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Habitat selection and diet of badgers (*Meles meles*) in Biscay (northern Iberian Peninsula)

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ABSTRACT

The diet and habitat selection of a badger clan from Biscay were studied. The diet was mainly composed of earthworms and fruit, with the relative contribution of each item changing seasonally. Fruit was the staple food in summer, while earthworms were the main item in the other seasons. Badgers used meadows and rejected pine woods and eucalyptus woods, while other habitat categories were used as available. The most probable explanation for the observed habitat selection pattern in the area is food availability at the different habitats and, to a lesser extent, shelter availability.

KEY WORDS: Badger - *Meles meles* - Diet - Habitat selection - Southwestern Europe.

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INTRODUCTION

Badgers are widespread mustelids in Europe, present in most countries, from the Iberian Peninsula to Russia and from Norway to some Mediterranean islands. But while in some countries, such as Great Britain, there is a great deal of knowledge on their ecology, in southern Europe the most basic information is lacking, with very little available for the Mediterranean peninsulas (Griffiths & Thomas, 1993).

Diet has been the issue most studied in the ecology of badgers. Indeed, trophic resources may affect several aspects of animal ecology, influencing the activity (Lodè, 1995), reproduction (Kruuk, 1989; Begon *et al.*, 1995) and, especially in badgers, social and spatial organisation (Kruuk & Parish, 1982; Macdonald, 1983; Kruuk, 1989; Da Silva *et al.*, 1993, 1994; Broseth *et al.*, 1997b). Studies of badger diet have shown four major components: earthworms (Skoog, 1970; Kruuk & Parish, 1981; Neal, 1988; Shepherdson *et al.*, 1990; Goszczynski *et al.*, 2000), fruit (Pigozzi, 1991; Rodriguez & Delibes, 1992; Biancardi *et al.*, 1995), insects (Ciampalini & Lovari, 1985; Rinetti, 1987; Pigozzi, 1991), and small mammals (Weber & Aubry, 1994; Martín *et al.*, 1995). Nevertheless, trophic habits of badgers are still poorly understood in some areas such as that bordering the Euro--Siberian and Mediterranean regions.

Considering the importance that diet has in animal ecology, there are remarkably few works involving simultaneous studies of badger diet and habitat selection. While they could be expected to select those habitats possessing most resources (Macdonald, 1983; Shepherdson *et al.*, 1990; Kruuk, 1989), in some cases, also selection of habitats providing adequate shelter might be determinant (Doncaster & Woodroffe, 1993).

The aim of the present study is to provide preliminary information on badger ecology in an area located on the border between the Euro-Siberian and Mediterranean biogeographic regions. In addition, possible relationships between diet and habitat selection in the study area are discussed.

MATERIALS AND METHODS

Study area

The present study was conducted in the Urdaibai Biosphere Reserve (UBR) (43°29' N, 2°40' W), Basque Country, North Iberian Peninsula (Fig. 1). The UBR extends over a whole basin with an area of 270 km^2. Altitude ranges from 0 to 900 m a.s.l., climate is oceanic, average annual rainfall ranges between 1200 and 1600 mm, and January and July average temperatures are 6° C and 18° C respectively. Winters are mild and without effective snow cover.

The landscape is hilly, rugged, and patchy. The land is 70% forested, mainly *Pinus radiata* and *Eucalyptus globulus* plantations, deciduous woods being scarce and fragmented. Native holm oak (*Quercus ilex*) forests are also common in rocky areas. Meadows, pastures, and estuarine habitat occupy 25% of the area; the remaining 5% being urban area with circa 45,000 inhabitants. Traditional hamlets with small orchards and garden fruit are frequent and widespread. Small vineyards (*Vitis vinifera*) and maize

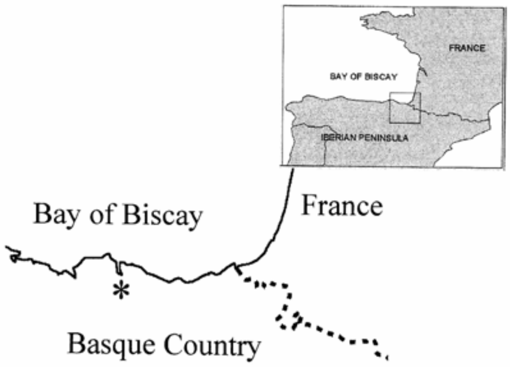

Fig. 1 - Study area location.

(*Zea mays*) crops, together with pastures grazed by dairy cattle and sheep, are also common.

