Badger, *Meles meles* (Mustelidae, Carnivora), diet assessed through scat-analysis: a comparison and critique of different methods

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Abstract. We studied the diet of the badger through scat analysis and used seven previously described methods to assess their comparability. Methods compared included those based on frequencies of occurrence of different food items and volumetric methods. Our results showed that, depending on the basic methodological procedure, we could classify methods in two groups: frequencies of appearance and volumetric methods. The depiction of the diet obtained is quite similar within these groups but differs between them, as each group depicts different aspects of the trophic ecology of the badger. In conclusion, we advise the use of more than one method when assessing the diets of badgers or other carnivores. The best option is the use of a frequency-based method combined with one or two volumetric methods.

Key words: badgers, *Meles meles*, diet, scat analysis, volumetric methods, frequency-based methods

Introduction

Trophic resources dominate several aspects of animal ecology, influencing activity (Lodé 1995), reproduction (Kruuk 1989, Begon et al. 1995) and, especially in the badger, social and spatial organisation (Kruuk & Parish 1982, MacDonald 1983, Kruuk 1989, Da Silva et al. 1993, 1994, Broseth et al. 1997). Therefore, accurate and reliable dietary knowledge is of paramount importance if a good understanding of the species' ecology is to be obtained. Information about Eurasian badger diets is useful not only from an ecological standpoint but also in economic terms, as badgers often damage crops or garden fruits (Wilson 1993, Roper et al. 1995, Moore et al. 1999).

The diet of the badger has been widely studied across its range. The main food items are earthworms (Skoog 1970, Kruuk & Parish 1981, Neal 1988, Shepherdson et al. 1990, Goszczynski et al. 2000), fruits (Pigozzi 1991, Rodriguez & Delibes 1992, Biancardi et al. 1995), insects (Ciampalani & Lovari 1985, Rinetti 1987, Pigozzi 1991), small mammals (Weber & Aubry 1994, Martín et al. 1995, Fedriani et al. 1998), amphibians (Ibañez & Ibañez 1977) and other items (see reviews by Roper & Mickevicius 1995, Neal & Cheeseman 1996, Goszczynski et al. 2000). Due to the diversity of the major food items in the diet and their wide geographical variation, some authors have considered badgers to be a food generalist (Roper & Mickevicius 1995, Neal & Cheeseman 1996), whilst others claim that the predominance of certain items the diet show the species to be a specialist (Kruuk & Parish 1981, Kruuk 1989, Martín et al. 1995, Fedriani et al. 1998).

Historically, a wide range of methods has been used to assess badger diets. Results obtained via analysis of either stomach contents or faeces show differences in diet composition, and may not be comparable (Cavallini & Volpi 1995). Scat analysis has been widely used to assess badger diets; this technique is easy to apply, allows large sample sizes to be examined and is non-intrusive and so compatible with the protected status of the badger in several European countries (Griffiths & Thomas 1993, Ciucci et al. 1996). However, scat analysis may present both technical and interpretative difficulties (Reynolds & Aebischer 1991). Irrespective of the sample source, there are many possible differences in analytical procedures and the presentation of results, and these undermine comparisons amongst studies and complicates their interpretation (Reynolds & Aebischer 1991, Ciucci et al. 1996).

In the present study we review the scat analysis methods described in the western literature and follow several of these to analyse a sample of badger scats. We also compared the results obtained using different methods, discussing the advantages and disadvantages of each. The main aim of the present study is not to portray a single method as being the best, but to point out the problems inherent in each method and to assess their comparability. We also make some recommendations for future work dealing with badger diets and advise against some techniques.

Study Area

Badger scats were collected at the Urdaibai Biosphere Reserve (UBR), Basque Country (SW Europe). The UBR spreads over an entire basin with an area of 270 km^2 ranging between 0 to 900 m a.s.l. The climate is oceanic, average rainfall ranges between 1,200 and 1,600 mm, and January and July average temperatures are 6°C and 18°C, respectively. Winters are mild and there is no effective snow cover.

The landscape is hilly and rugged. 70% of the land is forested, mainly by plantations of *Pinus radiata* and *Eucalyptus globulus*. Native holm oak *Quercus ilex* forests are also common in rocky areas. Meadows and estuarine habitats occupy 25% of the area; the remaining 5% is urban and hosts nearly 45,000 inhabitants.

