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DIET OF THE EURASIAN BADGER (*MELES MELES*) IN AN AGRICULTURAL RIVERINE HABITAT (NW ITALY)

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ABSTRACT – Badger *Meles meles* diet was studied throughout 2001-03 by the analysis of 199 scats collected in the River Po Park (Piedmont region, NW Italy). The study area (136 km^2) included a large portion of plain (129.2 km^2) dominated by agriculture (maize, rice and poplar plantations) with scarce riparian vegetation cover, and a small sector of hill (6.8 km^2) mainly covered by broadleaved woods.
Earthworms and maize were the staple foods in the overall badger diet and together accounted for 57% of the mean estimated volume (Vm%). Earthworm consumption varied seasonally with a marked decrease in summer, probably due to drought that reduced their availability (emergence of worms on the surface). This decline was compensated by a significant increase in the utilisation of fruits, mostly in hilly lands. Maize was consumed all year round without significant seasonal variation (percent frequency of occurrence: from 21% in summer to 44.6% in winter). Besides earthworms, the amount of protein of animal origin derived mainly from amphibians (Vm% = 9%) and mammals (Vm% = 7.2%), primarily rodents and lagomorphs. Badger diet consisted mainly of maize, amphibians and mammals in agricultural lowlands, and of earthworms, fruits and insects in hilly lands.
Trophic niche breadth (B) varied from a minimum of 0.34 in autumn to maximum of 0.55 in summer. Our results characterize the badger as a generalist or opportunist feeder.

Key words: Badger, *Meles meles,* diet, riverine habitat, Italy

RIASSUNTO – ***Dieta del Tasso* (Meles meles*) in un'area agricola fluviale dell'Italia nord occidentale***. La dieta è stata studiata nel 2001-03, tramite l'analisi di 199 feci raccolte nel Parco Fluviale del Po e dell'Orba (Tratto vercellese-alessandrino, regione Piemonte). L'area di studio (136 km^2) è ripartita tra le due sponde orografiche del Po: un'ampia porzione (129,2 km^2) è pianeggiante e prevalentemente coltivata a mais, riso e pioppi, con strette fasce di vegetazione riparia, la parte rimanente (6,8 km^2) è collinare e principalmente caratterizzata da formazioni boschive di latifoglie.
I lombrichi e il mais sono le componenti principali della dieta e insieme costituiscono il 57% del volume medio complessivo (Vm%) delle risorse utilizzate. Il consumo dei lombrichi varia stagionalmente con un calo consistente in estate, probabilmente imputabile alla siccità, fattore influenzante la disponibilità (scarsità di lombrichi in superficie) di questa risorsa per il tasso. Questo calo è compensato da un significativo incremento dell'utilizzo dei frutti (mele, susine e uva), riferito prevalentemente alla fascia collinare dell'area di studio. Il mais è consumato tutto l'anno senza variazioni stagionali significative (frequenza percentuale variabile dal 21% in estate al 44,6% in inverno). Oltre ai lombrichi, l'apporto di proteine d'origine animale è dovuto principalmente agli Anfibi (Vm% = 9%) e ai mammiferi (Vm% = 7,2%) rappresentati da roditori e lagomorfi. La dieta del tasso è caratterizzata da

un maggior consumo di mais, anfibi e mammiferi, nella fascia di pianura agricola, e di lombrichi, frutti e insetti, in quella di collina. L'ampiezza della nicchia trofica (B) varia da un minimo di 0,34 in autunno ad un massimo di 0,55 in estate.
Nel complesso, i dati acquisiti confermano che il tasso ha un comportamento trofico generalista o opportunista, come riscontrato nel centro-sud Europa.