This study was carried out in the centre of the UBR, in an area of 4 km^2, 44% of which was occupied by meadows; pine woods covered 33%, holm oak woods 13%, deciduous woods 6%, eucalypti 2%, and shrubland 2%.

Diet analysis

Badger scats were collected from typical latrines (*sensu* Kruuk, 1978) twice a month from April 1999 to March 2000. Badger-like scats found on the ground, as well as old or visibly weathered ones, were discarded. Due to difficulty and possible error inherent in separation of individual faeces found in the same latrine, latrine-content was taken as the sample unit; probably each latrine-content had two or more scats (Martín *et al.*, 1995). Scat-samples were stored individually in labelled polyethylene bags at -12° C for later analysis, prior to which they were thawed, dried in an oven at 50° C for 48 h, and weighed. They were then soaked in water and thoroughly rinsed through two sieves with a mesh size of 4 mm and 1 mm, respectively. The first litre of water and particles passing through the sieves were collected in a beaker, allowing the solid material to settle for 30 min. The deposition was thoroughly examined under a 30× binocular microscope to search for the presence of earthworm chaetae. Remains in the sieves were classified into eight categories: earthworms, fruit, vertebrates, insects, invertebrate larvae, vegetal material, grass, and others. These categories were chosen on the basis of a minimum volume or frequency of occurrence of at least 5% of the year-round total in any of them. The earthworms category contained every species of earthworm. The fruit category included garden fruit as well as wild fruit, but also maize and grapes. Vertebrates contained every type of vertebrate food, even eaten as carrion. Vegetal material contained every kind of food of vegetal source, excluding grass and fruit. Finally, 'others' included unidentified items, and items that appeared seldom and in small quantities, such as snails. Pieces of gravel and similar items assumed to be swallowed by mistake, or to be a consequence of the scat-collection procedure, were also grouped in the 'others' category. Most items were identified *de visu*, whilst mammal and bird remains were identified after Day (1966), but for fruit remains a local reference collection was used.

Diet was expressed in three ways, as advised by Zabala *et al.* (in press): frequency of occurrence expressed as percentage of the total number of scats, estimated relative volume of ingested biomass following the procedure proposed by Kruuk & Parish (1981), and estimation of ingested biomass calculated modifying dry weight of remains with correction factors. Correction factors were taken from Revilla (1998, Ph.D. thesis, Univ. of Leon) who calculated them using captive badgers from southern Spain.

To evaluate the relative abundance of worms, the amount of worm-nights (*sensu* Kruuk, 1989) was calculated for each season using data from the local meteorological station. We considered as worm-night every night with the lowest temperature above 0° C and at least 3 mm of rain in the preceding three days (Kruuk, 1989). Availability of worms in different habitats was taken from Lopez de Molina (1986, Master thesis, Univ. of the Basque Country).

Data were computed for the whole year and for the following seasons: spring (April, May, and June), summer (July, August, and September), autumn (October, November, and December) and winter (January, February, and March).

Radio-tracking and habitat selection analysis

Trapping lasted from 13^{th} of February 1999 to 3^{rd} of March 1999. Badgers were captured with snares, immobilised with a subcutaneous injection of zooletil (virbac. Carros, France), and fitted with radio collars (Biotrack, UK). The radiocollars had an expected life of six years, and a weight of approximately 100 g (i.e., less than 5% of the weight of animals). Three badgers were captured, two males and a female. From April 1999 to March 2000, the badgers were radio-tracked once a week using a three-element Yagi antenna and TRX-1000S receiver (Wildlife Materials Inc., Carbondale, USA). The radio-tracking period began one month after the last capture to avoid possible bias associated with post-capture behaviour. All together, badgers were tracked for 60 days, in some of which, two or all three badgers were tracked. A total of 88 individual full-night tracking periods was performed and six partial-night tracking periods since for some hours they could not be tracked, due to adverse weather or other causes. In addition to the locations obtained during the 60 tracking days, we gathered several random locations during other days. Locations were taken following the multiple triangulation procedure as described by Mech (1986) at regular time intervals of two hours to avoid serial correlation problems (Aebischer *et al.*, 1993), and between 50 and 100 m from the animal, in order to obtain reliable locations but not to condition the behaviour of the animal. Each location was given a habitat category: meadows, pine woods, holm oak woods, deciduous woods, eucalyptus forests, and shrubland. The meadows category included mainly pastureland, but also small orchards, garden fruit trees, vineyards and maize crops that could not be considered separately due to the small area they covered. Pine woods included the pine plantations of both species present in the area. Holm oak woods were woods of young holm oak trees with plenty of natural undergrowth mainly composed of shrubs and bindweed. Deciduous woods included several small patches of different species: mainly oaks (*Quercus robur*), but also willows (*Salix atrocinerea*) and poplars (*Populus nigra*). Eucalyptus forests were monospecific plantations of eucalypti. Finally, shrubland included *Ulex* sp. and *Rubus* sp. patches, some of considerable surface area (up to 6 ha). In order to fulfil the χ^2 test requirements, some categories were merged to the 'others' category for analysis (Chalmers & Parker, 1989).