Materials and Methods

Literature reviewed

We consulted a total of 22 works dealing with badger diets in Europe, including international as well as local papers. We noted how many and which methods each study used. The works consulted were: Skoog (1970), Ibañez & Ibañez (1977), Kruuk & Parish (1981), Mouches (1981), Henry (1984), Ciampalini & Lovari (1985), Rinetti (1987), Neal (1988), Guitian & Bermejo (1989), Shepherdson et al. (1990), Lüps et al. (1991), Pigozzi (1991), Rodríguez & Delibes (1992), Weber & Aubry (1994), Biancardi et al. (1995), Martín et al. (1995), Roper & Lüps (1995), Bradbury (unpublished data) in Neal & Cheeseman (1996), Fedriani et al. (1998), Kauhala et al. (1998), Revilla (1998) and Goszczynski et al. (2000).

S c a t   a n a l y s i s

Badger scats were collected from typical latrines (*sensu* K r u u k 1978) throughout one annual cycle. Badger-like scats found on the ground were discarded, as were old or visibly weathered scats. Latrines were visited on a two-weekly basis from April 1999 until March 2000. Due to difficulties encountered in the separation of individual faeces found in the same latrine, the entire latrine's contents were taken as a single sample unit. The mean content of each latrine was considered to be two scats (M a r t í n et al. 1995). Scat samples were stored individually in labelled polyethylene bags at -12 °C prior to analysis.

The contents of a total of 80 latrines were collected over one year. These samples were evenly distributed over the different seasons (χ^2=2.3, df=1, p=0.19): 24 scat samples were collected in spring, 19 in summer, 15 in autumn and 22 in winter.

Prior to analysis, scats were thawed, oven dried at 50 °C for 48 hours, and then weighed. They were then soaked in water and thoroughly washed through two sieves with mesh sizes of 4 mm and 1 mm, respectively. The first litre of water and particles passing through the sieves was collected in a beaker, and the solid material allowed to settle for 30 minutes. This deposit was thoroughly screened under a 30× binocular microscope for the presence of earthworm chaetae. Food remains retained in the sieves were classified into eight categories: earthworms, fruit (including maize), vertebrates, insects, invertebrate larvae, grass, vegetable material (including leaves, roots, bark, bulbs and any other material excluding grasses and fruits) and other items (including unidentified material and items with very low overall representations such as snails, garbage, etc.). Fruit remains were identified using a local reference collection, and mammal hairs and bird feathers after D a y (1966).

Diet calculations from undigested food remains were undertaken following several methods described in literature, of which we compared the following: (1) frequency of occurrence expressed as a percentage of the total number of scats (FOC) (S k o o g 1970); (2) frequency of occurrence expressed as a percentage of the total number of occurrences of all food items (FOCI) (K a u h a l a et al. 1998); (3) estimated relative volume of ingested biomass (EVIM) (M o u c h e s 1981); (4) estimated relative volume of ingested biomass following K r u u k & P a r i s h (1981) (KRUUK); (5) estimated relative volume in faeces (EVF) (K a u h a l a et al. 1998); (6) estimated proportion of remains in scats modified by correction factors (EPRCF) (R o d r í g u e z & D e l i b e s 1992); (7) estimated ingested biomass calculated as the dry weight of remains modified by correction factors (G o s z c z y n s k i et al. 2000).

General concordance between the seven methods was assessed using Kendall's test. Comparisons between two methods were tested with Spearman's rank correlation coefficient (C i u c c i et al. 1996, Z a r 1999) which performs better here than Kendall's tau (Z a r 1999). For large n values in Kendall's test, Q was computed following the χ^2_{n-1} approximation (D i c k i n s o n & C h a k r a b o r t i 1993). Statistical significance was set at 0.05 in all cases.

Results

Three papers out of 22 consulted depicted badger diets through stomach contents analysis, 18 used scats and another analysed both scats and stomachs separately. Of these papers three analysed badger diets via three different methods, 13 used two methods and six assessed the diet through the use of a single method.

The most frequently used method (82% of studies) was frequency of occurrence expressed as a percentage of the total number of samples, whilst only one study used frequency of occurrence expressed as a percentage of the total number of occurrences of all food items. The estimated relative volume of ingested biomass was used in nine studies (41%), six of them following the methodology put forward by K r u u k & P a r i s h (1981). In six studies (27%) correction coefficients were used, five were applied to estimated dry weights and one to the measured actual dry weights.

