J. Raptor Res. 36(1 Supplement):55–61

GOLDEN EAGLES IN A MULTIPLE LAND-USE ENVIRONMENT: A CASE STUDY IN CONFLICT MANAGEMENT

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ABSTRACT.—Sheep farming and forestry dominate land use over much of western Scotland, and these activities have important implications for the nesting density and reproductive success of Golden Eagles (*Aquila chrysaetos*). In some areas, secondary land uses such as wind energy developments and opencast quarrying are being considered. The additive effects of such developments have prompted concern among conservationists that eagles will be adversely affected. In this paper, we summarize an approach used to investigate and reduce to acceptable levels the impacts of sheep, forestry, and a planned wind energy development on a territorial pair of eagles in the Kintyre peninsula. Site-specific studies of eagle ranging, diet, and prey distribution indicated: (1) eagle activity was greatest in a contiguous area of high elevation moorland that included part of the proposed wind farm; (2) eagles avoided forest habitats, except where the trees were young, or the stands were small; (3) avian prey, particularly Red Grouse (*Lagopus lagopus scoticus*), was an important component of diet during a summer in which the eagles bred successfully; and (4) an important population of Red Grouse occupied the proposed wind farm. We concluded that avoidance of the wind farm by eagles would result in the forfeiture of an important prey resource. Alternatively, in the absence of any modification of ranging behavior, eagles were at considerable risk of collision with wind turbines. This paradigm led us to develop a large-scale management scheme with the aim of reducing the cumulative impacts of the various land uses. A key objective of the scheme is to increase the overall number of grouse available to eagles. We intend to achieve this through the conversion of forest habitat to moorland and extensive management of sheep. Simultaneously, the scheme seeks to discourage eagles from entering the wind farm by impoverishing the local habitat for grouse. We suggest that secondary developments such as wind farms sometimes represent an opportunity to enhance landscapes that have been degraded by previous land use decisions.

KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *land use*; *wind energy*; *cumulative impacts*; *habitat management.*

Aguilas reales en un ambiente de multiples usos de la tierra: un caso de estudio en conflictos de manejo

RESÚMEN.—Las granjas de ovejas y la silvicultura dominan el uso de la tierra en la mayoría del oeste de Escocia, y estas actividades tienen importantes implicaciones para la densidad de anidación y éxito reproductivo de las águilas reales (*Aquila chrysaetos*). En algunas áreas, los usos secundarios de la tierra tales como proyectos de energía eólica y extracciones de cantera a cielo abierto están siendo considerados. Los efectos aditivos de tales desarrollos han incentivado la preocupación entre conservacionistas de que las águilas serán adversamente afectadas. En este articulo, sintetizamos una metodología usada para investigar y reducir a niveles aceptables el impacto de las ovejas, la silvicultura, y de un programa planificado de energía eólica sobre un par de águilas territoriales en la península de Kintyre. Estudios específicos en un sitio del rango de las águilas, su dieta, y la distribución de presas indican que: (1) la actividad de las águilas fue mayor en un área contigua a un brezal de gran elevación que incluía parte de la granja propuesta para energía eólica; (2) las águilas evitaban los hábitats boscosos, excepto donde los arboles eran jóvenes o donde las perchas eran pequeñas; (3) las aves presa, particularmente el urogallo rojo (*Lagopus lagopus scoticus*), fueron un importante componente de la dieta durante un verano en el cual las águilas se reprodujeron exitosamente; y (4) una población importante de urogallos rojos ocupaba la granja eólica propuesta. Concluimos que si las avitan águilas evitan las granjas eólicas esto podría resultar en la confiscación de una importante fuente de presas. Alternativamente, en la ausencia de alguna modificación en el comportamiento de rango, las águilas estaban en un riesgo considerable de colisión con las turbinas de viento. Este paradigma nos llevo a desarrollar un esquema de manejo a gran escala con el propósito de reducir los impactos acumulativos de los diversos usos de la tierra. Un objetivo clave del esquema es incrementar el numero total de urogallos disponibles para las águilas. Nosotros tenemos la intención de lograr esto a través de la conversión de hábitats boscosos a brezales y del manejo extensivo de ovejas. Simultáneamente, el esquema busca desalentar el ingreso de las águilas a la granja de energía eólica reduciendo allí el hábitat local para los urogallos. Sugerimos que los desarrollos secundarios tales como las granjas eólicas algunas veces representan una oportunidad para dar relieve a los paisajes que han sido degradados por previas decisiones en el uso de la tierra.

