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Food habits of the wildcat (*Felis silvestris*) in a peculiar habitat: the Mediterranean high mountain

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Abstract

The feeding spectrum of the wildcat *Felis silvestris* Schreber, 1777 was studied in two sites with different ecological characteristics, both situated in the same Mediterranean environment in the high mountain of the Sierra Nevada National Park, south-east Spain, where the rabbit *Oryctolagus cuniculus* is absent. Scat analysis ($n = 101$ faeces; $n = 402$ prey items) showed that the diet is based on rodents, fundamentally wood mouse *Apodemus sylvaticus*, Mediterranean pine vole *Microtus duodecimcostatus* and south-western water vole *Arvicola sapidus*. Results showed strong differences between the two sites ($\chi^2 = 74.04$, d.f. $= 5$, $P < 0.001$), that is a predominance of voles in the mesic Chico river, whereas mice are predominant in the xeric Tejos ravine. Red-legged partridge *Alectoris rufa* and carrion also played an important role, especially in biomass terms. The overall diet differed essentially from that of the Mediterranean region, which surrounds the study area, since in these areas rabbits constitute the primary prey. However, the diet of the mountain wildcats is similar to that in the Eurosiberian floral region, despite its distance from the Sierra Nevada. In conclusion, the Iberian wildcat seems to behave as a facultative specialist, since it prefers rabbits whenever they are available, but rodents constitute most of its diet if rabbits are scarce or absent.

Key words: diet, facultative specialist, *Felis silvestris*, Mediterranean high mountain, rodents

INTRODUCTION

Just like other small-sized species of felid (Corbett, 1979; Nowell & Jackson, 1996), rodents constitute the primary prey in the diet of wildcats *Felis silvestris* Schreber, 1777 in Eurosiberian Europe. Particularly, members of the subfamily Microtinae (voles) are the most frequent prey, especially the common vole *Microtus arvalis*, whereas Murinae (mice) are taken less often (Lindemann, 1953; Condé *et al*., 1972; Sladek, 1973; Hewson, 1983; Kozená, 1990). Wildcats are specialized consumers in capturing small mammals at this latitude.

In contrast, in some areas of Scotland, wildcats prefer rabbits *Oryctolagus cuniculus* (Corbett, 1979). In Mediterranean environments, such as the middle and south of the Iberian Peninsula, rabbits are again the main prey of wildcats. Although rabbits are not the most frequently caught prey, they provide the most biomass, as most studies suggest (Aymerich *et al*., 1980; Aymerich, 1982; Gil-Sánchez, 1998; Gil-Sánchez, Valenzuela & Sánchez, 1999). In this context, the only exception is found at the Sierra de Malcata, Portugal, where rabbits are not such an important prey as in other Mediterranean areas; however, this lagomorph seems to be scarce in Malcata (Sarmento, 1996). This can be related to the high population densities of rabbits in Scotland and the middle and south of the Iberian Peninsula, and a high incidence of myxomatosis, which makes infected rabbits vulnerable to predation (Corbett, 1979). Moreover, the high consumption rate could be facilitated by the larger size of the Iberian and Scottish wildcats (Gil-Sánchez, Valenzuela *et al*., 1999). So, rabbits are an important food of wildcats from the Mediterranean region of the Iberian Peninsula. However, wildcats do not depend on this lagomorph as much as the other Iberian felid, the Iberian lynx *Lynx pardinus* (Delibes *et al*., 1975; Delibes, 1980; Aymerich, 1982; Aldama, Beltrán & Delibes, 1991; Beltrán & Delibes, 1991; Gil-Sánchez, Molino & Valenzuela, 1997; Gil-Sánchez, Valenzuela *et al*., 1999).

Our main aim was to study the composition of the Iberian wildcat's feeding spectrum at a particular Mediterranean enclave, the high mountain, where there are no rabbits, its main prey in Mediterranean environments (Castells & Mayo, 1993). The identification of alternative prey in these areas represents another step in the conservation of wildcats in the centre and south of the Iberian

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Peninsula, where rabbits have suffered a drastic decline during past decades, caused by illness (myxomatosis and viral haemorrhagic disease; Castells & Mayo, 1993; Blanco, 1998; Fenner & Fantini, 1999).