To obtain habitat availability, the minimum convex polygon was performed with 95% of the locations of all badgers (White & Garrot, 1990). This was done with the aid of a Geographic Information System (GIS) (Arcview 3.2, ESRI, California, U.S.A.). Then, the total area of each habitat category that fell into the home range polygon was calculated.

Statistics

The χ^2 analysis was used to test relationships between seasons and worm-nights or scat number, and presence of considerable amounts of grass and worm remains. The Yates correction was applied in cases of double dichotomy (Zar, 1999). In the same way, independence between availability and use of habitat categories was tested by χ^2 analysis (Zar, 1999), and Bonferroni's inequality was used to test statistical significance of selection in each category (Manly *et al.*, 1993). In addition, Jacobs' index was used to assess selectivity of different habitat categories (Krebs, 1989). General concordance in habitat selectivity through seasons was assessed using Kendall's test for concordance (Zar, 1999).

The statistical significance levels for differences of food categories' estimated consumed biomass, and frequencies of occurrence among seasons were tested by χ^2 and Kruskal-Wallis analyses (Zar, 1999). Analyses were performed manually or with the aid of SPSS 11.0 for Windows (SPSS Inc.).

The statistical significance limit was set at 0.05 in all cases.

RESULTS

Altogether, 80 latrine contents were collected: 24 in spring, 19 in summer, 15 in autumn and 22 in winter, the different seasons being evenly represented (χ^2 = 2.3, df = 1, P = 0.12,). Throughout the year, the most frequently eaten category was grass (Table I), but it had no volumetric importance. Volumetrically staple categories were earthworms and fruit, consumption of which changed seasonally (Fig. 2, Table II). Earthworm intake was maximal in spring and minimal in summer, whilst fruit consumption was maximal in summer and minimal in autumn. Also frequencies of occurrence of main food items showed seasonal changes; fruit and insects had a peak during summer whilst earthworms and grass showed the opposite tendency (Table III). Most of the fruit eaten was garden fruit (86% of the whole volume), mainly *Prunus* species such as cherry or plum

TABLE I - *Annual diet of badgers assessed through different methods: FO, frequency of occurrence; ERVIB, estimated relative volume of ingested biomass following the procedure proposed by Kruuk & Parish (1981); ECB, estimated consumed biomass.*

	FO	ERVIB	ECB
Earthworms	72.50	38.31	53.01
Fruit	68.75	39.61	38.38
Vertebrates	8.75	3.03	1.08
Insects	71.25	2.81	0.12
Invertebrate larvae	28.75	2.60	0.17
Vegetal material	18.75	4.55	3.98
Grass	91.12	3.90	0.41
Others	18.75	5.19	2.85

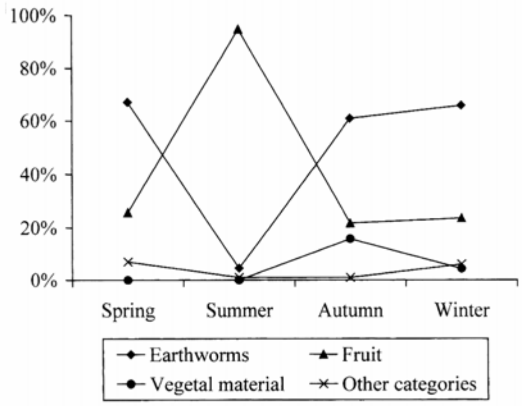

Fig. 2 - Seasonal variation in the volumetric intake of different food items, expressed as estimated consumed biomass.

(Table IV). The remaining categories were of very slight importance, with the sole exception of vegetal material that accounted for 15% of the volume in autumn.

Grass found in scat-samples was divided into two types; entire leaves probably swallowed by mistake, or never eaten and collected with the scat, and chewed grass that passed through the digestive tract. The presence of considerable amounts of the latter (more than 3%) was positively associated with the presence in the same sample of a great amount of earthworm remains (χ^2 Yates = 19.40, df = 1, P < 0.001).

