Chancellor, R. D. & B.-U. Meyburg eds. 2004
Raptors Worldwide
WWGBP/MME

Diet of Booted Eagles *Hieraaetus pennatus* in Southeastern Spain

J.E. Martínez, M. Cremades, I. Pagán and J.F. Calvo

ABSTRACT

The diet of Booted Eagles in southeastern Spain was determined by analysing prey remains and pellets collected from 23 nesting sites between 1997 and 2000. The Booted Eagle has a generalist diet, including at least 33 types of prey. Medium-sized birds and ocellated lizard formed the bulk of the diet, while rabbits and medium-sized birds were the main source of biomass. The proportion of medium-sized birds increased during the breeding season, while the proportion of small-sized prey decreased. As regards prey biomass, the proportion of small prey was significantly greater during the incubation period. A comparison of the diets of the Booted Eagle and its potential competitor, the Common Buzzard, showed that the former species takes proportionally more small and medium-sized birds, while Buzzards prey mainly on rabbits, reptiles and amphibians, resulting in a low degree of diet overlap.

INTRODUCTION

The food habits of the Booted Eagle *Hieraaetus pennatus* have been little investigated. This species has been described as a dietary generalist, preying on small and medium-sized birds, small mammals and reptiles. Early studies report anecdotal observations made in the Iberian Peninsula (Suetens 1969; Elosegui 1974; Garzón 1974; Araújo 1974; Pérez Chiscano 1974; Iribarren 1975; Iribarren & Rodríguez 1988). Although some other papers have examined in more detail the food habits of this species during the breeding season in several South African and Palearctic populations (Steyn & Grobler 1981; Veiga 1986; Nevado *et al.* 1988), information is still limited.

In this paper we studied the diet of a Booted Eagle population in a woodland area of southeastern Spain. Our objectives were to analyse: (i) food habits; (ii) seasonal changes in diet composition; and (iii) diet overlap with Common Buzzard *Buteo buteo*.

STUDY AREA AND METHODS

The research was conducted between 1997 and 2000 in a forested area located in the region of Murcia (southeastern Spain; 37°55'-38°05'N, 1°40'-1°50'W). The study area covers about 10,000 ha and ranges from 550 to 1521m, with a Mediterranean climate and a topography characterized by rugged slopes dominated by pine forests (*Pinus halepensis*) interspersed with traditional agroecosystems (cereals, vineyards, olive and almond groves).

The diet was determined by combined analysis of prey remains and pellets collected from 23 breeding territories. This method reduces biases in diet quantification (Collopy 1983; Arroyo 1997; Martínez & Zuberogoitia 2001), and has been shown to be useful for species with a diet rich in birds and small mammals (Simmons *et al.* 1991). Samples were collected weekly during the nesting period, from laying to fledging. All pellets and prey remains from each visit were pooled and analysed together. The quantification of the diet was made using the procedure described in Mañosa (1994).

Pellets were dissected using standard techniques (Sabo & Laybourne 1994). Prey remains were identified using skeletons and skulls of reference specimens collected in the study area, and taxonomic keys (Moreno 1983, 1985, 1986; Brown *et al.* 1987).

When possible, vertebrate prey were determined to species level. The biomass of different prey types was estimated following Van den Brick & Barruel (1971) and Mañosa (1991). Prey-items were assigned to the biomass classes established by Veiga (1986): 0-9g, 10-27g, 28-81g, 82-243g, 244-729g and > 729g. Unidentified vertebrates were classified into three types: small birds, medium-sized birds, and rodents, with an assigned biomass of 20, 200 and 100g, respectively. Insects were identified to the family level.