MATERIALS AND METHODS

Study area

Our study area is located in the eastern Penibetic mountain range, south-east Spain (Mediterranean region), in the Sierra Nevada National Park. It shows marked bioclimatic gradients on a relatively small area (1690 km^2), resulting from the latitude (*c*. 37°N and > 600 km south from the Eurosiberian floral region), the altitude (Mulhacén, 3483 m) and the proximity of the Mediterranean sea (Fig. 1). So, all the 5 Mediterranean bioclimatic stages described for this climatic zone are found in Sierra Nevada. Within this mountain, 2 sites located between 1650 m and 2200 m a.s.l., and among supra- and oro-mediterranean stages (2 environments of the Mediterranean high mountain; Rivas-Martínez, 1986) were selected. Both areas differ in their levels of humidity. The Chico river (36°58′N, 3°25′E) is a south-side and Tejos ravine (37°07′N, 3°06′E) is a north-side. Due to microclimates produced by the relief, Chico river valley (1750–2200 m a.s.l.) is a mesic habitat characterized by supramediterranean oak *Quercus pyrenaica* woods, whereas Tejos ravine (1650–1950 m a.s.l.) is a typical xeric habitat characterized by supramediterranean holm oak *Quercus rotundifolia* woods. In fact, both sites constitute the ecotone between forests and oromediterranean shrublands, typically of *Genista* sp. and *Juniperus* sp. Nevertheless, conifer plantations, especially of *Pinus sylvestris*, have transformed these areas in past decades. Rabbits are absent at this altitude of the mountain range (Castells & Mayo, 1993; J. M. Gil-Sánchez, M. Moleón, F. Molino & G. Valenzuela, pers. obs.). Wildcats have inhabited, historically and currently, all the mountain range, reaching > 2200 m in areas such as Chico river valley (Sánchez-García, 1885; Chapman & Buck, 1910; Gil-Sánchez, Moleón *et al*., 2001).

Wildcat's diet and data analysis

Scats were collected and analysed for this study. This is the easiest and most common method used for researching the diet of mammalian carnivores (Delibes, 1980), despite its disadvantages, such as the underestimation of mice in relation to voles in our study (Stahl, Aubert & Artois, 1992). Samples were collected from September 1999 to July 2000, over a pre-established path for each site at the end of every season. The lengths of the paths were 3 km in Chico river and 2.5 km in Tejos ravine. At the beginning of summer 1999, the scats previously dropped were removed. Overall sample size was 101 scats, 57 from Chico river and 44 from Tejos ravine. In spring the number of collected scats was not enough for a reliable analysis, since the length of the grass made it difficult to detect the faeces. In the laboratory, the scats were broken up to identify, at species level if possible, the different prey represented. The minimum number of individuals was estimated by bone remains, especially jaws and teeth. The ingested biomass was estimated from data of Aymerich (1982) and Gil-Sánchez (1998). The composition of the diet was expressed as relative frequency '%N' (number of individuals from the same species or taxonomic group × 100/total numbers of prey) and percentage of consumed biomass '%B' (ingested biomass of the same species or taxonomic group × 100/total consumed biomass).

Fig. 1. Geographical location of the study area (circle). Thick line separates the Mediterranean (below) and the Eurosiberian floral-region (above).

Results from each studied area were compared with a χ^2 test on 6 × 2 contingency tables (Siegel, 1956). Different items of prey were grouped together in the following 6 categories based on the taxa: mice, voles, other mammals, birds, reptiles, and others (Arthropoda and bird eggs).

Seasonal variations in diet for the same prey categories are represented by relative frequencies and by the total percentage of consumed biomass. For this, only those seasons in which the number of prey-individuals obtained was ≥ 30 have been considered: summer and winter in the Tejos ravine, and summer, autumn and winter in the Chico river valley. Possible seasonal variations in each area were tested with a χ^2 analysis on 6 × 3 contingency tables for the data from Chico river and 6 × 2 for those from Tejos ravine.

The trophic niche breadth was estimated from the relative frequencies using Levins B index (Levins, 1968) for our global results and for each part of our study area, and using the same 6 categories of prey.