Parole chiave: Tasso, *Meles meles*, dieta, ambiente fluviale, Italia

INTRODUCTION

The food habits of the Eurasian badger (*Meles meles*) have been extensively studied, particularly in temperate Eurosiberian environments. This medium sized mustelid is considered a "forager" (Neal, 1986) more than a "predator". It has been described as an earthworm-specialist in Great Britain (Kruuk and Parish, 1981; Kruuk, 1989) and as an omnivore and generalist species in continental and Mediterranean Europe, where its diet is rather varied (Roper, 1994) with cereals, wild and cultivated fruits, insects and, sometimes, rodents (Weber and Aubry, 1994) and lagomorphs (Martin *et al*., 1995).
In northern and central Italy, fruits and invertebrates form the bulk of its diet both in sub-to-alpine and Mediterranean habitats (Kruuk and de Kock, 1981; Ciampalini and Lovari, 1985; Rinetti, 1987; Pigozzi, 1991; Biancardi *et al*., 1995; Lucherini and Crema, 1995; Biancardi and Rinetti, 1999; Deflorian *et al*., 2002; Melis *et al*., 2002).
Because of its ecological plasticity, the badger is distributed in a wide range of habitats, including extensive agricultural lowlands, such as the Po plain (northern Italy) dominated in the west by cereal crops, mainly maize and rice. In this man-made landscape, the survival of badgers depends on the availability of (semi-) natural vegetation (small woods, shrubs, uncultivated spot lands, poplar plantations), occurring almost exclusively along riversides (Prigioni *et al*., 2001).
Here, less is known about the badger's diet: Prigioni *et al.* (1988) reported a wide use of earthworms and maize.
The present study was carried out in a riverine area of the Po valley characterized by a large area of agricultural lowlands and a relatively small wooded hilly zone. Small badger setts were recorded, with a density ranging from 0.21 setts/km^2 in cultivated areas to 1.32 setts/km^2 in hilly areas (Prigioni *et al*., 2002). These values suggest a low density badger population, as is generally found in Mediterranean areas (e.g. Revilla *et al*., 2001).
The main aims of this paper are to analyse a) the diet composition and trophic niche breadth of badgers, b) the seasonal variation in use of key food resources and c) the dietary patterns in plain and hill.

STUDY AREA

The study area is included in the River Po Park (Piedmont region, NW Italy) and covers 136 km^2 on both sides of the river. Almost the whole territory (129.2 km^2) is flat, mainly cultivated for rice, maize and poplar plantations. Gravely soils are covered

with high herbaceous vegetation formed by *Euphorbia cyparissias*, *Carex liparocarpos*, *Muscari botryoides*, *M. comosum* and drought-resistant Graminaceae. Woods are dominated by willows (*Salix cinerea*, *S. alba*), poplars (*Populus alba* and various hybrids), alder (*Alnus glutinosa*) and rarely oak (*Quercus robur*). Black locust (*Robinia pseudoacacia*) is common along roads and railways embankments.

About 5% of the study area is wooded hills extended from 100 to 260 m a.s.l. on the right orographic side of the River Po. Oak (*Quercus pubescens*), wild cherry (*Prunus* sp.), smooth-leaved elm (*Ulmus minor*), black locust and black elder (*Sambucus nigra*) are the main tree species.

The study area has a sub-continental temperate climate, with an average yearly temperature of 12.4°C and an average yearly precipitation of about 1000 mm. Urbanisation is limited.

METHODS

Faeces were collected monthly from January 2001 to July 2003 by surveying known latrines of badgers. Faeces found in a single pit were distinguished according to colour, shape and water content. A total of 199 faecal samples (100 from plain and 99 from hill) were stored in polythene bags and refrigerated until processing.

The analysis was performed according to Kruuk and Parish (1981) and Prigioni (1991).

Samples were washed with three sieves of 1.5, 0.3 and 0.1 mm mesh and food remains were inspected to count or estimate the total numbers of each kind of food.

Mammalian hairs were compared at 20x and 40x magnifications with the keys of Debrot *et al*. (1982), while reptiles and amphibians were detected by the keys of Di Palma and Massa (1981). Bird feathers were identified with reference to Day (1966). The undigested remains of insects (wings, legs and cuticle parts) and wild or cultivated fruits (seeds) were identified using personal collections. Sediment remained in the smallest sieve was examined under a binocular microscope to detect earthworm chetae: it was diluted in a known volume (V) of water and 3-5 water samples of 0.5 ml were observed under a 40x binocular microscope in order to record the mean number (n°) of chetae. Considering 400 the mean number of chetae per earthworm and 31% the mean error due to chetae missed during faeces washing (Prigioni, unpublished data), the number (N) of earthworms eaten was found as:

$$N = (2V \times n° \times 1.31)/400$$

Results were expressed as percent frequency of occurrence (F% = number of faecal samples containing a specific food items/total number of faecal samples x 100) and percent relative frequency of occurrence (FR% = number of occurrences of an item/total number of items x 100); in addition, according to Kruuk and Parish (1981) it was estimated the percent volume (V% = total estimated volume of each food item as ingested/number of faecal samples containing that item) and the mean percent volume (Vm% = total estimated volume of each food item as ingested/ total number of faecal samples).

