

The diet of Bonelli's Eagle *Hieraetus fasciatus* in Cyprus

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ABSTRACT

The feeding habits of 14 Bonelli's Eagle pairs nesting in Calabrian Pine forest in Cyprus during 1999-2001 is described. In total, 1734 prey items were identified from 612 pellets and 528 prey remain collected during the breeding period. Birds were found to be the main prey category, followed by mammals and reptiles. Birds always formed >50% of the diet over the years and breeding stages. However, the proportion of the prey species in the diet varied seasonally with Chukar predominating in all stages, while *Columbidae* formed an increasing proportion in the pre-laying and incubation stages (November to February). Mammals (mainly Black Rats) formed a constant proportion (>30%) of the diet during the breeding period, whilst reptiles (mainly Sling-tailed Agama) increased in importance during the period of brooding, both in pellets and prey remains analysed.

Bonelli's Eagle seems to be an opportunistic predator, which may be explained by the seasonal variation of food availability in the island of Cyprus. Its influence on game species also is discussed.

INTRODUCTION

It is recognised by ecologists that knowledge of the diet of a raptor species is a critical step in understanding its ecology (Newton 1979) and this information could help wildlife managers to take measures to conserve its breeding population.

Food habit studies of Bonelli's Eagle have been carried out only in Spain and France (Cheylan 1977; Simeon & Wilhelm 1988; Martinez *et al.* 1994; Real 1987; 1996), while they are lacking from other Mediterranean countries which support valuable breeding populations, such as Greece, Italy, Croatia and Cyprus. In most of these countries Bonelli's Eagle exploits a wide range of prey species (mammals, birds and reptiles), some of which, in some countries,

have an important value for hunting. This was regarded as an important cause of its population decline as the eagle is threatened by direct persecution from shooting and poisoning. The aim of this study was to describe the species' feeding habits and evaluate its impact on such game species as Chukar Partridge *Alectoris chukar* and Brown Hare *Lepus europaeus* in Cyprus.

STUDY AREA

The study was carried out over the entire free part of Cyprus, which covers approximately 60% of the island.

The structure and composition of the vegetation in the study area reflects a combination of many factors such as climate, soil, topography and past human influence. Calabrian Pine and Black Pine are the most important forest cover types, found mainly in remote parts of the study area. Maquis vegetation type consists of evergreen *sclerophyllous* shrubs with scattered trees, found on hilly terrain up to 1,000m above sea level and dominated by Carob, Mastic Tree, Juniper, *Cistus* spp. and Golden Oak. Garigue, rocky areas, wetlands, riparian habitats and cultivated land are also present. The Forestry Department manages most of these types of habitat and is responsible for the protection and development of the land in the study area. Cyprus, due to its mosaic of habitats, encompasses an extremely rich and diverse fauna, including many endemic species.

MATERIAL AND METHODS

Regurgitated pellets and prey remains were collected from 1999 to 2001 at roosting sites or below nests. Intensive searches were carried out for 14 breeding pairs, usually once per week, and all the material was collected and sorted by nest and date. Nest searches were conducted throughout the breeding and non-breeding period, but different amounts of material were collected from each nesting area due to varying accessibility.

Pellets were stored individually in plastic bags and dried prior to laboratory analysis (Marti 1987). For the identification of prey species contained in each pellet, we used a reference collection of the species that occur in the Island of Cyprus. In addition, we used a mammal identification key in order to identify the genus of each species. Prey remains were reconstructed and a minimum count of individuals was determined in order to avoid over-representation biases (Real 1996; Papageorgiou *et al.* 1997).

Estimates of abundance of Chukar Partridge were collected from autumn 2000 through to summer 2002. Three 10ha plots in each representative habitat type, namely pine forest, maquis, garigue, grasslands and cultivated land, were identified within or close to Bonelli's Eagles nesting territories and surveyed once per season (Sutherland 1996). The mean number of birds observed in each habitat type was used to test that there are no differences between the censused habitat types, seasons and study years.