Table 1. Distribution of the number of scats and prey of *Felis silvestris* for both study areas and for seasons of the year

	Summer Scats/prey	Autumn Scats/prey	Winter Scats/prey	Total Scats/prey
Chico river	33/125	16/101	8/41	57/267
Tejos ravine	24/87	7/18	13/30	44/135

RESULTS

A minimum of 402 prey individuals was found. The distribution of the number of prey and scats per season and per area is shown in Table 1. The diet of wildcats from Sierra Nevada consisted mainly of rodents, especially wood mouse *Apodemus sylvaticus*, Mediterranean pine vole *Microtus duodecimcostatus*, and the south-western water vole *Arvicola sapidus*. Red-legged partridge *Alectoris rufa* and Spanish ibex *Capra pyrenaica* were also a significant contribution to the consumed biomass percentage. Remarkably, eight ungulates (six Spanish ibexes, one sheep and one unidentified) were found, of which four were juveniles (three young ibexes and one lamb), and the rest could not be identified. The secondary prey group included mostly Iberian hare *Lepus granatensis*, and the rest were birds and reptiles. Among the marginal prey, a stone marten *Martes foina* and a young common genet *Genetta genetta* (Table 2) were found. The vegetal remains, principally grass, have not been included in our study, despite being quite frequent, because their nutritional value is low or zero (Kozená, 1990).

Highly significant differences were found between the two sites of our study area ($\chi^2 = 74.04$, d.f. $= 5$, $P < 0.001$) as a result of the different rates of consumption of mice and voles at each site. At the oak-shrubland domain (Chico river valley) voles were the principal prey, whereas at the holm oak-shrubland domain (Tejos ravine) mice were the primary prey. Other less important differences were a higher consumption of red-legged partridge and ungulates in the Tejos ravine, and a higher predation on reptiles (mostly *Psammodromus algirus*) in

Table 2. Overall diet composition of *Felis silvestris* in Sierra Nevada National Park. *n*, minimum number of individuals; %N, relative frequency; %B, percentage of consumed biomass. Levins B index is also indicated

	Chico river			Tejos ravine			Total		
	n	%N	%B	*n*	%N	%B	*n*	%N	%B
Murinae	75	28.1	17.9	83	61.5	19.0	158	39.3	18.5
Apodemus sylvaticus	73	27.3	16.0	83	61.5	19.0	156	38.8	17.5
Mus spretus	1	0.4	0.1	0	–	–	1	0.2	0.1
Rattus sp.	1	0.4	1.8	0	–	–	1	0.2	0.9
Microtinae	136	50.9	51.6	21	15.6	13.2	157	39.1	32.7
Microtus duodecimcostatus	110	41.2	17.4	13	9.6	2.1	123	30.6	9.9
Arvicola sapidus	26	9.7	34.2	8	5.9	11.0	34	8.4	22.8
Other mammals	5	1.9	14.1	11	8.0	35.9	16	4.0	24.7
Sciurus vulgaris	0	–	–	1	0.7	2.7	1	0.2	1.3
Crocidura russula	1	0.4	0.1	1	0.7	0.1	2	0.5	0.1
Lepus granatensis	0	–	–	3	2.2	11.0	3	0.7	5.4
Capra pyrenaica (3 juvenile ibexes)	3	1.1	10.5	3	2.2	11.0	6	1.5	10.7
Ovis aries (lamb)	0	–	–	1	0.7	3.7	1	0.2	1.8
Ungulates (unidentified)	0	–	–	1	0.7	3.7	1	0.2	1.8
Martes foina	1	0.4	3.5	0	–	–	1	0.2	1.8
Genetta genetta (juvenile)	0	–	–	1	0.7	3.7	1	0.2	1.8
Birds	10	3.7	10.8	12	8.9	29.1	22	5.3	19.7
Alectoris rufa	2	0.7	7.0	7	5.2	25.6	9	2.2	16.1
Columba sp.	1	0.4	2.2	0	–	–	1	0.2	1.1
Pica pica	0	–	–	1	0.7	2.3	1	0.2	1.1
Parus major	1	0.4	0.1	0	–	–	1	0.2	0.1
Carduelis cannabina	1	0.4	0.2	0	–	–	1	0.2	0.1
Passeriformes (unidentified)	5	1.9	1.3	4	3.0	1.1	9	2.2	1.2
Reptiles	17	6.4	5.0	4	3.0	2.6	21	5.2	3.9
Lacerta lepida	5	1.9	3.3	2	1.5	1.4	7	1.7	2.4
Psammodromus algirus	11	4.1	0.8	1	0.7	0.1	12	3.0	0.4
Elaphe scalaris	1	0.4	0.9	0	–	–	1	0.2	0.4
Malpolon monspessulanus	0	–	–	1	0.7	1.4	1	0.2	0.7
Others	24	9.0	0.3	4	3.0	0.4	28	7.1	0.4
Bird eggs	1	0.4	0.2	2	1.4	0.4	3	0.7	0.3
Cerambix cerdo	2	0.7	0.0	0	–	–	2	0.5	0.0
Rhizotrogus sp.	20	7.5	0.1	1	0.7	0.0	21	5.2	0.0
Licinus sp.	0	–	–	1	0.7	0.0	1	0.2	0.0
Orthoptera (unidentified)	1	0.4	0.0	0	–	–	1	0.2	0.0
n	267			135			402		
B	3.677			3.370			3.865		