[Traducción de César Márquez y Victor Vanegas]

Land-use change is often implicated in declines in Golden Eagle (*Aquila chrysaetos*) numbers in the uplands of Scotland (e.g., Marquiss et al. 1985, Watson 1992, 1997, Gregory 1996). In the past, attention has focused on changes in primary land use. These changes can be conspicuous, such as the planting of large areas of open ground with commercial plantations of mainly exotic conifer trees or insidious, as in the long-term degradation of habitat by grazing livestock and red deer (*Cervus elaphus*). In recent times, a number of schemes to catastrophically alter upland landscapes have been proposed. These plans usually involve modification of specific parts of the landscape and we, therefore, refer to them as secondary land-use changes. Examples include wind energy facilities and open-cast quarrying. Such developments are often controversial because they have the potential to severely impact eagles, resulting in lengthy and adversarial debates between developers and conservationists. The development of wind energy in Scotland is still in its infancy, and the impacts on eagles are therefore unknown. Studies in the U.S. have shown that eagles are vulnerable to collision mortality (Orloff and Flannery 1992, PBRG 1997). However, the relevance of these studies is limited by crucial technical and ecological differences. In reality, impacts depend on the cumulative effects of new developments and the existing land uses. In many cases, the magnitude of impacts is significant mainly because the primary land uses are unsympathetic toward eagles. Impacts will vary regionally and locally depending on the effects and nature of primary land use and the specific location of any new developments.

Two primary land uses predominate in much of western Scotland: sheep grazing and forestry. Sheep provide eagles with a useful source of carrion, especially in winter, but suppress populations of important live prey such as Red Grouse (*Lagopus lagopus scoticus*) and mountain hares (*Lepus timidus*) by impoverishing the cover of heather and other ground vegetation (Thompson et al. 1988, Watson 1997). Eagle population density has been shown to vary in relation to the abundance of carrion, whereas reproductive success appears to be related to the availability of live prey (Watson et al. 1992). Afforested ground does not support sheep carrion and ultimately yields little if any suitable live prey (Marquiss et al. 1985). In any case, eagles generally avoid plantation forests because they are probably unable or unwilling to hunt prey amongst the closely-spaced trees (McGrady et al. 1997). Furthermore, forestry can fragment eagle territories by creating barriers which eagles are reluctant to cross.

Secondary land uses may reduce prey abundance, displace eagles, or both. Thus, eagles might be forced to occupy less suitable foraging and nesting areas, resulting in a decline in hunting and breeding success. Because secondary developments tend to be industrial in nature, with associated noise and human disturbance, displacement effects often extend well beyond the boundary of the site. In the case of wind energy, while displacement may be detrimental if it results in the loss of foraging habitat, it benefits eagles by lessening the risk that a bird will collide with rotating turbine blades.

In this paper, we summarize the approaches used to address cumulative land use impacts in relation to a proposal by ScottishPower to build a 30 MW wind energy facility in central Kintyre, west Scotland. The development involves the construction of 46 wind turbines (rotor blade length 45 m) within the territory of a resident pair of Golden Eagles, <2 km from the area used for nesting. The territory is dominated by a north–south ridge rising to 454 m elevation. The ground west of this ridge slopes gradually down to the sea, whereas the eastern slopes are steeper with several subsidiary ridges dividing deep valleys. The planned turbines are to be located between 350–450 m at the south end of the main ridge. The reproductive success of the eagle pair in recent years has been poor with only one young raised since 1990 (M. Gregory pers. comm.). This is probably due to the fact that much of the foraging range is occupied by plantation forestry. Elsewhere on Kintyre, forest establishment has resulted in a substantial reduction in the number of pairs of breeding eagles (Gregory 1996, Watson 1997). Further loss of moorland habitat is therefore considered highly undesirable, since it might compromise the ability of the area to support a pair of eagles.