RESULTS AND DISCUSSION

Chukar Partridge abundance

In total, 356 Chukar Partridges were recorded during the years 2001-2002. Both years' data were pooled since there was no difference between the mean number of partridges per plot as recorded in the two years ($F_{(1, 118)} = 0.07$, $P = 0.795$). From the data analysis it was seen that the mean number of partridges per plot did not differ statistically during the seasons that the surveys took place (Kruskal-Wallis test: $H = 4.21$, $P = 0.239$), although some variation in the mean density (individuals/10ha) was observed between the four seasons. In particular larger densities were recorded during the summer (mean density = 4.60 ± 1.3 ind./10 ha) and autumn (mean density = 3.93 ± 2.1 ind./10 ha), when young birds were recruited into the population after the breeding season and many releases of captive-bred birds had taken place. On the other hand, smaller densities were observed during the winter (mean density = 0.47 ± 0.1 ind./10 ha) and spring (mean density = 0.60 ± 0.3 ind./10 ha), when hunting takes place, but there is also high natural mortality due to various biotic (predation, diseases) and abiotic factors (weather conditions, lack of food, etc.).

Although some variation of mean density was recorded among the different habitat types in Cyprus, these differences did not differ statistically (Kruskal-Wallis test: $H = 4.64$, $P = 0.326$). However, larger densities of partridges were observed in farmlands (mean density = 3.92 ± 1.4 ind./10 ha), in shrub lands (mean density = 3.86 ± 2.6 ind./10 ha) and forested areas (mean density = 1.92 ± 0.6 ind./10 ha), whereas the densities were smaller in grasslands (mean density = 1.54 ± 0.9 ind./10 ha) and brush lands (mean density = 0.75 ± 0.4 ind./10 ha).

Pellet analysis

A total of 612 pellets were collected from 14 different breeding pairs. 1206 prey items were identified and classified in three taxa, namely mammals, birds and reptiles, comprising 11 families and 16 species (Table 1). Birds (56.6%) were found in highest frequency of occurrence, followed by mammals (34.2%) and reptiles (9.3%). From pellet analyses, we found that two species were always present with frequencies above 30%. Chukar Partridge was the commonest avian prey, contributing 32.4%, while Black Rat *Rattus rattus* ranked as the commonest mammalian prey, contributing 31.9% to frequency of occurrence, and these percentages were similar during the three study years ($\chi^2_2 = 3.797$, $P = 0.150$). Other species which appeared often in the pellets were Woodpigeon *Columba palumbus*, Rock Dove *Columba livia* and Sling-tailed Agama *Agama stellio* with 10.9% and 8% respectively. However, these percentages differed significantly among the study years ($\chi^2_2 = 44.75$, $P < 0.001$), with pigeons comprising a larger proportion in 1999 and 2000 and Sling-tailed Agama in 2000. Brown Hare constituted a low proportion in pellets, ranging from 0.3% in 2001 to 2.4% in 2000.

The pellets were moreover classified into the three different breeding stages of Bonelli's Eagle. Before the breeding period 110 pellets were collected, whereas during the incubation period and rearing of the young 129 and 373 pellets were collected respectively. The contributions of Chukar Partridge as well as Black Rat were high and stable in all three breeding stages ($\chi^2 = 0.630$,

$P = 0.740$). These results are similar to those observed by Cheylan (1977), where Red-legged Partridge *Alectoris rufa* was the principal prey item, but in contrast to those of Real (1987) for Spain, where *Columba* spp. and Rabbit *Oryctolagus cuniculus* comprised 28.5% and 23.6% of the eagle's diet respectively. Contrary to this, other species that contributed significantly to the eagle's diet in Cyprus, such as pigeons, doves and Sling-tailed Agama, varied among the three breeding stages ($\chi^2 = 45.610$, $P < 0.001$). Pigeons and doves had a higher frequency of occurrence during the non-breeding and incubation periods, reaching almost 25% of the combined prey items, while that of the Sling-tailed Agama was low. This overbalance of Columbidae was reversed later, during the period of the rearing of the young, when the frequency of occurrence of the Sling-tailed Agama in the diet increased significantly (12.1%), while that of the Columbidae decreased. The contribution of the Brown Hare in the diet was low and stable (1.4%) during all three breeding stages. This finding is in contrast with that of Real (1987) for Spain, Catalonia, where rabbits constituted almost 24% of the eagle's diet during the breeding period from 1980 to 1984.