Data were grouped annually and seasonally (winter: I-III; spring: IV-VI; summer: VII-IX; autumn: X-XII) in order to investigate time variations.

Trophic niche breadth was estimated by the Levins B index (Feinsinger *et al.*, 1981), using FR (p_i) and grouping data in 11 main food categories (R): fruits, plant litter, maize, earthworms, insects, fishes, molluscs, amphibians, reptiles, birds and mammals):

$$B = \frac{1}{R\sum_{i=1}^{n} p_i^2}$$

The raw frequency data for different habitats (plain and hill) and seasons were compared using χ^2 tests. Because of the great number of repeated tests on related data, the level of significance was calculated as ratio between $\propto = 0.05$ and the number of tests (12) conducted (Rice, 1989); the significance level was 0.004. Kruskall Wallis test and Mann-Whitney U test were applied for evaluating respectively seasonal variation and differences between plain and hill of the main food categories expressed as total estimated volume (V%).

RESULTS

Earthworms and maize (F% = 82.4% and 38.2% respectively) represented the bulk of badger diet and together accounted for 57% in Vm% of the overall diet (Tab. 1 and Fig. 1). Wild and cultivated Rosaceae (wild cherries and apples) and grapes made the largest portion (Vm% = 8%) of fruits taken by badgers. Leaves, grass and other vegetable matter were often associated with earthworm consumption, but sometimes the ingested amount suggested an intentional consumption. Amphibians and mammals (Vm%: 9% and 7.2% respectively) provided supplementary sources of proteins of animal origin. Mammals included rodents, lagomorphs and domestic carnivores (cats and dogs) probably killed by road traffic and eaten as carrion. The other main food categories had values below 5% in Vm%. Among these, birds were represented mainly by small Passeriformes, while insects included large-sized ground beetles, such as Carabidae (*Pterostichus* sp. and *Carabus* sp.), Lucanidae (*Sinodendron* sp.) and Scarabeidae (*Aphodius* sp.).

Seasonal variation of the main food resources was recorded for earthworm consumption with a marked decrease in summer (V%: $\chi^2 = 11.47$, d.f. = 3, P = 0.009; Tab. 2 and Fig. 2) and for fruits mainly eaten in summer (Tab. 2). Trophic niche breadth did not show great variations, being similar in winter and spring (B = 0.48 and B = 0.47, respectively), rather larger in summer (B = 0.55) and being a little narrower in autumn (B = 0.34), when earthworms represented the main item of the diet.

Badger diet recorded in the plain differed from that in the hill for some food categories, considering their frequency of occurrence (Tab. 3). Fruits and insects were significantly more consumed in the hill, while maize, amphibians and mammals were predominant in the plain. These differences were not recorded by comparing the percentage of estimated volume (V%) of each category. On the contrary, the frequency of occurrence of earthworms did not vary between the two areas, while the estimated volume was larger in the hill than in the plain (60.7% *vs.* 24.7%, U = 1594; P = 0.0001). On the whole, trophic niche breadth values were almost identical (0.44 in plain and 0.45 in hill).

DISCUSSION

According to Prigioni *et al.* (1988), earthworms and maize were the staple foods used by badgers in the study area. Earthworm consumption showed intermediate values between those of temperate and Mediterranean Europe (Goszczynski *et al.*, 2000).

Badgers capture earthworms predominantly on the surface (Kruuk and

Table 1 - Overall badger diet in the study area. For abbreviations see Methods; number of faeces samples: 199; number of items: 484.