Worm-nights were common during autumn and spring (62% and 52% of the nights, respectively) but scarcer during winter and summer (29% and 24%, respectively) (χ^2 Yates = 34.17, df = 1, P < 0.001).

During the tracking period, a total of 520 radiolocations was gathered, 441 of them while badgers were active (105 in spring, 125 in summer, 102 in autumn and 109 in winter).

Jacob's indices of habitat selectivity and selection after Bonferroni's test for habitat categories and seasons are listed in Table V. Meadows were the only selected habitat, while pine woods were avoided all year round. Deciduous woods were also avoided in the year-round analysis, but the negative selection was only significant

TABLE II - *Statistical significance level of the differences of categories' estimated consumed biomass (ECB) and frequencies of occurrence (FO) among seasons. Values given for FO represent the χ^2 value with df = 3. Values quoted for categories ECB represent the Kruskal-Wallis* H *value with df = 3. In both cases, the asterisk (*) denotes when differences among seasons reached statistical significance at P < 0.05.*

	Earthworms	Fruit	Vegetal material	Vertebrates	Insects	Invertebrate larvae	Grass	Others
FO	25.06*	16.45*	93.59*	39.51*	3.07	7.60	5.30	1.90
ECB	23.17*	23.14*	20.86*	4.11	13.68*	0.76	2.58	6.09

TABLE III - *Seasonal frequencies of occurrence of food categories.*

	Spring	Summer	Autumn	Winter
Earthworms	75.0	36.8	93.4	81.8
Fruit	50.0	94.7	73.3	59.1
Vertebrates	4.4	0.0	0.0	18.2
Insects	66.7	84.2	66.7	68.2
Invertebrate larvae	33.3	21.1	20.0	36.4
Vegetal material	4.2	5.3	53.3	9.1
Grass	100.0	89.5	93.3	81.8
Others	16.7	15.8	26.6	27.3

in summer. Habitat selection for the other categories was not statistically significant. Selection of habitats ranked by their Jacob's index showed no variation throughout the year ($\chi^2_{4,\ 5}$ = 9.8, df = 5, P < 0.001, Kendall test). During the research, the badgers used eight setts: four in holm oak woods (23% of inactive locations), one in shrubland (29% of locations), one in pine woods (3% of locations), one in deciduous woodland (19% of locations), and the last one beneath a *Rubus* sp. patch in the boundary between holm oak wood and meadow (26% of locations). As the setts were used irregularly, with badgers moving frequently from one to another, they could not be classified as main or subsidiary.

TABLE IV - *Seasonal and annual composition of fruit-intake expressed as estimated relative volume of ingested biomass following the procedure proposed by Kruuk & Parish (1981). Note that this table refers only to the fruit intake; therefore, values indicate the proportion of the fruit type in the fruit intake, and not the total intake (See Table I).*

	Spring	Summer	Autumn	Winter	Year
Grapes (*Vitis vinifera*)	0.0	30.0	34.0	0.0	21.1
Cherries (*Prunus avium*)	94.5	11.3	0.0	0.0	24.6
Maize (*Zea mays*)	0.0	8.8	0.0	0.0	4.8
Plums (*Prunus domestica*)	0.0	7.0	0.0	0.0	3.5
Nuts (*Juglans regia*)	0.0	0.0	0.0	6.8	0.9
Hazelnuts (*Corylus avellana*)	0.0	14.0	49.1	76.6	24.1
Figs (*Ficus carica*)	0.0	2.8	0.0	0.0	1.3
Pears (*Pyrus* sp.)	0.0	6.0	0.0	0.0	2.3
Apples (*Malus* sp.)	4.5	0.1	0.0	6.8	3.5
Wild fruits	1.0	19.8	16.9	9.8	13.8

TABLE V - *Habitat selectivity of badgers expressed through the Jacobs' index. Values that reached statistical significance through Bonferroni's inequality are denoted with an asterisk (*). Note that Bonferroni's inequality cannot test -1 values. For seasonal analysis, the 'eucalypti' and 'shrubland' categories have been merged in the 'others' category whilst analysed separately in the year-round analysis.*

Habitat	Spring	Summer	Autumn	Winter	Year
Meadows	0.23	0.47*	0.54*	0.45*	0.39*
Pine woods	-0.44*	-0.50*	-0.86*	-0.73*	-0.64*
Holm oak woods	0.15	-0.04	0.13	0.26	0.10
Deciduous woods	-0.20	-0.66*	-0.01	-0.14	-0.25*
Eucalypti	-	-	-	-	-1.00
Shrubland	-	-	-	-	0.32
Others	0.31	0.01	-0.53	-1.00	-