It is not our intention to present a detailed account of the studies undertaken, many of which are still in progress. Rather, we wish to show how our results to date have been used to define conservation goals and guide management practices aimed at reducing the impacts to an acceptable level. Our main objective is to establish the pattern of eagle ranging behavior, activity, diet, and prey distribution to show the relative importance of the area occupied by the proposed wind turbines.

RANGING BEHAVIOR

Systematic observations were undertaken from four discrete vantage points in 1997–99. Between them, these vantage points allowed us to observe eagles in an area of about 100 km^2. We observed eagles for approximately 50 hr during about 400 hr of observation. The time eagles spent within various spatial components of their territory was recorded. The data were adjusted to account for differences in observation time and overlap in visibility between vantage points. In addition, the routes followed by eagles were plotted onto 1:25 000 scale maps, enabling us to identify terrain and habitat features important to eagles at a fine scale. We expected eagle behavior to vary seasonally and annually due to variations in the available prey. Observations were, therefore, stratified by season and undertaken in a year in which breeding was successful and a year in which it was not.

The time eagles spent perched and the distribution of plotted flight routes were used to construct a map that estimated the relative importance of different parts of the territory (Fig. 1). This indicated that activity was greatest in areas of high elevation where trees were absent. Therefore, eagles tended to follow unafforested ridgelines to the north and east of the proposed wind farm. Afforested areas exploited by eagles comprised either trees <8-yr-old in the western part of the territory or narrow strips of forest that divided unplanted ridges in the northern part. Eagles frequently used the northeastern part of the proposed wind farm, but the remainder of the site did not appear to be important. Despite this, use of the proposed wind farm was considered sufficient to cause significant concern due to the risk of displacement and collision. As a first step to reducing this potential impact, planned locations of turbines in the northeastern portion of the site were relocated to the southwestern part of the proposed wind farm.

DIET

Dietary analysis was undertaken using a sample of 68 pellets collected at known roost sites. Prey remains were identified to the lowest practical taxonomic level. The results suggested that little avian prey was taken in winter, when sheep and deer carrion were mostly eaten (Fig. 2). However, in the one successful breeding summer studied, birds were found to make a much greater contribution to the overall diet. Of the birds taken, Red Grouse were the most important prey in terms of biomass. Interestingly, in summers when no young were raised, the diet more closely resembled that in winter with few birds taken. Therefore, it appeared that birds are more important prey when eagles had young to feed than at other times.

PREY DISTRIBUTION

Initial surveys indicated that Red Grouse were the only potential live prey of any importance (Shepherd 1997, Madders unpubl. data). Subsequently, grouse territories were plotted during spring using dawn point counts (Watson and O'Hare 1979), and their distribution confirmed in August during searches for grouse broods with trained pointing dogs. The distribution of grouse was closely associated with the cover of heather (*Calluna vulgaris*), the main food of grouse. As a result, grouse abundance was greater at higher altitudes, where the development of heather was less affected by grazing sheep. We estimated that around 25 grouse territories were located within the proposed wind farm.

