Chancellor, R.D., B.-U. Meyburg & J.J. Ferrero eds. 1998
Holarctic Birds of Prey
ADENEX-WWGBP

# A Preliminary Analysis of the Relation between Land Cover and Golden Eagle *Aquila chrysaetos* Ranging Behaviour in Argyll, Western Scotland

M. J. Mc Grady, J. G. Grant and D.R.A. McLeod

## ABSTRACT

Data from 5 radio-tagged adult territorial golden eagles were used to investigate habitat preferences. Measures of selection were made using generalised linear models (GLIM) and levels of significance were tested using randomization techniques. Although no significant differences were found between the expected densities of locations in each habitat predicted by the log-linear model and those observed or between the relative densities of any pair of habitats, the rank of habitat use by eagles was: Montane > Grass > Heather > High Forest > Bog > Pre-thicket Forest > Other Woodland > Water. Suggestions are made concerning future paths of analysis.

## INTRODUCTION

Since 1991 the Royal Society for the Protection of Birds (RSPB) has been examining the relationship between Golden Eagles and their habitat. The impetus for this project came from the belief that changing land use within Scotland was having an effect upon eagle numbers. In particular, the increasing amount of plantation forestry was suspected of restricting the amount of open area over which the eagles could hunt, and in effect, lowering the availability of prey (Watson *et al.* 1987). Preliminary data are presented on the relationship between land cover and ranging behaviour.

# STUDY AREA AND METHODS

The study area comprises almost 500,000 hectares of south Argyll in western Scotland. This area is mostly rural, with hill-sheep farming and forestry being the dominant land uses. The terrain is quite rugged, with mountains rising from the sea to a maximum altitude of about 1000 m. The weather is maritime in character, receiving about 3000 mm of rain per year.

Radio tracking data were collected for five adult, territorial female eagles. Data on eagle locations were collected in all types of weather, at all times of the day and throughout the year. Radio transmitters allowed us to make visual sightings of birds, and relate them to geographical features in the field which enabled us to be accurate to within 100 metres. Radio locations derived from triangulation and visual sightings which could not be assigned to a position on the map with a high degree of accuracy were excluded. Data were sorted to promote independence, with sequential fixes being separated by at least one hour. Although we had radio tracking information for four more birds, we did not have enough ranging points (> 60) to include them in this analysis. Also, radio tracking is still going on in three of the territories for which we are presenting information, so data for these territories is incomplete.

Because we were not satisfied that the incomplete ranging data represented the territories fully, we modelled the ranging boundaries using radio tracking data and observations of untagged eagles. The rules for the model are:

1. Eagles in the study area range around a centre derived from the nesting places known to be used in the past, weighted for frequency of use.
2. Eagles range up to 6 km from the centre of their territory unless the entre of the neighbouring territory is nearer than 12 km.
3. Eagles occupying neighbouring territories which have centres which are less than 12 km apart range half way to the centre of their neighbours territory.
4. Eagles use all altitudes within 2 km of the nest centre.
5. Eagles use only the land above 150 m of elevation outside the 2 km central kernel.

Figure 1 shows our model overlaid on the ranging data at all five territories, and applied to other territories for which we have no radiotracing information.

Data on land cover were taken from the MacAulay Land Use Research Institute (MLURI) map of the land cover of Scotland (LCS88). The LCS88

land cover map is derived from the interpretation of aerial photographs taken in 1988 covering the whole of Scotland. The MLURI data separates land cover into mosaics with primary, secondary and tertiary land cover characteristics. We aggregated the 56 mosaics which occurred within the eagle territories into eight, self-explanatory, categories: Water, Heather, Grass, Montane, Pre-thicket forestry (Coniferous), High Forest (Coniferous), Other Woodland (Mixed or Broad-leaved), and Bog. Land cover types were aggregated into Pre-thicket forestry if any characteristics (i.e. ploughing) indicated recent planting. All other aggregations were composed of all land cover mosaics in which the primary characteristic was the same as the aggregation. So, a mosaic of heather, mixed with grass and stones would be classified as 'Heather' and a mosaic of grass, with heather and no stones was classified as 'Grass', but a mosaic of heather, grass and coniferous trees would be classified as 'Pre-thicket'.

Both the land cover and radio tracking data were held within the ARC/INFO geographical information system (GIS) environment. Within ARC/INFO the land cover under each eagle location and the amount of each land cover aggregation within the territory model as a whole were determined, and compared to see if some land cover types were selected over others.