FOOD ITEMS	N	F%	FR%	V%	Vm%
VEGETABLE MATTER	138	69.3	28.5	58.5	40.6
Plant litter (e.g. leaves, grass)	34	17.1	7.0	48.8	8.3
Fruits	39	19.6	8.1	55.7	10.9
Undetermined fruits	10	5.0	2.1	45.1	2.3
Quercus sp.	1	0.5	0.2	2.0	0.01
Corylus sp.	2	1.0	0.4	9.0	0.1
Prunus sp.	20	10.0	4.1	53.5	5.4
Malus communis	3	1.5	0.6	57.7	0.9
Vitis vinifera	6	3.0	1.2	60.0	1.8
Solanum nigra	1	0.5	0.2	100.0	0.5
Zea mais	76	38.2	15.7	55.8	21.3
MOLLUSCS	17	8.5	3.5	3.5	0.3
EARTHWORMS	164	82.4	33.9	43.3	35.7
INSECTS	67	33.7	13.8	9.1	3.1
Orthoptera	3	1.5	0.6	25.3	0.4
Coleoptera	63	31.7	13.0	8.5	2.7
Hymenoptera	2	1.0	0.4	1.0	0.01
Lepidoptera larvae	1	0.5	0.2	5.0	0.03
FISHES	1	0.5	0.2	60.0	0.3
AMPHIBIANS	41	20.6	8.5	43.9	9.0
REPTILES	1	0.5	0.2	33.0	0.2
BIRDS	11	5.5	2.3	40.6	2.2
Passeriformes	9	4.5	1.9	39.7	1.8
Rallidae	1	0.5	0.2	40.0	0.2
Anatidae	1	0.5	0.2	50.0	0.2
MAMMALS	24	12.1	5.0	59.7	7.2
Rodents	14	7.0	2.9	46.3	3.3
Undetermined rodents	3	1.5	0.6	36.3	0.5
Apodemus sp.	3	1.5	0.6	47.3	0.7
Clethrionomys glareolus	3	1.5	0.6	51.0	0.8
Muscardinus avellanarius	5	2.5	1.0	48.8	1.2
Lagomorphs	7	3.5	1.4	83.9	2.9
Carrion (domestic carnivores)	6	3.0	1.2	77.2	2.3

Parish, 1981). Humidity and temperature are the main factors affecting the seasonal activity (Satchell, 1983) and consequently the emergence of earthworms. Judd and Mason (1995) observed that several worm species move deeper in response to drier soil conditions. In our study area, badgers used worms all year round with a marked fall in summer. Therefore, drought should be a major determinant in availability of worms to badgers rather than winter low temperatures. Compared to the plain, the major consumption of worms in the hill might be explained by a difference in abundance of this resource.

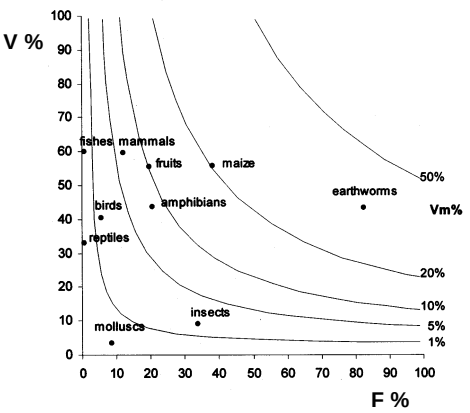

Figure 1 - Estimated volume (V%) of badger food categories, whenever eaten, *vs.* their frequency of occurrence (F%). Isopleths connect points of equal relative volume (Vm%) in the overall diet.

Soil moisture content in wooded hills should be more suitable to earthworms because of a large quantity of decomposing organic matter deriving from greater plant productivity. In the plain, agricultural practices generally depress earthworms population density and small numbers occur only where sufficient litter is present (Paoletti and Omodeo, 1981). Earthworm sampling carried out in our study area showed that earthworms were nearly absent in the widespread maize and rice fields, whilst low densities occurred in poplar plantations and riparian vegetation.

The low consumption of earthworms in summer was compensated for by an increase in the consumption of fruits, which badgers could get from small orchards and sometimes vineyards, mostly in the hilly lands.

Among vegetable matter, maize was the primary trophic resource of badgers, as has been recorded for wheat and oats in temperate Europe (Kruuk, 1989; Neal and Cheeseman, 1996). In northern Italy, maize is the most widespread cereal crop in the lowlands. Its availability to badgers is obviously highest at harvest (autumn). Nevertheless, significant seasonal variation in the diet was not found. In winter and spring evidence was found of badgers looking for cobs left on the ground or buried because of ploughing or snow.