Temporal changes in diet composition were considered by reference to three periods: (a) incubation and hatching, from April 1 to May 15; (b) nestling, from May 16 to June 30; (c) pre-fledging, from July 1 to August 15. Prey items were classified into six classes, based on taxonomic and size criteria: small birds (20-100g), medium-sized birds (115-400g), small mammals (20-250g); large mammals (adult rabbits, >1000g), reptiles and insects. For comparative purposes, the initial biomass classes were reduced to four categories: <100g, 101-250g, 251-400g and >400g. Samples from territories with fewer than 20 prey-items collected were excluded (Mañosa 1994). Chi-squared tests were used to assess differences in the proportions of prey types and biomass classes between periods. Observed cell frequencies were considered to be significantly different from the expected frequencies when the absolute value of the standardized residual was $> z_{\alpha/2}$ (Mañosa 1994). Statistical significance was set at $\alpha=0.05$.

To compare diet composition between Common Buzzards and Booted Eagles, we also collected pellets and prey remains from 10 territories of the former species in the study area. Comparisons were made using chi-squared tests and considering only four taxonomic classes: birds, mammals, reptiles/amphibians and insects.

Table 1. Diet of Booted Eagles estimated from pellets and prey remains collected in 23 nest sites in Murcia region (1997-2000).

Prey type	*N*	*%*	*Biomass* [1] *(g)*	*%*
Mammals				
Lagomorpha	49	5.87	41500	26.41
Muridae	7	0.84	790	0.50
Sciuridae	10	1.20	2500	1.59
Unidentified rodent	27	3.23	2700	1.72
Birds				
Columbidae	110	13.17	13980	8.90
Galliformes	33	3.95	11600	7.40
Estrigidae	10	1.20	1000	0.64
Falconidae	15	1.80	3000	1.91
Upupidae	18	2.15	1188	0.76
Meropidae	14	1.68	770	0.49
Picidae	3	0.36	600	0.38
Apodidae	3	0.36	135	0.08
Corvidae	69	8.26	12320	7.84
Turdidae	17	2.03	1615	1.03
Sturnidae	3	0.36	270	0.17
Passeridae	3	0.36	90	0.06
Sylvidae	2	0.24	24	0.01
Laniidae	2	0.24	115	0.07
Fringillidae	5	0.60	93	0.06
Emberizidae	1	0.12	50	0.03
Alaudidae	10	1.20	430	0.27
Unidentified medium-sized bird	210	25.15	42000	26.73
Unidentified small bird	40	1.20	430	0.30
Insects				
Crisomelidae	42	5.03	84	0.05
Reptiles				
Lacertidae	132	15.81	19800	12.60

[1] Biomass for each prey species was estimated following Van den Brick & Barruel (1971) and Mañosa (1991). For unidentified small birds, medium-sized birds, and rodents the assigned biomass was 20, 200 and 100g, respectively.

A total of 835 prey items were collected during the study period (Table 1). Birds, reptiles, mammals and insects, in this order, constitute the main prey types of the Booted Eagle diet. The Ocellated Lizard (*Lacerta lepida*) was the most consumed species (15.81%), followed by two bird species: Feral Pigeon (*Columba livia*, 12.60%) and Jay (*Garrulus glandarius*, 7.19%). Mammals formed only a minor component in the diet. However, with respect to biomass,

Rabbit (*Oryctolagus cuniculus*) and Ocellated Lizard represented the most important prey species (26.41% and 12.60%, respectively; Table 1). Most prey-items fall under the 82-243g and 244-729g biomass categories (Table 2).

Table 2. Numbers of prey items (grouped by biomass and taxonomic class) identified from pellets and prey remains collected in 23 Booted Eagle territories in Murcia region (1997-2000).

Biomass class [1]	*Mammals (%)*	*Birds (%)*	*Reptiles (%)*	*Insects (%)*	*Total (%)*	*Biomass %*
0-9 g	0 (0.00)	0 (0.00)	0 (0.0)	42 (5.03)	42 (5.03)	0.05
10-27 g	2 (0.24)	48 (5.75)	0 (0.0)	0 (0.00)	50 (5.99)	0.42
28-81 g	0 (0.00)	52 (6.23)	0 (0.0)	0 (0.00)	52 (6.23)	2.01
82-243 g	32 (3.83)	334 (40.00)	132 (15.81)	0 (0.00)	498 (59.64)	53.20
244-729 g	20 (2.40)	134 (16.04)	0 (0.00)	0 (0.00)	154 (18.44)	19.41
>729 g	39 (4.67)	0 (0.00)	0 (0.00)	0 (0.00)	39 (4.67)	24.82
Total	**93 (11.14)**	**568 (68.02)**	**132 (15.81)**	**42 (5.03)**	**835 (100.0)**	**100.00**