Table 1. Percentage (%) of prey items in the Bonelli's Eagle diet according to pellet analysis method in Cyprus, during 1999-2001.

Species	Non-breeding	Incubation	Brooding	Total
Mammals	33.2	35.2	34.3	34.2
<i>Lepus europaeus c.</i>	1.8	1.3	1.4	1.4
<i>Hiemiechinus auritus d.</i>	1.2	0	0.7	0.7
<i>Rattus rattus</i>	29.2	33	32.2	31.9
Carcasses	0	0.9	0	0.2
Birds	66.7	60.4	53.3	56.6
<i>Alectoris chukar</i>	31.6	30	33.3	32.4
<i>Columba palumbus</i>	15.8	13.2	7.9	10.0
<i>C. livia, C. domestica</i>	10.5	12.3	6.2	8.0
<i>Pica pica</i>	1.2	0.4	3.0	2.2
<i>Corvus monedula</i>	4.1	1.3	0.9	1.4
<i>Garrulus glandarius</i>	2.3	0.9	0.5	0.8
<i>Turdus merula</i>	0	0.4	0.1	0.2
<i>Athene noctua</i>	0	0	0.2	0.2
<i>Asio otus</i>	0	0.4	0.1	0.2
Unknown	1.2	1.3	1.1	1.2
Reptiles	1.2	4.4	12.4	34.2
<i>Agama stellio</i>	1.2	4.0	12.1	9.0
<i>Eumeces schneideri</i>	0	0.4	0.2	0.2
TOTAL	100	100	100	100
No. of pellets	110	129	373	612

Prey remains analysis

During the study period (1999-2001) prey remains were collected around nest and roosting trees of 16 different breeding pairs of Bonelli's Eagle. A total of 528 prey items were identified and classified in three classes (mammals, birds and reptiles), comprising 10 families and 15 species.

Overall, in the three years of the study the contribution of birds to the Bonelli's Eagle diet was the highest (74.6%), followed by the mammals (18.8%) and reptiles (6.6%). Moreover, the Chukar (31.4%) occurred most frequently in the prey remains. Other species with a high frequency of occurrence were Black Rat (15.5%), Rock Dove and domestic doves (14.6%), Woodpigeon (13.1%), Jackdaw *Corvus monedula* (7.6%) and Sling-tailed Agama from the reptile class with a percentage of 5.8%. The frequency of occurrence of the three classes of prey items varied between the three study years ($\chi^2 = 51.535$, $P < 0.001$), the proportion of birds being significantly lower in 2000 (58.9%) compared with 1999 (84.4%) and 2001 (77.9%), while on the other hand the proportion of reptiles was significantly higher in 2000 (17.1%) compared with 1999 (5.0%) and 2001 (0.2%). The Brown Hare had a low contribution (2.5%) in the eagle's prey remains and showed great variation between the different study years, from 0.5% in 2001 to 6.2% in 2000.

The prey remains were also classified according to their date of collection during the three breeding stages as shown in Table 2. 85% of prey remains were collected during the rearing of the young and the rest during the two other breeding stages. As shown in Table 2, the diet consisted of a variety of prey species during the three breeding stages. Although the number of species during the non-breeding and incubation periods was eight and six respectively, this almost doubled during the rearing stage (14 species). However, the composition of the diet varied during the three breeding stages ($\chi^2 = 11.414$, $P = 0.023$); during the non-breeding period it consisted almost entirely of birds (92.6%), with mammals providing only a small proportion (7.4%) while reptiles were absent. In the following breeding stages mammals and reptiles contributed with a larger proportion. During the non-breeding stage the Woodpigeon was the most important prey species (29.6% frequency of occurrence), followed by Rock Dove, domestic dove and Chukar Partridge with 18.5%, as well as Jackdaw, which also formed a large proportion (13.0%). During the following breeding stages, on the other hand, the Chukar Partridge was the most important prey species (62.5% during the incubation period and 31.3% during the brooding stage), followed by the Black Rat (16.7% and 16.4% respectively). The species with a lower proportion in the last breeding stage were the Columbidae, Jackdaw and Sling-tailed Agama.

