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Implications for conservation of foraging sites selected by Short-toed Eagles (*Circaetus gallicus*) in Greece

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The major threat to Short-toed Eagles (*Circaetus gallicus*) is the reduction of suitable foraging habitats, but no quantitative studies have been conducted to understand this process. Here, the spatial distribution of foraging Short-toed Eagles was studied in relation to nine habitat types in Dadia-Lefkimi-Soufli National Park, Greece, during 1996–1998. Compared to the observed occurrence of foraging individuals over a particular habitat type with the expected utilization of that same habitat type, Short-toed Eagles concentrated their foraging efforts on three types of open habitat: intensive and non-intensive cultivation, and grasslands. Forested areas (pine forests, oak forests and mixed oak-pine forests) were largely avoided by foraging individuals. The density of prey items on the ground may not necessarily be a good indicator as to where an eagle individual will forage, as vegetation structure is also highly influential. The results highlight the importance of open habitat types which provide foraging opportunities for the Short-toed Eagle population. Management guidelines that maintain the region as a patchy network of open and wooded habitats are discussed in order to conserve a viable population of Short-toed Eagles, and possibly certain other raptor species that forage over open areas.

1. Introduction

Detailed knowledge on foraging ecology is critical for understanding avian biology, and raptor ecology in particular (Janes 1985). Information about the foraging ecology of a particular raptor species is often needed, for example, to assess the habitat quality in a particular region (Newton 1979). Forestry and agricultural practices have altered nesting and foraging habitats of many raptor species during the last few decades, often resulting in declines of their populations (Tella & Forero 2000, Franco & Sutherland 2004). However, the same human activities have appeared beneficial for certain other species.

Being a member of the European Union since 1981, Greece is subject to the Common Agricultural Policy (CAP). The CAP aims to increase agricultural efficiency and intensification. These agreements have led to large monocultures of industrial crops and increased field sizes, particularly after the 1960's (Handrinos & Akriotis 1997), and widespread hedge elimination and use of artificial fertilisers and pesticides.

The Short-toed Eagle (*Circaetus gallicus*) is a medium-sized diurnal bird of prey. It is an unusual specialist among raptors in that it feeds exclusively on reptiles and mainly on snakes (Bakaloudis *et al.* 1998a, Gil & Pleguezuelos 2001, Moreno-Rueda & Pizarro 2007). It is a migratory breeder in the Palaearctic (Cramp & Simmons 1980; Bakaloudis *et al*. 2005), falling into the "least concern" category (IUCN 2007) but with an unfavourable conservation status (SPEC category 3; Species of European Conservation Concern). The species is considered rare in Europe (Tucker & Heath 1994, Hagemeijer & Blair 1997). It has disappeared from most northern European countries (Germany, Holland, Denmark, and Belgium) during the last century and has declined markedly in numbers and range (Tucker & Heath 1994). Its numbers have also declined across most of Eastern Europe during the 1970's and 1980's but presently its population is considered stable in most Mediterranean countries, including Spain, France, Italy, Croatia and Greece. Short-toed Eagles require both forested areas with mature trees for nesting (Bakaloudis *et al*. 2000, 2001) and open areas for hunting (Bakaloudis *et al*. 1998a, Moreno-Rueda & Pizarro 2007). National laws protect the species in most countries within its distribution, but reduction of suitable foraging habitats, forest fires, construction of forest roads, hunting, nest destruction and electrocutions have been listed as the factors that threaten their populations (Tucker & Heath 1994). Therefore, as the Short-toed Eagle has low reproductive potential (clutch size is only a single egg, low reproductive rate and long period of immaturity), it remains susceptible in most parts of the Mediterranean region, including Greece.

The aforementioned factors are the main causes of the Short-toed Eagle population declines in many northern European countries (Tucker & Heath 1994). Few efforts have been made to encourage traditional low-intensity farming in Mediterranean countries in which most breeding Short-toed Eagles are concentrated. Although the foraging ecology of several raptor species have been intensively studied (Bechard 1982; Newton 1986; Village 1990; Donazar *et al*. 1990; Thirgood *et al*. 2003; Franco & Sutherland 2004), no quantitative information is available on the foraging-habitat selection by the Short-toed Eagle. Such information is needed for a better understanding on the species foraging ecology, to help wildlife managers manage landscape structure to improve the availability and accessibility of prey species for these eagles. Moreover, conservation of a specialist predator is difficult without information on the species' foraging habitats.