The measure of selection used was the density of radio locations in each habitat. This was calculated using log-linear models fitted by means of GLIM (GLIM 4, Royal Statistical Society, 1994), and the approach was that used by Heisey (1985). GLIM output yields estimates of the standard errors of individual values of habitat use, and the statistical significance of the variation in relative density among habitat types can be estimated by a randomisation test (Manly, 1991). A score was calculated which described the variation among the relative density values for each habitat. Using the higher of either the observed or expected number of locations as the weighting, the labels of the habitats found in each range were shuffled randomly. The log-linear model was then fitted to the randomised data and the variation score was compared with that from the real data. Randomisation was performed 1000 times and the number of times the score was equal to or larger than the real score was obtained, and was equal to P.

The significance of differences in relative density of locations of members of pairs of habitats was also tested by randomisation. All possible pairs of habitats were considered, and only eagle territories where both habitats of the given pair occurred were considered. The log-linear model was fitted to the reduced data set and the densities of locations in one habitat relative to the other habitat were recorded. The labels for the pair of habitats under consideration were then shuffled randomly for each range, the other habitat

labels being unchanged. The log-linear model was fitted to the randomised data and the absolute value of the log e relative density in one habitat to that in the other of the pair was compared to the value obtained for the real data. The randomization was performed 1000 times and the number of occasions on which the absolute log relative density was equal to or exceeded the value for the real data was obtained. This equalled P.

## RESULTS

Tables 1 presents the comparison between the density of radio locations of territorial Golden Eagles found within 8 habitat types and the density expected from a null model generated within GLIM.

Randomisation tests indicate that the use of the habitats by the eagle was not significantly different than one would expect from their abundance within the territories (P=0.266). However, Water, Pre-thicket Forestry, and

**Figure 1 The range model overlaid onto a map of locations of radio tagged eagles to illustrate the accuracy with which the model predicts the range boundaries. The figure also shows predicted range boundaries in areas where eagles have not been radio tagged.**

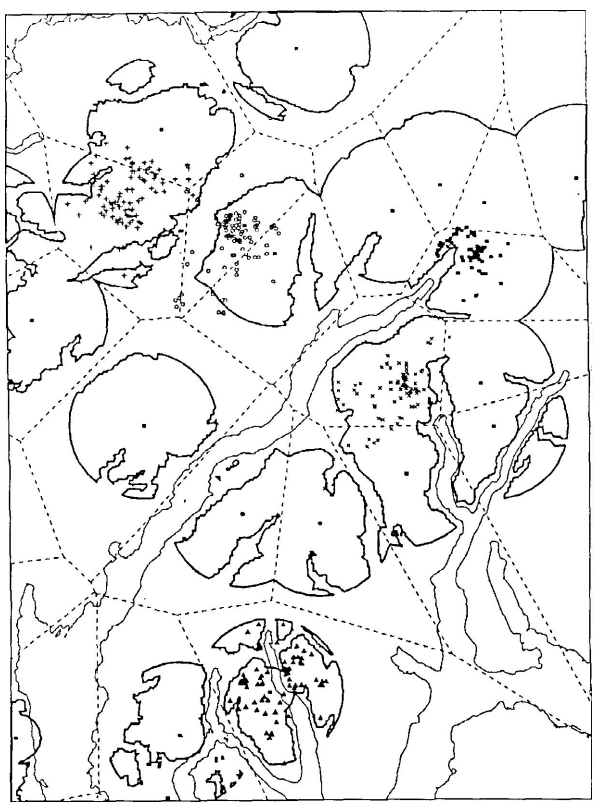

**Table 1. Numbers of radio locations of 5 territorial Golden Eagles in each of 8 habitat types compared with the expected number of locations from a null model generated in GLIM. The density of radio locations in each of the habitats 2-8 relative to that in habitat 1 (heather) has been estimated from a log-linear model. The number of territories with each habitat present within their range is also given.**

| Habitat | Habitat number | No. of Fixes | Expected no. of Fixes | Relative Densities from GLIM | No. of Territories with Habitat |
|---|---|---|---|---|---|
| Heather | 1 | 249 | 259.419 | 1.000 | 5 |
| High Forest | 2 | 10 | 12.323 | 0.843 | 4 |
| Pre-thicket Forest | 3 | 16 | 20.973 | 0.809 | 5 |
| Grass | 4 | 104 | 96.400 | 1.187 | 5 |
| Water | 5 | 2 | 3.829 | 0.536 | 3 |
| Montane | 6 | 36 | 19.733 | 2.038 | 4 |
| Bog | 7 | 8 | 11.588 | 0.813 | 2 |
| Other Woodland | 8 | 2 | 2.734 | 0.779 | 5 |
| Total | 8 | 427 | 427 | | |