HABITAT MANAGEMENT

Rather than simply accept the idea that the wind farm would be detrimental to an already stressed pair of eagles, we argued that the development represented an opportunity to redress some of the territory's existing shortcomings (i.e., to lessen the impact of sheep and forestry). Accordingly, we devised an integrated habitat management scheme that aimed to increase the overall live prey base

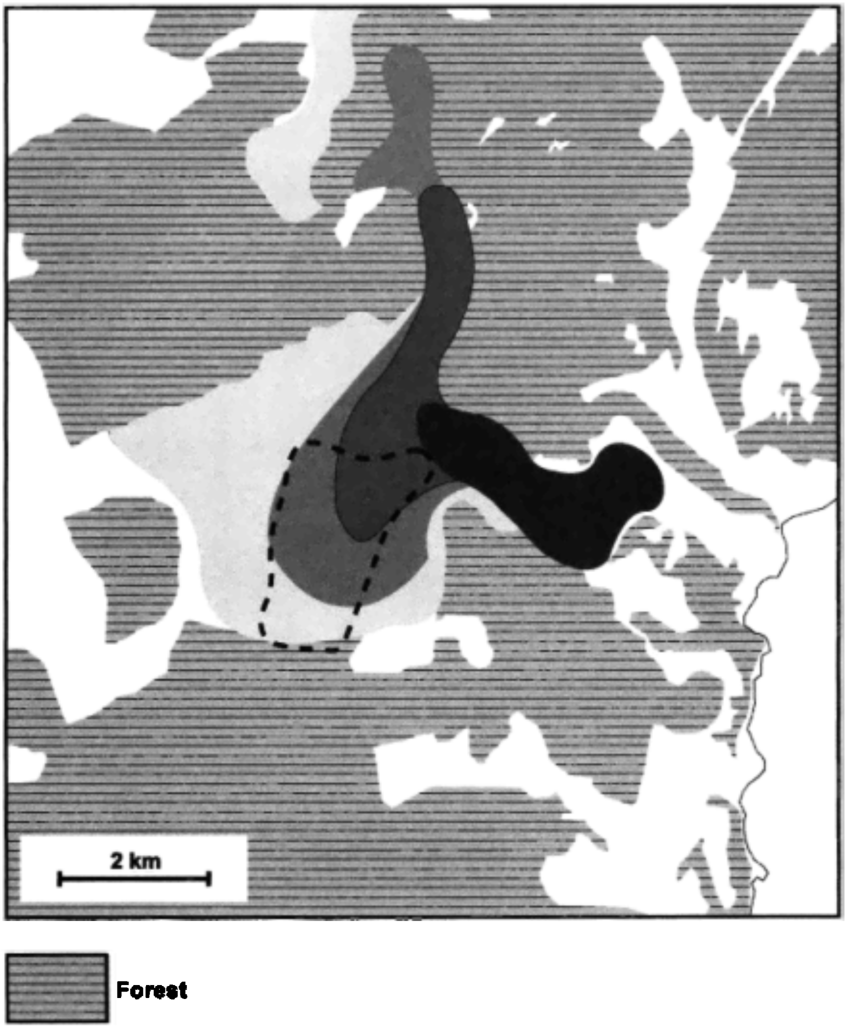

Figure 1. Diagrammatic representation of eagle ranging behavior 1997–99 showing the extent of forestry. Black and grey tones indicate the varying intensity of use by eagles (black = most used), based on the frequency with which eagles were observed to use different flight lines and perches during systematic timed observations. The broken line indicates the proposed location of the wind farm before revision of the turbine layout to accommodate eagles.

available to eagles (mainly Red Grouse), while simultaneously discouraging eagles from entering the wind farm. In other words, we wanted to improve breeding success and limit the risk of turbine collision.

The plan seeks to achieve these aims by increasing the cover and structural diversity of heather in the northern portion of the territory, thereby promoting a pattern of prey distribution that will encourage eagles to hunt outside the wind farm. Structural diversity is important because Red Grouse require a mosaic of short and tall heather between 5–40 cm for feeding and nesting (Moss 1989). An important objective is to provide a minimum of 22 additional pairs of Red Grouse. This is the estimated number of grouse that will become unavailable if eagles avoid the area occupied by the proposed wind turbines (INGENCO 2000). Effort will be concentrated on improving the habitat for grouse in areas adjacent to those already used intensively by eagles (Fig. 3). The principal features of the management plan include the conversion of