[1] Biomass classes were established following Veiga (1986)

We found significant differences in the proportion of prey type (χ^2=34.27; P=0.0002) and prey biomass classes (χ^2=24.27; P=0.0005) between the three considered periods (Table 3). Medium-sized birds were the dominant type, increasing in proportion as the nesting period progressed. Small mammals and insects showed the opposite trend. In terms of prey biomass, class 101-250g was the most consumed in all three periods. Significant differences were observed only in the incubation period, due to the larger proportion of smaller prey consumed at this time (Table 3).

Table 3. Changes in prey type and biomass delivered to nests by Booted Eagles during the breeding season. Asterisks indicate significant differences between observed and expected frequencies (P<0.05).

Prey type	*Incubation and hatching* [1]	*Nestling* [2] *(%)*	*Pre-fledging* [3] *(%)*
Medium-sized birds	28* (37.84)	38 (55.88)	255 (62.96)
Small birds	12 (16.22)	9 (13.23)	30 (7.41)
Smalls mammals	10* (13.51)	1 (1.48)	22 (5.43)
Large mammals	4 (5.40)	6 (8.82)	14 (3.46)
Reptiles	12 (16.22)	11 (16.18)	70 (17.28)
Insects	8* (10.82)	3 (4.41)	14 (3.46)
Biomass			
<100 g	32* (43.24)	14 (20.59)	86 (21.23)
101-250 g	32 (43.24)	40 (58.82)	236 (58.27)
251-400 g	5 (6.76)	6 (8.82)	62 (15.31)
>400 g	5 (6.76)	8 (11.77)	21 (5.19)
Total	**74 (100.00)**	**68 (100.00)**	**405 (100.00)**

[1] Incubation period: from April 1 to May 15.
[2] Nestling period: from May 16 to June 30.
[3] Pre-fledging period: from July 1 to August 15.

Table 4 shows a comparison between the diets of Common Buzzards and Booted Eagles. Differences were significant (χ^2=67.25; P<0.0001). Compared with Booted Eagles, Common Buzzards consume a smaller proportion of birds and a larger proportion of mammals, reptiles and amphibians.

Table 4. Comparison of food habits between Booted Eagles and Common Buzzards in Murcia region (1997-2000). Diet composition was estimated from pellets and prey remains collected in 23 and 10 nest sites respectively. Asterisks indicate significant differences between observed and expected frequencies (P<0.05).

Prey type	*Booted Eagle (%)*	*Common Buzzard (%)*
Mammals	93 (11.14)	37* (22.15)
Birds	568 (68.02)	64* (38.32)
Reptiles and Amphibians	132* (15.81)	62* (37.13)
Insects	42 (5.03)	4 (2.40)
Total	**835 (100.00)**	**167 (100.00)**

DISCUSSION

The Booted Eagle has been previously described as a consummate bird and, to a lesser extent, reptile hunter (Cramp & Simmons 1980; del Hoyo *et al.* 1994). Our results agree with the above statement and are similar to those obtained in other Mediterranean areas of the Iberian Peninsula and South Africa (Cramp & Simmons 1980; Steyn & Grobler 1981; Nevado *et al.* 1988). Nonetheless, the percentages of mammals in the diet were lower than those recorded in central and northern areas of Spain, where rabbits are a basic prey species for Booted Eagles (Veiga 1986; Iribarren & Rodríguez 1988). With regard to biomass classes, Booted Eagles show a marked preference for medium-sized prey (82-243g), which is a consequence of their high consumption of birds.

