvesting operations and recreational activities can disturb nesting eagles and result in breeding failure. Eagles are particularly sensitive to human activities near the nest during February–July inclusive. Therefore, it is recommended that disturbance-free zones of about 1 km radius should be established around occupied nests (Petty, in press). This distance may need to be modified depending upon local circumstances. Larger disturbance-free zones (up to 1.5 km) may be required when the disturbance is in direct line-of-sight from the nest. Conversely, these zones may be reduced when a nest is shielded from the disturbance by topographical features, but should never be less than 750 m radius.

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