When using a single method, frequencies of occurrence were mostly used (five out of six) – these being understood as being the percentage of scats in which appeared a specific category (FOC). The most widely used methodological pair was FOC together with a volumetric method, especially that put forward by K r u u k & P a r i s h (1991) (five studies).

The composition of diets following different methods is shown in Fig. 1. Staple foods following most methods were earthworms and fruit. However, after methods 1-FOC and 2-FOCI, the staple foods were grass and, in second position, insects followed by earthworms and fruit. In the other methods insects and grass were of low importance.

There is a general concordance in the ranking of the food items established by the different methods (Kendall test, $(\chi^2)_{7,8}$=27.893, p<0.001). When testing the methods in pairs for correlation between couples, methods based on frequencies of occurrence were strongly correlated between them but with no volumetric method (Table 1). On the other hand, volumetric methods showed correlation between them in most cases.

Discussion

Depending on basic methodological procedure we can classify the methods used to assess badger diets into two groups: frequencies of appearance and volumetric methods. Volumetric

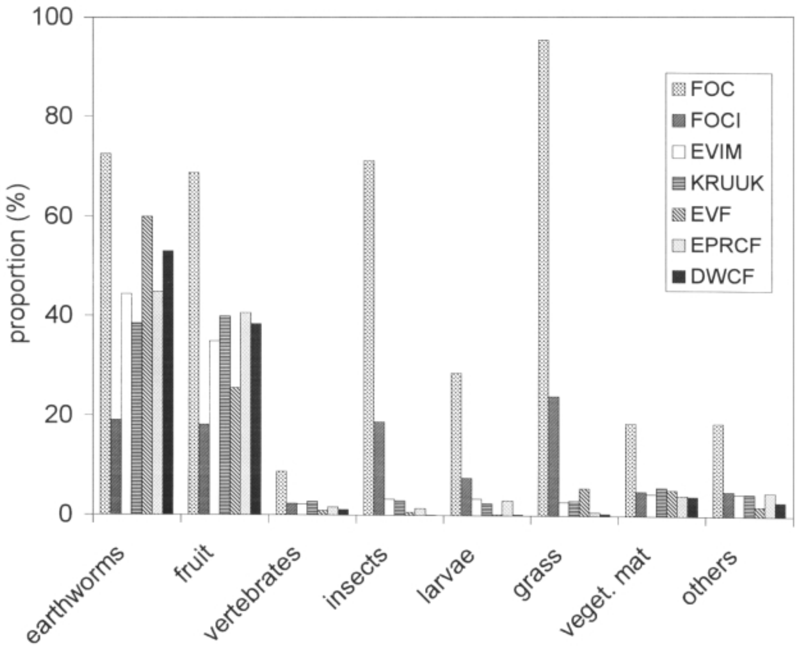

Fig. 1. Proportion (percentage) of principal components in the badger's diet assessed through seven different methods.

Table 1. Spearman's rank correlation coefficient for methods compared by pairs. To express statistical significance we used * for p<0.05, **for p<0.02 and *** for p< 0.001. Other pairs were not correlated.

Method	FOC	FOCI	EVIM	KRUUK	EVF	EPRCF
DWCF	0.030	0.030	0.827*	0.857**	0.833**	0.857**
EPRCF	0.101	0.101	0.899**	0.714	0.548	
EVF	0.446	0.446	0.708	0.881**		
KRUUK	0.256	0.256	0.827*			
EVIM	0.238	0.238				
FOCI	1.000***					

methods express the importance of each food category in the overall diet, whilst frequency of appearance based methods provide information about how often a given item is eaten.