The food habits of Booted Eagles in the study area combined the following characteristics: (1) generalist diet; (2) high consumption of birds and lizards; and (3) low consumption of rabbits. Generalist strategies characterize medium-sized raptors which exploit a wide range of prey types (Steenhof & Kochert 1988). The high availability of Ocellated Lizards in Mediterranean ecosystems could determine the high percentages of this species in the eagles' diet (Mañosa 1994; Tella *et al.* 1998). In contrast, the reduced presence of rabbits may be attributed to their low abundance in the study area (Martínez 2002).

We found temporal variations in diet composition which may have been related to changes in prey availability. For example, the proportion of small mammals diminished throughout the breeding season. A similar trend has been observed for Montagu's Harrier *Circus pygargus* in central Spain (Arroyo 1997). The proportion of medium-sized birds, on the other hand, increased from the incubation to the nestling period. Several authors have suggested that this pattern is caused by the increasing availability of young birds (Donázar 1989; Mañosa 1994) and the greater activity and mobility of adults during the nesting period (Castro & Jaksic 1995; Sarno & Gubanich 1995).

With respect to prey size preferences, our results show a significantly higher frequency of small birds in the first period, which can be attributed to the availability of nestlings and immature birds (Tornberg 1997), and to the constraints imposed by the nutritional requirements of eagle nestlings (Pulliam 1975; Taylor & Konarzewski 1992).

Both Booted Eagle and Common Buzzard can be described as dietary generalists in the study area. The latter preys on a wide spectrum of species, mainly birds, reptiles and mammals, but also amphibians and insects. Therefore a presumed shortage of prey could determine the appearance of interspecific competition (Martin 1986). However, there are significant differences in diet composition between the two species. Buzzards consume a greater proportion of mammals, reptiles and amphibians, and a smaller proportion of birds than Booted Eagles, a fact which could facilitate their coexistence in the study area.

REFERENCES

MAÑOSA, S. 1994. Goshawk diet in a Mediterranean area of northeastern Spain. *Journal of Raptor*

ARAÚJO, J. 1974. Falconiformes del Guadarrama Suroccidental. *Ardeola* 19: 257-278.

ARROYO, B. 1997. Diet of Montagu's Harrier *Circus pygargus* in central Spain: analysis of temporal and geographic variation. *Ibis* 139: 664-672.

BROWN, R., J. FERGUSON, M. LAWRENCE & D. LEES 1987. *Tracks and signs of the birds of Britain and Europe*. Christopher Helm, London.

CASTRO, S.A. & F.J. JAKSIC 1995. Great Horned and Barn Owls prey differentially according to the age/size of a rodent in North Central Chile. *Journal of Raptor Research* 29: 245-249.

COLLOPY, M.W. 1983. A comparison of direct observations and collections of prey remains in determining the diet of Golden Eagles. *Journal of Wildlife Management* 47: 360-368.

CRAMP, S. & K.E.L. SIMMONS 1980. *The birds of the Western Palearctic*. Oxford University Press, Oxford.

DEL HOYO, J., A. ELLIOT & J. SARGATAL 1994. *Handbook of the Birds of the World. Volume 2. New World Vultures to Guineafowl*. Lynx Edicions, Barcelona.

DONÁZAR, J.A. 1989. Variaciones geográficas y estacionales en la alimentación del Búho Real (*Bubo bubo*) en Navarra. *Ardeola* 36: 25-39.

ELOSEGUI, J. 1974. Informe preliminar sobre alimentación de aves rapaces en Navarra y provincias limítrofes. *Ardeola* 19: 249-278.

GARZÓN, J. 1974. Contribución al estudio del estatus, alimentación y protección de los Falconiformes en España Central. *Ardeola* 19: 279-336.

IRIBARREN, J.J. 1975. Biología del Águila Calzada durante el período de nidificación en Navarra. *Ardeola* 21: 305-320.

IRIBARREN, J.J. & A. RODRÍGUEZ 1988. Sobre la biología del águila calzada *Hieraaetus pennatus* (Gmelin, 1788) en Navarra. *Publ. Biol. Univ. Navarra, Ser. Zool.* 17: 1-27.