The aim of the present study was to provide a tool for identifying habitat-management strategies for the conservation of the national Short-toed Eagle population and other raptor species that depend on open foraging habitats. In this paper, the use of different habitat types by foraging Short-toed Eagles were studied in Dadia-Lefkimi-Soufli National Park, Greece, during 1996–1998. This area supports the highest density of this species known in Europe: less than 16.9 km^2 per pair (Bakaloudis *et al*. 2005).

2. Material and methods

2.1. Study area

The study was conducted in the Dadia-Lefkimi-Soufli National Park (hereafter DLSNP) on the eastern edge of the Rodopi mountain chain in north-eastern Greece (40°59' to 41°15'N, 26°19' to 26°36'E). Elevations range from 20 to 700 m above sea level, and the whole area is criss-crossed with steep valleys and rainwater gullies. The climate is sub-Mediterranean with a strong continental character: dry summers and cold winters. Mean monthly temperatures in the area range from +4° C in January to +25° C in July, with the mean annual precipitation being 664 mm.

The study area is diverse in structure and vegetation composition because of a combination of climate, soils, and past human influence. The area is covered by several plant associations, though dominated by woodlands. Of the 43,326 ha of the DLSNP, 79% is public and 21% is private land. Sixty-one percent is forested (32% pine forests, 12% oak forests and 17% mixed pine-oak forests), 16% is partially forested (3% shrublands, 3% degraded oak forests and 10% grasslands with sparse trees or shrubs), 2% is barren (rocky areas) and 21% is cultivated land (4% intensive and 17% non-intensively cultivated areas). Intensively-cultivated areas generally have little vertical structure and the crops are mostly cotton, corn and sugar-

beet. These are irrigated during the summer and are used to being treated with synthetic fertilisers and pesticides. In contrast, non-intensively cultivated areas are non-irrigated hilly areas that used to produce cereals, sunflowers, grapes, and almond trees with little or no agrochemical application. The main tree species are pines (e.g., Calabrian Pine *Pinus brutia* and Black Pine *Pinus nigra*) and oaks (*Quercus frainetto*, *Q. sessiliflora*, *Q. pubescens* and *Q. cerris*). For the purpose of the present study, nine different habitat types were identified as described in Bakaloudis *et al*. (1998a).

The study area supports one of the most diverse raptor assemblages in the world, and 36 different raptorial species can be seen all year round. In addition, other wildlife taxa are abundant, such as mammals, reptiles (Bakaloudis *et al*. 1998a), amphibians (Kati *et al*. 2007) and insects (Grill & Cleary 2003). The study area was a Wildlife Reserve from 1980, but in 2006 it was declared a National Park and is now controlled and managed by the local Forestry Service in Soufli. Recently the Management Authority has taken over responsibilities for the region. Two strictly protected cores have been established for the conservation of birds of prey, covering approximately 16.8% of the DLSNP. Human activities have been prohibited in these core areas, and a Specific Management Plan should take place in order to apply management measures.

2.2. Data collecting

Throughout the breeding seasons (from April to September) of 1996, 1997 and 1998, data were collected on the habitat type over which Short-toed Eagles were seen hunting. Fifteen representative observation points were established across the study area at least 4 km apart. Each observation point was located on the highest peaks that provided 360° visibility. The visual field around each vantage point was at least 1.5 km in all directions, with most of the sightings being made well within this range. From each vantage point, the number of habitat types in view ranged from four to eight due to the highly heterogeneous landscape in the study area. The arrangement of vantage points covered approximately 24% of the study area.

During the three field seasons, four to five days were spent collecting Short-toed Eagle foraging data every month. Days were divided into three periods: morning (from sunrise to 11:00 AM), midday (from 11:00 AM to 3:00 PM), and afternoon (from 3:00 PM to sunset). Data were collected during these periods in a 1:1:1 ratio to control for time-of-day effects. Each vantage point was visited once a month during one of the above-listed three time periods, resulting in a total of 18 visits per vantage point over the whole study period. Observations were made from the vantage point using 10×40 binoculars and a 30–60× spotting scope. Every time a Short-toed Eagle was observed actively searching for food, the initial habitat type over which it was hunting was noted. As sightings were made from points well above the surrounding landscape, potential bias from being able to see hunting eagles more easily over open rather than closed habitats was minimised. Eagles engaged in hunting were easy to recognize as they frequently hover and search the ground with lowered head and drop to the ground periodically during prey-capture attempts. Moreover, the vantage points were sufficiently far apart for us to be reasonably confident that hunting eagles were not recorded twice. If an eagle was seen twice, it would have moved a long way in a short period of time and would almost certainly have ceased hunting.