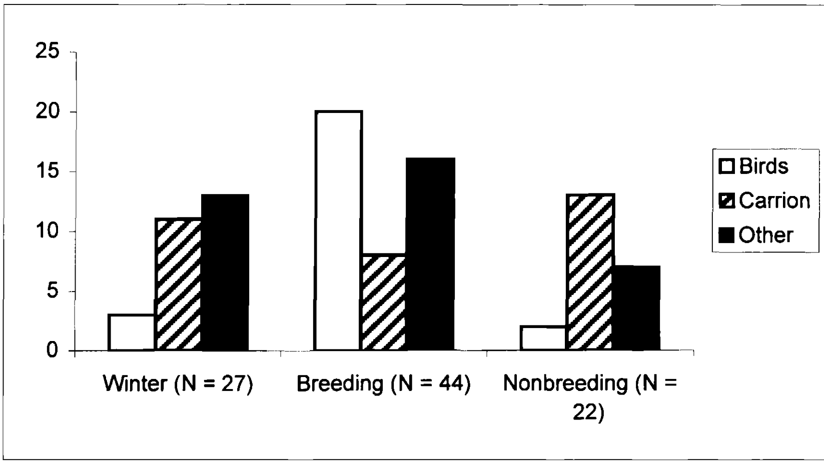

Figure 2. Diet of eagles during summer 1997 to winter 1998–99. The graph shows the number of occurrences of three prey types in pellets collected from roosts used by adult eagles (N = total occurrences in each group). Other prey included lagomorphs, field vole (*Microtus agrestis*), and hedgehog (*Erinaceus europaeus*).

450 ha of maturing coniferous forest to heather-dominated moorland. The trees to be felled occupy ridgelines and other high terrain. Trees will be cut using a mechanical flail and reduced to irregular-sized chips that will be distributed on site. Trials suggest that this approach causes minimal damage to the ground vegetation and does not suppress the subsequent development of heather. Felling operations began in September 1999 and it is anticipated that work will be completed by summer 2001.

The plan also includes the exclusion of sheep from 230 ha of moor where heather has been suppressed by grazing. Increased grazing of heather within the wind farm area will reduce the suitability of the habitat for grouse in the vicinity of the turbines. Carrion will also be removed from the wind farm and intensive shepherding will be undertaken outside the wind farm to prevent damage to areas of developing heather and achieve the required structural diversity within areas of established heather. Occasional cutting or burning of dense heather may be necessary to maintain a mosaic of habitat that provides grouse with both food and cover. We expect this approach to benefit not only grouse, but also mountain hare (*Lepus timidus*), a potentially important prey species that also feeds on heather (Hewson 1962). Significant benefits are also likely for ground-nesting raptors such as Hen Harriers (*Circus cyaneus*) and Merlins (*Falco columbarius*) that prefer to nest in dwarf shrub vegetation.

The management plan will have been in place for approximately two years by the time the turbines are erected. In addition, we wish to test a number of novel ideas for increasing live prey abundance. These include creating artificial warrens on low-lying grassland and establishing small populations of rabbits (*Oryctolagus cuniculus*). The scheme features a strong research component to generate information that will be useful in wider debates concerning upland management. For example, a study examining the process whereby heather becomes established on prematurely felled plantation forest is planned. A site ranger has been employed to undertake day to day management and research routines. In addition to monitoring eagle ranging behavior, annual surveys will measure the responses of vegetation and Red Grouse. We also intend to investigate the nature and extent of any avoidance behavior exhibited by eagles flying in the vicinity of the wind turbines.