**Table 2. The density of radio locations of Golden Eagles in habitat pairs. Relative densities were obtained from log-linear models fitted only to the data from eagles in whose territories both of the pair of habitats were present.**

| Habitat pairs | Relative density | No. of territories with both habitats | Randomisation test P |
|---|---|---|---|
| 1 2 | 0.8587 | 4 | 0.367 |
| 1 3 | 0.8095 | 5 | 0.128 |
| 1 4 | 1.187 | 5 | 0.061 |
| 1 5 | 0.5394 | 3 | 0.252 |
| 1 6 | 2.071 | 4 | 0.118 |
| 1 7 | 0.6835 | 2 | 0.502 |
| 1 8 | 0.7790 | 5 | 0.128 |
| 2 3 | 0.9068 | 4 | 0.490 |
| 2 4 | 1.330 | 4 | 0.125 |
| 2 5 | 0.5802 | 3 | 0.252 |
| 2 6 | 3.101 | 3 | 0.248 |
| 2 7 | 4405. | 1 | 1.000 |
| 2 8 | 1.017 | 4 | 1.000 |
| 3 4 | 1.466 | 5 | 0.061 |
| 3 5 | 0.5997 | 3 | 0.252 |
| 3 6 | 2.753 | 4 | 0.248 |
| 3 7 | 0.6992 | 2 | 0.502 |
| 3 8 | 0.9624 | 5 | 0.866 |
| 4 5 | 4454 | 3 | 0.252 |
| 4 6 | 1.665 | 4 | 0.118 |
| 4 7 | 0.6524 | 2 | 0.502 |
| 4 8 | 0.6563 | 2 | 0.061 |
| 5 6 | 4555 | 2 | 1.000 |
| 5 7 | 4555 | 1 | 1.000 |
| 5 8 | 2.793 | 3 | 0.252 |
| 6 7 | 0.6513 | 2 | 1.000 |
| 6 8 | 0.2586 | 3 | 0.118 |
| 7 8 | 1.432 | 1 | 0.502 |

Productive High Forest, Bog, and Other Woodland were used less than Grass, Heather, and Montane. More specifically, habitat preference ranked in the order Montane > Grass > Heather > High Forest > Bog > Pre-thicket Forest > Other Woodland > Water. The weighted variance score was 0.05005.

Table 2 shows the relative densities of radio locations in pairs of habitat, and the results of statistical tests of the difference between the estimated relative density and 1. There was no significant difference between any of the pairs.

## DISCUSSION

Although the rank of habitat preference seemed to make sense in terms of eagle biology with habitats in which eagles can fly and locate prey more easily being used more, no significant differences were found between the number of radio locations found within different habitats and the number predicted by a log-linear model. Also, no difference was found between the densities of locations found within pairs of habitats, although the differences between 'Grass' and 'Pre-thicket Forestry' and between 'Grass' and 'Other Woodland' did approach significance. Certainly, Golden Eagle territories are, on the whole, open in nature (Brown & Amadon, 1968, Cramp *et al.*, 1980). When eagle territories occur in forests the tree spacing is wide and the age structure is normally skewed toward the older age classes or there are open areas nearby (See Tjernberg, 1983). In many forested territories where crags do not exist, it is probable that it is the nest tree which draws the Golden Eagle into the forest rather than the food resource.

These preliminary results are inconclusive. However, they point the way to further analyses. The first and most obvious step will be to use the full set of observational data. For adult birds this will include 9 birds on 7 different territories, and for all aged birds will include 12 eagles on 7 territories. For eagles for which we have a large number of locations, we will be better able to estimate their territory using those data to generate territory outlines rather than relying upon a model. However, it is likely that with more information a more sophisticated, and realistic model will be developed which will predict the actual size and shape of the range more accurately.

Also, the land cover aggregates we have chosen and the means by which the aggregations are made must be re-examined, perhaps with more extensive ground-truthing of the aggregates. In eagle territories in Argyll, much of the land cover is comprised of mosaics of heather and grass. It seems sensible to re-analyse the data focusing on the impact of heather and grass as secondary and tertiary components of land cover classifications. This seems particularly appropriate because two of the main prey of eagles in Scotland are closely associated with these two land cover types, rabbits with grass and Red Grouse with heather.