2.3. Statistical analyses

The data on the foraging habitat selection were analysed following Neu *et al*. (1974). This method allows statistical evaluation of whether or not an animal uses habitat types proportional to their occurrence or abundance, by comparing the observed occurrence of foraging eagles over a particular habitat type with the expected utilization of that same habitat type. The expected frequencies were based on the availability of each habitat type in the study area. When a statistically significant difference was detected by the chi-square test between the observed and expected utilization of the habitat types, Bonferroni *z*-statistic was used to construct simultaneous confidence intervals determining whether each habitat type was preferred (used more than expected) or avoided (used less than expected). For further investigation, an index

Table 1. Numbers of observations (*n*) and percentages of year totals of Short-toed Eagles hunting over different habitat types in DLS NP during 1996–1998.

Year	1996		1997		1998		Total	
Habitat	*n*	%	*n*	%	*n*	%	*n*	%
Intensively-cultivated areas	10	9.2	24	20	18	17.5	52	15.7
Low-intensity cultivated areas	53	48.6	40	33.3	33	32	126	38
Shrublands	5	4.6	5	4.2	3	2.9	13	3.9
Pine forest	2	1.8	1	0.8	2	1.9	5	1.5
Mixed oak-pine forest	5	4.6	5	4.2	6	5.8	16	4.8
Oak forest	0	0	0	0	0	0	0	0
Degraded oak forest	6	5.5	6	5	4	3.9	16	4.8
Grasslands	26	23.9	34	28.3	33	32	93	28
Rocky areas	2	1.8	5	4.2	4	3.9	11	3.3
Total	109	100	120	100	103	100	332	100
Chi-square statistic	76.81		89.53		71.89		235.68	
P	<0.001		<0.001		<0.001		<0.001	

of preference was constructed using a modified Ivlev's index (Jacobs 1974):

$$E_i = (r_i + p_i) / (r_i - p_i + 2r_i p_i) \quad (1)$$

where E_i = Ivlev's electivity measure for habitat i, r_i = proportion of eagles observed foraging over habitat i, and p_i = proportion of habitat i in the study area. The electivity index varies from –1.0 to +1.0, with negative values (from –1.0 to 0) indicating avoidance and positive values (from 0 to +1.0) indicating preference for a particular habitat.

An analysis of the utilization of each habitat (observed frequency) in relation to the percentage of land cover by each habitat (which determines expected frequency) was carried out following the procedure described by Neu *et al*. (1974) and Byers *et al*. (1984).

All statistical analyses (chi-square tests) were performed using the Minitab (release 13) statistical package. All analyses were evaluated at the a = 0.05 significance level.

3. Results

Short-toed Eagles were frequently observed hunting over open habitats, as for each year there was an association between foraging eagles and habitat types (P <0.001 for each year; Table 1). Of particular importance were the cultivated areas (both intensive and non-intensive) and grasslands. Degraded oak forests also appeared important, followed by shrubland and rocky areas. According to the habitat-utilization analysis, the distribution of sightings across the habitat types remained similar between years (χ_{14}^2 = 13.45, P = 0.492) and the data were combined for further analysis. There was a highly significant difference between the expected and observed level of usage of each habitat type (χ_8^2 = 235.68, P <0.001; Table 2). After Bonferroni corrections, intensive cultivation, grasslands and non-intensive cultivation (preference indices 0.634, 0.556 and 0.498, respectively) had been utilized more than expected, while pine, mixed and oak forests (preference indices –0.938, –0.604 and –1, respectively) had been utilised less than expected (P < 0.05 in all cases). Although there was a slight preference for the remaining three habitat types (shrublands, degraded oak forest and rocky areas) by the Short-toed Eagles, the degree of utilization did not deviate significantly from the expected.

4. Discussion

4.1. The importance of food and habitat availability

The use-availability analyses suggested that Short-toed Eagles frequently use open habitat types for foraging, as previously noted by other authors (Amores & Franco 1981, Petretti 1988,

Table 2. Habitat types used by foraging Short-toed Eagles in the study area during 1996–1998.

Habitat type	Relative area	No. eagles observed	No. eagles expected	Proportion observed	Bonferroni conf. int.[a]	Preference index[b]
Intensively cultivated areas	0.04	52	13	0.157	0.106–0.207 [c]	+0.634
Low-intensity cultivated areas	0.17	126	56	0.380	0.312–0.447[c]	+0.498
Shrublands	0.03	13	10	0.039	0.012–0.066	+0.137
Pine forest	0.32	5	106	0.015	–0.002–0.032[c]	–0.937
Mixed oak-pine forest	0.17	16	56	0.048	0.018–0.078[c]	–0.604
Oak forest	0.12	0	40	0.000	0.000–0.000[c]	–1.000
Degraded oak forest	0.03	16	10	0.048	0.018–0.078	+0.242
Grasslands	0.10	93	33	0.280	0.218–0.343[c]	+0.556
Rocky areas	0.02	11	7	0.033	0.008–0.058	+0.253
Total	1.00	332	332	1.000		

a Calculated according to Neu *et al*. (1974).
b Calculated using a modified Ivlev's (Jacobs 1974).
c Difference at the 0.05 alpha level between proportions of habitat used and habitat available.