MAÑOSA, S. 1991. *Biologia tròfica, ús de l'habitat i biologia de la reproducció de l'astor (Accipiter gentilis*, Linnaeus, 1758) *a la Segarra*. Ph.D. Thesis. Universidad de Barcelona.

Research 28: 84-92.

MARTÍN, T.E. 1986. Competition in breeding birds. On the importance of considering processes at the level of the individual. *Current Ornithology* 4: 181-210.

MARTÍNEZ, J.E. 2002. *Ecología del Águila Calzada (Hieraaetus pennatus) en ambientes mediterráneos*. Ph.D. Thesis. University of Murcia.

MARTÍNEZ, J.A. & I. ZUBEROGOITIA 2001. The response of the Eagle Owl (*Bubo bubo*) to an outbreak of the rabbit haemorrhagic disease. *Journal für Ornithologie* 142: 204-211.

MORENO, E. 1983. Una variación del patrón general del *Sternum* de los Passeriformes. *Ardeola* 30: 109-113.

MORENO, E. 1985. Clave osteológica para la identificación de los Passeriformes ibéricos. *Ardeola* 32: 295-377.

MORENO, E. 1986. Clave osteológica para la identificación de los Passeriformes ibéricos. *Ardeola* 33: 69-129.

NEVADO, J.C., L. GARCÍA & J.A. OÑA 1988. Sobre la alimentación del Águila Calzada (*Hieraaetus pennatus*) en las Sierras del norte de Almería en la época de reproducción. *Ardeola* 35: 147-150.

PÉREZ CHISCANO, J.L. 1974. Sumario informe sobre la alimentación de rapaces en el noreste de la provincia de Badajoz. *Ardeola* 19: 331-336.

PULLIAM, H.R. 1975. Diet optimization with nutrient constraints. *American Naturalist* 109: 765-768.

SABO, B.A. & R.C. LAYBOURNE 1994. Preparation of avian material recovered from pellets and as prey remains. *Journal of Raptor Research* 28: 192-193.

SARNO, R.J. & A.A. GUBANICH 1995. Prey selection of wild American Kestrels: the influence of prey size and activity. *Journal of Raptor Research* 29: 123-126.
SIMMONS, R.E., D.M. AVERY & G. AVERY 1991. Biases in diets determined from pellets and remains: correction factors for a mammal and bird-eating raptor. *Journal of Raptor Research* 25: 63-67.
STEENHOF, K. & M.N. KOCHERT 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. *Journal of Animal Ecology* 57: 37-48.
STEYN, P. & J.H. GROBLER 1981. Breeding biology of the Booted Eagle in South Africa. *Ostrich* 52: 108-117.
SUETENS, W. 1969. Notes sur l'Aigle Bonelli et de l'Aigle Botté en Espagne Meridional. *Ardeola* 15: 115-125.
TAYLOR, J.R.E. & M. KONARZEWSKI 1992. Budget of elements in little auk (*Alle alle*) chicks. *Functional Ecology* 6: 137-144.
TELLA, J.L., M.G. FORERO, F. HIRALDO & J.A. DONÁZAR 1998. Conflicts between Lesser Kestrels conservation and European agricultural policies as identified by habitat use analyses. *Conservation Biology* 12: 593-604.
TORNBERG, R. 1997. Prey selection of the Goshawk *Accipiter gentilis* during breeding season: the role of prey profitability and vulnerability. *Ornis Fennica* 74: 15-28.
VAN DEN BRICK, F.H. & P. BARRUEL 1971. *Guía de campo de los mamíferos salvajes de Europa Occidental.* Editorial Omega. Barcelona.
VEIGA, J.P. 1986. Food of the Booted Eagle (*Hieraaetus pennatus*) in Central Spain. *Raptor Research* 20: 120-123.

J.E. Martínez, M. Cremades, I. Pagán and J.F. Calvo
Departamento de Ecología e Hidrología
Universidad de Murcia
Campus de Espinardo
30100 Murcia
Spain