The frequency of occurrence of the Chukar Partridge in the prey remains statistically varied in the three breeding stages ($\chi^2 = 13.406$, $P = 0.001$). During the non-breeding period it contributed with a lower percentage (18.5%) while in the incubation period with a larger percentage (62.5%), higher than we were expecting. Finally, the frequency of the Brown Hare in the prey remains was low and contributed to the diet only during the rearing of the young, with a percentage of 2.9%.

Direct observations

Twenty daylong periods of observation were carried out during the study years at eight nests of breeding pairs, spread over all the stages of the growth of the young (Table 3). Two nests with one young, five nests with two and one nest with three young were monitored.

Data analysis showed that the number of the prey items delivered to each nest differed significantly between the two sexes ($\chi^2 = 7.619$, $P = 0.006$); in particular the male brought more prey items to the nest than the female. This is usual, when the female spends time feeding and protecting the young, while the male has the main role in providing the nest with food. It can also arise that there is uniformity in the arrivals of the parents delivering prey to the nest during a day ($\chi^2 = 0.196$, $P = 0.907$).

Table 2. Percentage (%) of prey remains found in Bonelli's Eagle nests and roosts in Cyprus, during 1999-2001.

<i>Species</i>	<i>Non-breeding</i>	<i>Incubation</i>	<i>Brooding</i>	<i>Total</i>
Mammals	7.4	16.7	20.2	18.8
<i>Lepus europaeus c.</i>	0	0	2.9	2.5
<i>Hiemiechinus auritus d.</i>	0	0	0.9	0.8
<i>Rattus rattus</i>	7.4	16.7	16.4	15.5
Birds	92.6	79.2	72.2	74.6
<i>Alectoris chukar</i>	18.5	62.5	31.5	31.4
<i>Columba palumbus</i>	29.6	4.2	11.6	13.1
<i>C. livia, C. domestica</i>	18.5	4.2	14.7	14.6
<i>Pica pica</i>	7.4	0	4.7	4.7
<i>Corvus monedula</i>	13.0	0	7.3	7.6
<i>Garrulus glandarius</i>	0	0	0.2	0.2
<i>Falco tinnunculus</i>	3.7	0	0.4	0.8
<i>Asio otus</i>	0	0	0.4	0.4
<i>Francolinus francolinus</i>	0	0	0.2	0.2
Unknown	1.9	8.3	1.3	1.7
Reptiles	0	4.2	7.6	6.6
<i>Agama stellio</i>	0	4.2	6.7	5.9
<i>Eumeces schneideri</i>	0	0	0.9	0.8
TOTAL	100	100	100	100
<i>No. of prey remains</i>	54	24	450	528

Table 3. Prey delivered by Bonelli's Eagles to eight different nests during the breeding season in Cyprus.

<i>Species</i>	<i>n</i>	<i>%</i>
Mammals	6	30
<i>Rattus rattus</i>	6	30
Birds	14	70
<i>Alectoris chukar</i>	5	25
<i>Columba palumbus</i>	2	10
<i>C. livia</i>	1	5
<i>C. domestica</i>	2	10
<i>Corvus monedula</i>	2	10
Unknown	2	10
Total	20	100

Using direct observation 20 arrivals with prey were recorded and six different prey species were identified. Table 3 shows that birds formed the greatest proportion in the Bonelli's Eagle diet, with a percentage of occurrence

of 70%, followed by mammals with 30%. The main species brought to the nest were the Black Rat with 30%, followed by Chukar Partridge (25%). Other prey observed were species of Columbidae and Jackdaw (10%). No Brown Hare or reptiles were recorded during our observations.

CONCLUSION

Our results suggest that the Bonelli's Eagle in Cyprus is an opportunistic predator, although concentrating its hunting efforts on avian prey, mainly on Chukar Partridges which are abundant across the different habitat types. This study has identified the importance of other game species (e.g. Woodpigeon) on which the eagles rely, even though there are no detailed studies on the population dynamics of these species. However, more research is needed to understand the role of such species in the eagle's diet, as well as education campaigns to the Hunting Association in order to minimise illegal shooting, especially in Cyprus, where Bonelli's Eagle associates closely with game species.

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