DISCUSSION

Earthworms and fruit were the staple food items of badgers in the study area. In general, the dominant food types of badgers in Europe are earthworm and vegetable food, complemented with other secondary food items (Goszczynski *et al.*, 2000). Earthworm importance increases from nil at 37-40° N to 40-70% of the volume at 55-63° N, whereas the opposite trend is observed for vegetable food (Goszczynski *et al.*, 2000). According to a strictly latitudinal pattern, diet in our study area should be composed mainly of vegetable food and complemented with insects, as in a study carried out at 46° N in the province of Varese (Italy) (Biancardi *et al.*, 1995). Due to the Atlantic rainy climate of the UBR, which allows earthworm activity, the diet of badgers at the UBR most resembles that in Switzerland (Lüps *et al.*, 1991) or France (Mouches, 1981). Provided the climate is the Atlantic rainy type, earthworms are likely to play an important role in badger diet even in lower latitudes, for instance the North and Northwest shores of the Iberian Peninsula (Walter, 1997).

The intake of earthworms and fruit showed marked seasonality, following the availability of these resources. Worm-nights (*sensu* Kruuk, 1989) were very common in the UBR during spring and autumn, but in winter they were less common due to cold temperatures preventing worm activity on some nights. Finally, they were scarcest in summer as a result of the lack of rain together with high temperatures. Indeed, as we only used minimum temperatures as a limit for worm activity (after Kruuk, 1989), instead of minimum and maximum temperatures, worm-nights during summer might be still scarcer than estimated. On the other hand, fruit was markedly seasonal, especially garden fruit, being almost restricted to summer and the early autumn, when worm availability was minimal.

Other food items were of scarce volumetric importance, but some of them could have biological importance adding to the diet vitamins or some proteins that are uncommon in the staple foods, especially items such as insects which are eaten throughout the year but in small quantities (Clevenger, 1995). On the other hand, Neal & Cheeseman (1996) stated that badgers do eat grass. But the relation we found between grass occurrence and earthworm intake suggests that this statement might be an artefact and that grass is swallowed unintentionally while eating earthworms or invertebrates, as has been found for other carnivores (Cavallini & Volpi, 1996).

The badger's habitat selection may be explained by two factors: food availability (Kruuk, 1989; Shepherdson *et al.*, 1990; Broseth *et al.*, 1997b; Revilla, 1998; Revilla *et al.*, 2000) and shelter availability and the possibility to dig setts (Doncaster & Woodroffe, 1993; Broseth *et al.*, 1997a).

With regard to the first factor, earthworms and fruit are more abundant in meadows than elsewhere (Lopez de Molina, 1986; Kruuk, 1978, 1989; Kruuk & Parish, 1981; Shepherdson *et al.*, 1990; Da Silva *et al.*, 1993). So, the fact that meadows were the only positively selected habitat bears out the hypothesis that the badger's habitat use is governed by availability of food resources, at least at the UBR. Pine woods, which were avoided throughout the year, tend to be poor in earthworms (Lopez de Molina, 1986; Kruuk & Parish, 1981; Shepherdson *et al.*, 1990; Da Silva *et al.*, 1993) and there is neither garden fruit nor wild fruit, especially in forestry plantations.

Regarding shelter, pine plantations also lack natural undergrowth, and therefore, provide no adequate shelter for setts. It has been proposed that the expansion of badgers in the region could be related to the spread of pine plantations in the last decades (Aihartza *et al.*, 1999), although our work suggests that this is not true in our study area. Nevertheless, in other areas pine plantations with natural undergrowth could provide badgers with satisfactory shelter for setts, and thus allow them to colonise areas where they were previously absent due to lack of adequate places for setts (Zuberogoitia *et al.*, 2001).

All the other categories were used in a generalistic way, and some of them were avoided in some season. This generalistic use may be explained as a result of the utilisation of some habitats, like holm oak woods, because of the shelter they provide. The fact that 50% of the setts were located in holm oak woods supports this theory. Deciduous woods might provide higher earthworm biomass during cold nights (Kruuk, 1989), but woods at the UBR tend to be small and fragmented and they probably do not do so. They, and also holm oak woods, may also be an important source of acorns, but those were rarely found in scats. It was in autumn when deciduous woods were most used, just when acorn production is maximal. Eucalyptus plantations were never used, and the use of shrubs, which computes for all the seasonal variation in the 'others' category, changed markedly throughout the year. This might have been an effect of human disturbance, as late summer forestry activities destroyed the sett located in this habitat, which until then had often been used.

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