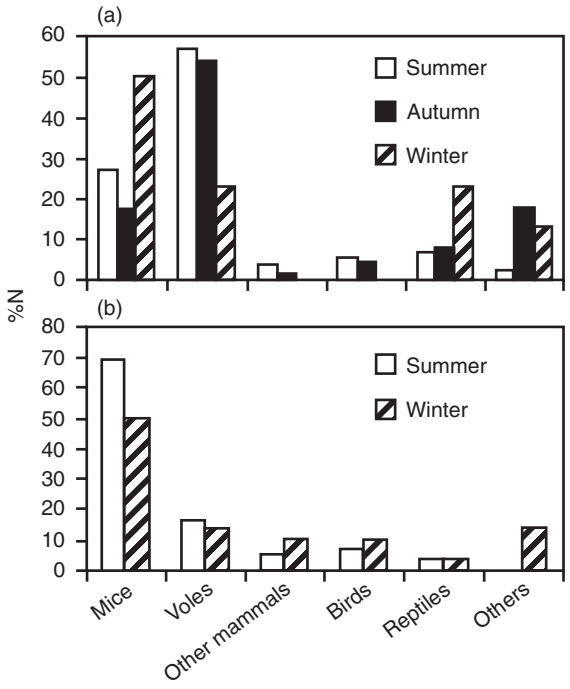

Fig. 2. Seasonal variations in diet composition of the wildcat in: (a) Chico river valley; (b) Tejos ravine. %N, Relative frequency. See text for details of represented seasons.

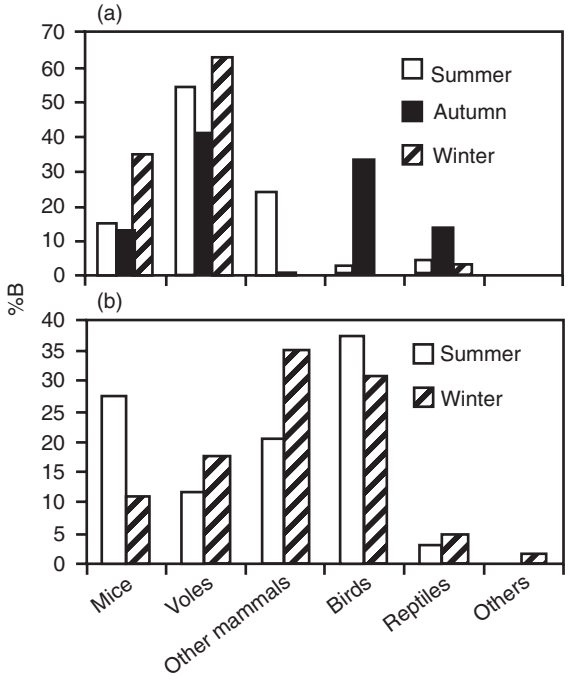

Fig. 3. Seasonal variations in diet composition of the wildcat in: (a) Chico river valley; (b) Tejos ravine. %B, Percentage of consumed biomass. See text for details of represented seasons.

the Chico river valley. Hares were exclusively captured in the Tejos ravine. The small sample size from Tejos ravine could have biased the %B results towards frequent but heavy prey (hares, carrion and partridges; Table 2, Figs 2 & 3).

Concerning seasonal variations, statistically significant differences were estimated for both sites, especially in Chico river (Chico river: $\chi^2 = 55.80$, d.f. $= 10$, $P < 0.0001$ for %N and $\chi^2 = 132.79$, d.f. $= 10$, $P < 0.0001$ for %B; Tejos ravine: $\chi^2 = 19.26$, d.f. $= 5$, $P = 0.017$ for %N and $\chi^2 = 14.40$, d.f. $= 5$, $P = 0.013$ for %B). Chico river variations were mainly correlated to a higher capture index for mice and lower capture index for voles during the winter season; however, the preponderance of mice disappeared when the consumed biomass percentage was analysed, since water voles weigh much more than mice. The main determinant factor of the seasonal differences in Tejos ravine is the decreasing winter capture rates of mice in spite of an increasing consumption rate of ungulates (Figs 2 & 3). The Levins B index is similar for both sites (Table 2).

