The diet of the Bonelli's Eagle *Hieraaetus fasciatus*, in Cyprus

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ABSTRACT

The feeding habits of 14 Bonelli's Eagle (*Hieraaetus fasciatus*) pairs nesting in Calabrian Pine (*Pinus brutia*) forest in Cyprus was described, during 1999-2001.

In total, 1734 prey items were identified from 612 pellets and 528 prey remains, which were 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 among the years and breeding stages. However, the proportion of the prey species in the diet varied seasonally with Chukar (*Alectoris chukar*) predominating in all stages, while *Columbidae* species (*Columba palumbus*, *C. livia* and *C. domestica*) formed an increasing proportion in the pre-laying and incubation stage (from November to February). Mammals (mainly Black Rat *Rattus rattus*) formed a constant proportion (>30%) of the diet during the breeding period, whilst reptiles (mainly Sling-tailed Agama a*gama stellio*) increased in importance during the period of brooding, both in pellets and prey remains analyses.

Bonelli's Eagle seemed to be an opportunistic predator and this predation 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 the knowledge of the diet of a raptor species is a critical step in understanding its ecology (Newton 1979) and this information could help the wildlife managers to take measures to conserve its breeding population in a region.

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 absent from other Mediterranean countries which support valuable breeding population, 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 hunting value. This reason 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 feeding habits of the species, and to evaluate its impact on the game species such 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 island of Cyprus is located in the south-eastern Mediterranean.

The structure and composition of the vegetation in the study area reflects the 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 areas of the study area. Maquis vegetation type which consisted of evergreen *sclerophyllous* shrubs with scattered trees, found on hilly terrain up to 1,000 m 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 in the study area. The Forestry Department manages most of these types of habitats and is responsible for the protection and development of the land in the study area. The island of Cyprus due to the mosaic of habitats encompasses an extremely rich and diverse fauna, including many endemic species.

MATERIALS AND METHODS

Regurgitated pellets and prey remains were collected at roosting sites or under the nests from 1999 to 2001. Intensive searches were carried out at 14 breeding pairs, usually once per week, and all the materials were collected and sorted by nest and date. Nest searches were conducted throughout the breeding and non-breeding period,

but different numbers of materials were collected from each nesting area due to their different accessibility.

Regurgitated 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 recognise 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 abundances of Chukar Partridge were collected from the autumn of 2000 through to the summer of 2002. Three 10-ha 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). Mean number of birds observed in each habitat type was used to test that there are no differences among the censused habitat types, seasons and between the 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, which was 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 among the seasons that the surveys took place (Kruskal-Wallis test: $H = 4.21$, $P = 0.239$), although some variation in the mean density (individuals/10 ha) 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 the autumn (mean density = 3.93 ± 2.1 ind./10 ha) when young birds were recruited to the population after the breeding season and many releases of captive-bred birds had taken place. On the contrary, smaller densities were observed during the winter (mean density = 0.47 ± 0.1 ind./10 ha) and the 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 in 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 in brush lands (mean density = 0.75 ± 0.4 ind./10 ha).

Pellets analysis

A total of 612 pellets were collected from 14 different breeding pairs. 1206 prey items were identified and classified in 3 taxa, namely mammals, birds and reptiles, 11 families (Erinaceidae, Leporidae, Muridae, Bovidae, Phasianidae, Columbidae, Strigidae, Corvidae, Turdidae, Agamidae and Scincidae), and 16 species (Table 1). Birds (56.6%) were found in higher frequency of occurrence in pellets, followed by mammals (34.2%) and reptiles (9.3%). From pellet analyses, we found that two species were always presented with frequencies higher than 30%. Chukar Partridge was the most common avian prey, contributing 32.4% to frequency of occurrence, while Black Rat (*Rattus rattus*) ranked the most common mammalian prey of Bonelli's Eagle diet contributing 31.9% to frequency of occurrence and this percent contribution was 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*), Sling-tailed Agama (*Agama stellio*) and Rock Dove *(Columba livia*), 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 the frequency of occurrence in Bonelli's Eagle pellets, ranging from 0.3% in 2001 to 2.4% in 2000.

Moreover the pellets were classified in the three different breeding stages of the Bonelli's Eagle. Before the breeding period 110 pellets were collected, whereas during the incubation period and the period of the rearing of the young 129 and 373 pellets were collected respectively. The contribution of the Chukar Partridge as well as the Black Rat was high and stable in all three breeding stages of the Bonelli's Eagle diet ($\chi^2 = 0.630$, $P = 0.740$). These results are similar with that observed by Cheylan (1977) where Red-legged Partridge (*Alectoris rufa*) was the principal prey item ,but in

contrast with 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. On the contrary other species that contributed significantly in 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 the incubation period that reached almost 25% of the combined prey items, while the frequency of occurrence of the Sling-tailed Agama was low. This overbalance of the 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 of the Bonelli's Eagle diet. This finding is in contrast with that of Real (1987) for Spain, Catalonia, where Rabbit constituted almost 24% of the eagle's diet during the breeding period from 1980 to 1984.