Bocca 1989, Gil & Pleguezuelos 2001, Moreno-Rueda & Pizarro 2007). Indeed, many species of diurnal raptors rely on open areas for hunting (e.g., Wakeley 1978, Newton *et al*. 1996, Franco & Sutherland 2004). In the present study area, intensive cultivation had the highest mean number of snake species (2.23 / visit / 0.1 ha) of the habitat types. It contained many Grass Snakes (*Natrix natrix*), the favoured prey of Short-toed Eagle, so it is not surprising that Short-toed Eagles foraged over intensively-cultivated areas (Bakaloudis *et al*. 1998a). The other two habitat types significantly favoured for foraging were non-intensive cultivation and grasslands, with the mean numbers of snake species per visit over a 0.1-ha area being 0.19 and 0.21, respectively. Non-intensive cultivation was associated with a relatively high Grass Snake count, whereas grassland was not. Furthermore, neither of these habitats contained particularly high counts of any other snake species. In contrast, forested habitats, including pine forest, mixed oak-pine forest and oak forest (0.09, 0.18 and 0.2 snakes / visit / 0.1 ha, respectively), were mainly avoided by Short-toed Eagles for foraging. Most of the sightings of foraging eagles associated with these habitats were over roads or firebreaks, which exist in a dense network across the study area. These habitats were associated with high lizard counts, but not with high snake counts (Bakaloudis *et al*. 1998a; 1998b).

The distribution of potential food items on the ground cannot be used as an indicator of food availability (Thirgood *et al*. 2003, Ontiveros *et al*. 2005). Moreover, vegetation structure may greatly influence the foraging behaviour of Short-toed Eagles (Amar *et al*. 2004). Indeed, Short-toed Eagles foraged over open areas with short and sparse vegetation (such as grasslands and cultivated areas) more frequently than expected, and foraged over tall and dense vegetation (such as densely forested areas) less frequently than expected. The Short-toed Eagle usually hunts by hovering to locate its prey on the ground. In addition, the colouration of Short-toed Eagle under-parts is strikingly whitish, which may render it less conspicuous to prey against the sky. These observations concur to those reported for other raptors, such as Hen Harriers (*Circus cyaneus*; Schipper *et al*. 1975, Preston 1990) and Red-tailed Hawks (*Buteo jamaicensis*; Preston 1980).

The DLSNP is a patchwork of different habitats. Large areas remain wooded despite active forestry. These wooded areas – particularly those consisting of Calabrian Pine and Black Pine on south slopes – are used by Short-toed Eagles for nesting (Bakaloudis *et al*. 2001). Where the trees have been removed, a variety of open habitats exists, including cultivated areas, grassland and shrubland. These sections are kept open by human activities: crop cultivation and animal husbandry in particular. The present study showed that some of these open areas – especially non-intensive cultivation and grasslands – are crucial for foraging Short-toed Eagles. This is similar to foraging studies on a range of raptor species to which grasslands in particular are important, such as Red Kite (*Mil-*

vus milvus; Newton *et al*. 1996), Ferruginous Hawk (*Buteo regalis*; Wakeley 1978), Golden Eagle (*Aquila chrysaetos*; Tjernberg 1985), Lesser Kestrel (*Falco naumanni*; Franco & Sutherland 2004), and Cinereous Vulture (*Aegypius monachus*; Carrete & Donazar 2005).

Short-toed Eagles and other raptor species clearly benefit from human impact on the DLSNP landscape (Bakaloudis *et al*. 1998b, Poirazidis *et al*. 2004). The network of open and wooded patches explains why the Europe's highest density of Short-toed Eagle occurs in the study area (Bakaloudis *et al.* 2005) and why the population is not adversely affected by human activity. Probably the retention of activities that maintain the Dadia region as a patchy network of open and wooded habitats is the best way to maintain a viable population of Short-toed Eagles, and possibly certain other raptor species as well.

The main management objectives for the foraging areas of Short-toed Eagles should aim at maintaining open-wooded land in the proportion and distribution currently found in the study area, the provision of quality habitat for reptiles and conditions that provide eagles with foraging opportunities. In order to achieve these goals, different approaches should be implemented for each habitat type.