DISCUSSION

Wildcats in the Mediterranean high mountain have a similar diet to those from Eurosiberian European areas, i.e. mainly small mammals, especially rodents. In contrast, it has been found that rabbits are the principal prey for wildcats from low-altitude Mediterranean habitats (Aymerich *et al*., 1980; Aymerich, 1982; Gil-Sánchez, 1998; Gil-Sánchez, Valenzuela *et al*., 1999). The main observed difference with Eurosiberian habitats concerns a higher consumption rate of murinae by wildcats from Sierra Nevada. It is well known that mice replace voles when the latitude decreases in the Iberian Peninsula (Araujo *et al*., 1973; Herrera, 1973; Camacho, 1975; López-Gordo, Lázaro & Fernández-Jorge, 1976; Corral, Cortés & Gil, 1979; Aymerich *et al*., 1980; Camacho & Pleguezuelos, 1980; Delibes, Brunet-Lecomte & Máñez, 1983; Brunet-Lecomte & Delibes, 1984; Cortés, 1988; San Segundo, 1988; Alegre, Hernández & Sánchez, 1989; Alegre, Hernández, Purroy *et al*., 1989; Martínez-Pereda, 1996; Torre, Tella & Ballesteros, 1997; Blanco, 1998) and at European level (Galeotti & Canova, 1994; Mikkola, 1995; Ruíz, 1996). This is explained by a better adaptation of mice to the xeric conditions of the Mediterranean environments (Blanco, 1998), while mountains offer different conditions of humidity resulting from two factors: (1) altitude (Mediterranean mountains can be considered as mesic islands in a typical xeric matrix); (2) the appearance of microclimates produced by the relief (López-González, 1993). This happens in the two sites from the study area in Sierra Nevada, so at the same altitude, one site corresponds to a holm oak domain and the other site to an oak domain. Therefore, we can expect voles to be more abundant at the oak site than at the dry holm oak site.

Behavioural and climatic factors could explain the substitution of voles by mice as the most frequently captured prey during the winter season in Chico river valley. During winter, this site is usually covered by snow and pine voles are living underground, which provides protection against wildcat predation, while mice are still above ground (Castells & Mayo, 1993; Blanco, 1998).

Ungulates, mostly Spanish ibex, seem to be a valuable contribution to the diet of wildcats in the Sierra Nevada, especially in terms of biomass (%B = 14.3). A medium density of 7.69 ibexes/km^2 was recorded for the whole massif during 1993, as well as 19 ibexes/km^2 in one area of high altitude, where the National Park is located (Pérez, Granados & Soriguer, 1994; Granados, 2001). It is probable, however, that ungulates in Sierra Nevada were consumed as carrion, deaths being caused by illness or other reasons (Hewson, 1983; Kozená, 1990).

The high numbers of the lizard *Psammodromus algirus* found in wildcat faeces could be explained by the abundance of lizards in bushes into which they climb (Mellado *et al*., 1975; Mellado, 1980; Pérez-Mellado, 1998*a*) and by their nocturnal activity during the warmest months (Herrera, 1973; Pérez-Mellado, 1998*a*). Eyed lizard *Lacerta lepida* in southern Spain also seems to be nocturnal in habit during the warmest season (Herrera, 1973; Pérez-Mellado, 1998*b*). Lizards are therefore easily available to wildcats, which are nocturnal (Corbett, 1979; Nowell & Jackson, 1996; Blanco, 1998).

The capture of other predator species (stone marten and genet) gives the wildcat the character of a superpredator. On the other hand, the abundancy of *Rhizotrogus* sp. (a coleopteran beetle reaching high densities in Sierra Nevada; Garrido, 1997) in the diet, seems to result from active consumption by the wildcats rather than ingestion by the lizards, although lizards are specialists at capturing beetles (Mellado *et al*., 1975; Pérez-Mellado, 1998*a*,*b*). This view is supported because only one coleopteran was found together with lacertid remains in the same scat.

In conclusion, the Iberian wildcat seems to behave as a facultative specialist, in that it prefers rabbits whenever they are available, because of their higher biomass (Sarmento, 1996), but captures rodents if rabbits are scarce or absent. In this, the wildcat is not unique among Iberian mammalian predators for south-western Spain; a similar situation occurs in the Eurasian badger *Meles meles* with its consumption of young rabbits (Martín, Rodríguez & Delibes, 1995; Fedriani, Ferreras & Delibes, 1998).

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