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 3 classes (mammals, birds and reptiles), 10 families (Erinaceidae, Leporidae, Muridae, Falconidae, Strigidae, Columbidae, Corvidae, Phasianidae, Agamidae and Scincidae) and 15 species.

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

Bonelli's Eagle 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 stage and the rest during the two other breeding stages. As shown in Table 2, the diet of Bonelli's Eagle consisted of various prey species during the three breeding stages. Although the number of the prey species during the non-breeding period and the incubation period was 8 and 6 respectively, it almost doubled during the brooding stage (14 species). However the composition of the prey species varied during the three breeding stages ($\chi^2 = 11.414$, $P = 0.023$). During the non-breeding period the Bonelli's Eagle diet consisted almost entirely of birds (92.6%), and mammals had only a small proportion (7.4%) while reptiles were absent. In the following breeding stages mammals and reptiles contributed with a larger proportion in the diet. During the non-breeding stage the Woodpigeon was the most important prey species (29.6% frequency of occurrence), followed by the Rock Dove, the domestic dove and the Chukar Partridge with 18.5%, as well the Jackdaw which also was 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 that had a lower proportion in the last breeding stage were those of the Columbidae family, the Jackdaw and the 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%), a higher percentage than we were expecting. Finally, the frequency of occurrence of the Brown Hare in the prey remains was low and contributed in the eagle's diet only during the rearing of the young stage with a percentage of 2.9%.

Direct observations analysis

Twenty daily observations were carried out during the study years (1999-2001) at 8 nests of different breeding pairs. These observation days were distributed

to all the stages of the growth of the young (Table 3). Two nests with one young, five nests with two young and one nest with three young were observed.

From the data analysis it arises that the number of the prey items, which were delivered to each nest, differ significantly between the two sexes (χ^2 = 7.619, P = 0.006) and in particular the male brought more prey items to the nest than the female. This is interpreted by the distinguished roles of the two sexes during the breeding period where the female spends time to feed and protect the young while the male has the main role in providing the nest with food. It also arises that there is uniformity in the arrivals of the parents delivering prey to the nest during a day (χ^2 = 0.196, P = 0.907).

Using the method of direct observations 20 arrivals with prey were recorded and 6 different prey species were identified. From Table 3 it is shown that birds were the greatest proportion in the Bonelli's Eagle diet with a percentage of occurrence of 70%, followed by mammals with 30%. The main species, which was observed being carried to the nest, was the Black Rat with 30% of the number of carried prey items, followed by the Chukar Partridge (25%). Other prey carried to the nest were species of the Columbidae family and the Jackdaw (10%). No carrying of items of Brown Hare or reptiles was recorded during the observations.

CONCLUSION

Our results suggest that the Bonelli's Eagle in Cyprus is an opportunistic predator, although it concentrates its hunting efforts on avian prey, mainly on Chukar Partridge which is abundant across the different habitat types in the island of Cyprus. 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 these species in the eagle's diet, as well as education campaigns to the Hunting Association, suggested in order to minimise illegal shooting, especially in the case of Cyprus where Bonelli's Eagle associates closely with game species.

ACKNOWLEDGMENTS

We are most grateful to the Institute of Research Promotion of Cyprus and the "Leventis" Foundation for their financial support of this project. We also thank Robin Chancellor who provided helpful comments on the manuscript.

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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**
Lepus europaeus c.	1.8	1.3	1.4	1.4
Hiemiechinus auritus d.	1.2	0	0.7	0.7
Rattus rattus	29.2	33	32.2	31.9
carcasses	0	0.9	0	0.2
Birds	**66.7**	**60.4**	**53.3**	**56.6**
Alectoris chukar	31.6	30	33.3	32.4
Columba palumbus	15.8	13.2	7.9	10.0
C. livia, C. domestica	10.5	12.3	6.2	8.0
Pica pica	1.2	0.4	3.0	2.2
Corvus monedula	4.1	1.3	0.9	1.4
Garrulus glandarius	2.3	0.9	0.5	0.8
Turdus merula	0	0.4	0.1	0.2
Athene noctua	0	0	0.2	0.2
Asio otus	0	0.4	0.1	0.2.
unknown	1.2	1.3	1.1	1.2
Reptiles	**1.2**	**4.4**	**12.4**	**9.2**
Agama stellio	1.2	4.0	12.1	9.0
Eumeces schneideri	0	0.4	0.2	0.2
TOTAL	**100**	**100**	**100**	**100**
No. of pellets	***110***	***129***	***373***	***612***

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

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

Table 3. Prey delivered by Bonelli's Eagles to 8 different nests during breeding season, in Cyprus.

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