Also, the radio tracking data presented here include all behaviours. The analysis will be repeated after extracting data on different behaviours, thereby examining the relationship between habitat use and, say, hunting, perching, or soaring. This sorting may be difficult because even though we had the eagles in sight, we often did not know whether they were hunting, interacting with some other eagle unseen by us, or just moving from place to place within their territory. In the case of birds moving from place to place, the barrier effect certain land cover types might have upon eagles must also be investigated.

In the past, arguments over the impact of plantation forestry on eagles have centred largely upon the effects plantation forest would have upon the eagles' ability to catch their prey. It has been thought that eagles in western Scotland are most likely to benefit from plantation forests in the early stages of forest establishment. At that time the area to be planted is usually fenced and the sheep are removed. The resulting reduction in grazing pressure often allows heather regeneration and increases in amounts of some prey species like Red Grouse for the time between planting and thicket stage. Our results do not indicate any real difference in the amount of time spent by eagles over pre-thicket and post-thicket forests. Certainly, in areas of pre-thicket and in some larger open areas within post-thicket stage forests eagles do take some prey. We have witnessed territorial eagles seemingly hunt pre-thicket forestry in the summer when Red *Cervus elaphus* and Roe *Capreolus capreolus* deer calves are available, and we have seen the remains of these species at the nest. Whether the prey taken there contributes enough prey consistently to the diet of the eagles over many years is unknown. Data on prey numbers in the different habitats will be analysed.

The present analysis examines the land cover which occurs directly under the location of the bird. Because eagles are often flying at altitude and are therefore able to survey an area around them, and because our accuracy in the field is about 100 m, future analyses will be developed to examine the composition of land cover within a 100 m radius of the location of the bird. This should be relatively easy to initiate within the framework of the present analysis, requiring the fitting of a logit rather than a logarithmic function.

Other studies in Scotland have suggested that afforestation of open areas (primarily sheepwalk) is correlated with the reduction of breeding success and/or the disappearance of breeding pairs of eagles (Marquiss *et al*, 1985, Watson *et al*, 1987). These interim results seem to indirectly support those suggestions by showing that eagles in Argyll utilise the open rather than closed areas. Further analysis is planned to investigate the minimum amount of open area needed by breeding eagles within Argyll.

## ACKNOWLEDGEMENTS

The authors would like to thank the following people for providing data and assistance in bringing this information together: Drs. S.J. Petty (Forestry Commission Research Division), I.P. Bainbridge (RSPB), R. Aspinall (MLURI), P. Whitfield (Scottish Natural Heritage), Mr. G. Bull (Forestry Commission), Mr. C.J. Place (University of Edinburgh), and Mr. M. Gregory. Dr, R.E.Green (RSPB) contributed to the statistical analyses, and wrote the randomisation programmes used. This study was partially funded by the Forestry Commission Research Division under contract number RD9-4-CON-24.

## REFERENCES

**BROWN L.H. & AMADON, D. 1968**. Eagles, Hawks and Falcons of the World. Country Life Books.

**CRAMP, S. (Ed.). 1980.** Handbook of the Birds of Europe the Middle East and North Africa. The Birds of the Western Palearctic. Oxford University Press. Oxford.

**HEISEY, D.M. 1985.** Analysing selection experiments with log-linear models. Ecology 66: 1744-1748.

**MANLY, B.F.J. 1991.** Randomization and Monte Carlo Methods in Biology. London: Chapman & Hall.

**MARQUISS, M., RATCLIFFE, D.A. & ROXBURGH, R. 1985.** The numbers breeding success and diet of golden eagles in southern Scotland in relation to changes in land use. Biological Conservation 34:121-140.

**TJERNBERG, M. 1983.** Prey abundance and reproductive success of the golden eagle *Aquila chrysaetos* in Sweden. Holarctic Ecology 6:17-23.

**WATSON, J., S. RAE & LANGSLOW, D. 1987.** The impact of land-use changes on golden eagles in the Scottish highlands. CSD Report No. 720; Nature Conservancy Council, Peterborough.

**WATSON, J. 1992.** Golden eagle *Aquila chrysaetos* breeding success and afforestation in Argyll. Bird Study 203-206.

M. J. Mc Grady, J. G. Grant,
Royal Society for the Protection of Birds, 17 Regent Terrace,
Edinburgh, EH7 5BN, U.K.,

D.R.A. McLeod,
Royal Society for the Protection of Birds,
Geography Department, Edinburgh University,
Edinburgh, EH7 5BN, U.K.