CONCLUSIONS

What can we learn from this experience? First, we can learn that impact assessment needs to take into account the cumulative effects of existing and proposed land uses. Second, field research needs to be site specific, extensive, and detailed. The area occupied by the individuals potentially affected,

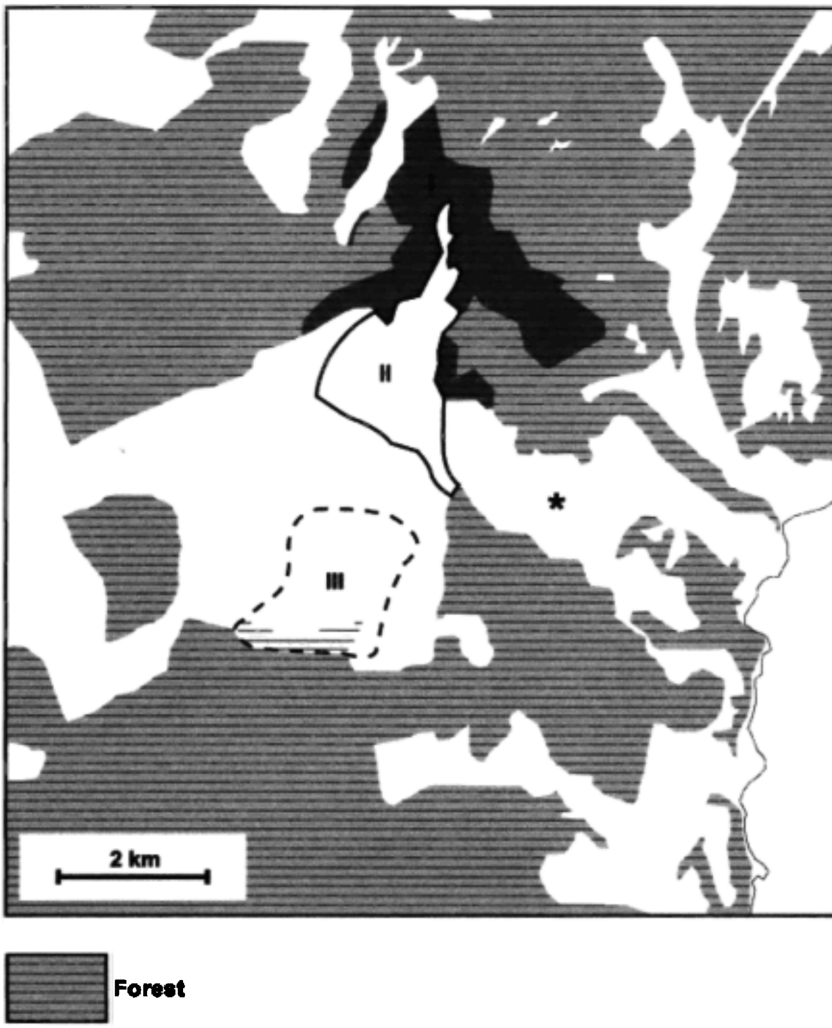

Figure 3. Summary map of proposed habitat management activities. Key: I = tree removal area; II = sheep exclosure area; III = modified location of wind farm, where increased grazing will reduce the abundance of eagle prey; * = area where grazing will be manipulated by intensive shepherding.

rather than the site proposed for development, should define the scale of study. Third, to be effective, mitigation must be done on a large-scale basis and provide habitat that is not only rich in prey but also appropriately distributed. Lastly, we can learn that developments can, in some circumstances and where the developer is willing, provide an opportunity to enhance degraded landscapes for the benefit of eagles and other raptors.

ACKNOWLEDGMENTS

CRE Energy Ltd., a subsidiary of ScottishPower plc, funded the work described in this paper. R. Moss designed and helped undertake the grouse surveys. For help with other aspects of the project we are grateful to R. Broad, S. Brooks, C. Cronin, M. Gregory, S. Harvey, D. Hayward, D. Hunt, F. Leckie, M. McGrady, J. McLaughlin, R. Marshall, A. Mortimer, R. Rylott, K. Shepherd, and J. Welstead. The cooperation of landowners and managers in central Kintyre is gratefully acknowledged. P. Whitfield made invaluable comments on an earlier draft of the manuscript.

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