Mammals and amphibians were secondary resources that increased the amount of animal proteins in the badger diet, mainly in cultivated habitats. Lagomorphs were probably young eastern cottontails *Sylvilagus floridanus*, an alien species very common in the study area. The common dormouse (*Muscardinus avellanarius*) was preyed before hibernation (in autumn), when it is more vulnerable to predation because of the scarce vegetation cover (Aloise *et al.*, 1990; Scaravelli and Aloise, 1995). Further animal proteins were contributed by carrion, which may represent an important food in times of shortage of key resources (Neal and Cheeseman, 1996).

Although amphibian consumption did not vary significantly throughout the year, badgers preyed extensively on frogs and probably toads mainly in winter and spring, during their hibernation and reproductive period respectively. This agreed with data recorded for other mustelids, such as the otter (*Lutra lutra*) in Mediterranean habitats (Prigioni *et al.*, 2003). The higher proportion of amphibians in the plain compared with the hill seemed to be connected to the relative availability, frogs and toads being particularly abundant in lowlands, along riversides covered

Table 2 - Seasonal variation in badger diet. Pooled data of the study period are expressed in percentage of frequency (F%); number of faeces samples in bracket; n.s. = not significant.

Food items	F% winter (83)	F% spring (79)	F% summer (19)	F% autumn (18)	χ^2	P
Fruits	8.4	22.8	52.6	22.2	20.3	0.0001
Maize	44.6	38.0	21.0	27.8	4.6	n.s.
Molluscs	8.4	11.4	5.3	0.0	2.8	n.s.
Earthworms	81.9	88.6	52.6	88.9	14.2	0.0002
Insects	27.7	45.6	31.6	11.1	10.5	n.s.
Amphibians	22.9	24.0	5.3	11.1	4.6	n.s.
Reptiles	1.2	0.0	0.0	0.0	1.4	n.s.
Birds	3.6	5.1	15.8	5.6	4.4	n.s.
Mammals	12.0	10.1	10.5	22.2	2.1	n.s.
Rodents	7.2	3.8	5.3	22.2	7.7	n.s.
Lagomorphs	3.6	3.8	5.3	0.0	0.8	n.s.
Carrion	1.2	6.3	0.0	0.0	5.0	n.s.

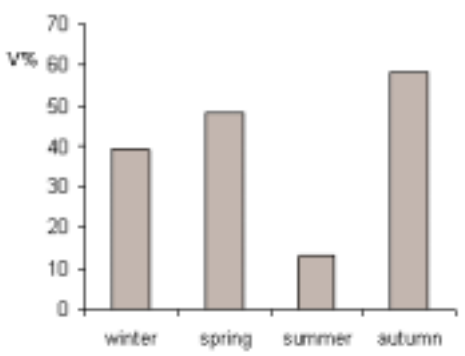

Figure 2. Seasonal variation in earthworm consumption. Data expressed as percentage of the estimated volume (V%) of the food category, whenever it was consumed.

by riparian vegetation.

Earthworm availability has been indicated to affect badger density, group and territory size (Kruuk and Parish, 1982; Kowalczyk *et al.*, 2000). Moreover, a certain number of authors have pointed out the role of sett-sites as a limiting resource of great survival value (Neal and Roper, 1991; Doncaster and Woodroffe, 1993; Roper, 1993).

Cultivated lowlands maintain low earthworm population density and offer few possibilities to badgers of suitable sites for digging setts, so that badgers can use road and railway embankments, sometimes causing serious damage (Balestrieri and Remonti, 2000). Both these factors should influence distribution and density of badgers in our study area. In this situation, their high trophic plasticity is a necessary adaptation for surviving in a habitat deeply modified by human activities.

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Table 3 - Comparison of the main food items (F%) between plain (100 samples) and hill (99 samples); n.s. = not significant.

Food items	F% plain	F% hill	χ^2	P
Fruits	4.0	35.3	31.04	<0.0001
Maize	51.0	25.2	13.97	0.0003
Molluscs	3.0	14.1	7.90	n.s.
Earthworms	79.0	85.9	1.61	n.s.
Insects	15.0	52.5	31.37	<0.0001
Amphibians	38.0	3.0	37.19	<0.0001
Reptiles	1.0	0.0	1.00	n.s.
Birds	5.0	6.1	0.11	n.s.
Mammals	20.0	4.0	11.95	0.0005
Rodents	12.0	2.0	7.57	n.s.
Lagomorphs	5.0	2.0	1.30	n.s.
Carrion	6.0	0.0	6.12	n.s.

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