4.2. Management guidelines and conclusions

4.2.1. Farmlands

The distribution, proportion and vegetation structure of agricultural land should be maintained in the current state in the DLSNP, especially in low-intensity cultivation areas. Fallow fields inside forests should be cultivated biennially or in three-year-cycles to prevent pine trees from colonising these open habitats. The recent increase in planting trees in non-irrigated marginal fields should be mitigated and low-intensity farming systems supported through an active EU agricultural policy. In addition, where re-allotment of land occurs, hedges containing shrubs and trees should be favoured at field margins (Chamberlain & Fuller 2000, Reif *et al*. 2008). The use of agrochemicals, including both artificial fertilisers and pesticides, in the intensively cultivated land should be minimised (Wadsworth *et al*. 2003), although their effects on wildlife have not yet been investigated in Greece.

4.2.2. Grasslands with scattered shrubs or trees

Grasslands, possibly with scattered shrubs and/or trees, within forests should be maintained through grazing. Livestock grazing (cattle and goats) has recently declined in the study area but wild ungulates could be used as a cheap management surrogates. Grazing could be concentrated on dense shrublands and, to a lesser extent, open areas. Sparse shrubby vegetation provides cover for many reptilian prey species and also facilitates Short-toed Eagle foraging activities (Moreno-Rueda & Pizarro 2007). Prescribed burning has been proposed as a conservation guideline for the preservation of open habitats in other Mediterranean areas (Sergio *et al*. 2005). However, this practice should be avoided in the DLSNP due to extended fire-fostered pine-forest associations in the region.

Water management could affect the distribution of forest openings and increase prey availability and diversity in two ways. Firstly, water spring cultivation or the construction of small ponds near openings may attract amphibians, mammals and snakes (particularly Grass and Montpellier Snakes *Malpolon monspessulanus*), which in turn are potential prey for the eagles. Secondly, water concentrations may attract wild ungulates and livestock, which in turn could graze the surrounding area more effectively, in turn improving the foraging conditions for Short-toed Eagles.

4.2.3. Conclusions

The present study supports previous observations that the Short-toed Eagle uses open habitats for foraging sites. Breeding Short-toed Eagles require – apart from mature pine trees for nesting in open forested areas – the presence of appropriate foraging habitats in close proximity to their nests. This study identified the foraging habitats on which the eagles at least locally rely. However, the distribution, proportion and vegetation structure of the open land is under threat, probably more so now

than at any other time in the past. These threats stem from two principal sources: changes in agricultural practices as a result of Greece's membership in the EU, and canopy closure which is exacerbated by the emigration of younger people to urban areas, resulting in less livestock grazing and the abandonment of traditional low-intensity cultivations. The apparent change in the landscape structure should be subjected to long-term monitoring. Moreover, the potential impact of agricultural pesticides on raptors should be carefully evaluated to ensure the continued survival of Short-toed Eagles and other raptor species in the region.

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Käärmekotkan ruokailuympäristöjen suojelu Kreikassa

Suurin uhka käärmekotkalle (*Circaetus gallicus*) on sopivien ruokailuympäristöjen väheneminen, mutta asiaa ei ole aiemmin arvioitu kvantitatiivisin menetelmin. Tässä tutkimuksessa tarkasteltiin ruokailevien käärmekotkien alueellista jakautumista suhteessa eri ympäristötyyppeihin Dadia-Lefkimi-Souflin kansallispuistossa Kreikassa 1996–1998. Yksilöiden esiintymistä eri ympäristötyypeissä (havaittu esiintyvyys) vertailtiin näiden ympäristötyyppien yleisyyteen tutkimusalueella (suhteellinen odotettu esiintyvyys).

Käärmekotkat keskittivät ruokailunsa kolmeen avomaatyyppiin: intensiivisesti ja ekstensiivisesti viljellyt maatalousmaat sekä ruohomaat. Metsämaat (mänty- ja tammimetsät sekä mänty-tammi-sekametsät) eivät olleet käärmekotkien suosiossa. Havaittujen saalisyksilöiden määrä ei välttämättä ole hyvä indikaattori sille, missä kotkat kulloinkin saalistavat, vaan myös kasvillisuuden rakenteella on merkittävä vaikutus.

Tulokset korostavat avointen ympäristöjen tärkeyttä käärmekotkapopulaation ravinnonhankinta-alueina. Maisemanhoidossa olisi kuitenkin säilytettävä laikuttainen metsien ja avomaiden verkosto, jotta käärmekotkapopulaatio säilyisi elinvoimaisena. Toimet saattavat auttaa muitakin avomailla ruokailevia petolintulajeja.

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