Even where there is a correlation between both methods based on frequencies, we should bear in mind that Spearman's rank correlation coefficient tests the ranking of the different food categories, but pays no attention to the differences existing among them. Therefore, even though it reaches statistical significance in some cases there may be biological differences. Frequencies of occurrence expressed as percentages of the total number of scats are higher than frequencies of occurrence expressed as percentages of the total number of occurrences of all food items. Moreover, while the meaning of frequencies of occurrence calculated as a percentage of the total number of scats expresses a clear concept, it is hard to understand what the biological significance is when expressed as a percentage of the total number of occurrences of all food items. This could be interpreted as an approximation of the volumetric importance of items in the diet, but it tends to overestimate items eaten frequently but in small quantities (e.g. insects) (Ciucci et al. 1996, Kauhala et al. 1998). Besides, the fact that this is correlated with no volumetric method suggests that it does not provide a good approximation. On the other hand, for species such as the wolf and the fox, it has been suggested that use of only items representing at least 2–3% of the sample gives a more accurate estimate (the pyloric sphincter does not allow large guard hairs to pass through except in small quantities). Therefore, although items may appear in several scats, they may have only been eaten once (Reynolds & Aebischer 1991, Ciucci et al. 1996). Nothing similar has been proposed so far for badgers as they seldom feed on large mammals, however, this could have some importance in areas where badgers feed on large mammal carrion.

Regarding volumetric methods, the less correlated were method 5 (estimated relative volume in faeces) and 6 (estimated proportion of remains of each prey modified by correction factors). These were each only correlated with two other methods. As not all kinds of food are digested equally, the proportion of remains changes with the type of item (Reynolds & Aebischer 1991). Therefore, the estimation of the relative volume in faeces may not be advisable as an accurate method. On the other hand, the estimated proportion of remains of each prey modified by correction factors has three problems. The first is that the estimate itself is quite subjective, however, error may be reduced with the aid of a grid, or by evaluation by several persons (Martín et al. 1995). The second problem is the assumption that all residues have the same density, i.e. that the volume in faeces is representative of the contribution of each residue type to the total weight of the scat. The bias created by this assumption is difficult to estimate and probably changes in each scat, and thus is usually accepted as an assumed error. The third problem is the calculation of the conversion factors. So far only Revilla (1998) and Goszczynzski et al. (2000) have calculated them expressly for the badger, while other studies used diverse conversion factors, such as those proposed by Lockie (1961) for the pine marten (*Martes martes*). This is undoubtedly a source of error as the badger's gut is relatively longer than that of other mustelids, a probable adaptation to a wider dietary array (Ewer 1998).

A further problem involved in all volumetric methods is the estimation of earthworm intake (Reynolds & Aebischer 1991); there are two ways of overcoming this. The first of these is based on the assumption that the dry weight of microscopic remains (mainly earth) is correlated with earthworm intake (Mouches 1981). Analysing the composition of the microscopic fraction under a binocular microscope, we found that it usually was not composed exclusively of earth, but also included small pieces of grass, insects, wood and flesh. In some cases there was a considerable microscopic fraction but no earthworm chaetae at all. Besides, earth may also be swallowed inadvertently while eating other items, e.g. invertebrate larvae. Reynolds & Aebischer's (1991) study of fox diets found that the number of chaetae accounted for only 40% of the variation in the volume of microscopic fragments and so this method tends to overestimate the importance of earthworms. The second way to overcome the problem consists of the analysis of a subsample and assumes that the number of earthworm chaetae found is representative of the intake (Kruuk & Parish 1981). As most information about earthworms is lacking for the Basque Country we could not test the precision of this method. But, as pointed out by Reynolds & Aebischer (1991) earthworm weights change along their range, and therefore the equation needs to be refined in each study area, even though most authors still use that of Kruuk & Parish (1981).

Both methods of estimating relative volume of ingested biomass (methods 3 and 4) were correlated with another three volumetric methods. Indeed, they only differed in the way of calculating earthworm intake: using the whole volume of the microscopic fraction or of analysing a subsample (cf. Kruuk & Parish 1981). On this point, our previous comments should be borne in mind. Another problem, common to both methods, is that the estimation of ingested biomass through the remains is quite subjective, and may be misleading when there are considerable amounts of several components in the same scat. But when scats are composed of a main food item and others appear in negligible quantities this problem loses importance.

Finally, the method consisting of measuring the dry weight of remains modified by correction factors has problems such as those already discussed due to the origin of the conversion factors or the calculation of earthworm intake. Another disadvantage is that this method is very time-consuming, while other methods allow a high number of scats to be processed in a short period. On the other hand, it is the only method that showed correlation with all other volumetric methods.

The best illustration of the trophic habits of the species is yielded by a combination of both a frequency-based and a volumetric method. As volumetric methods show what the relative importance of an item is in the diet and frequency-based methods show how often it is eaten, combining both gives a general idea of the trophic habits of the species. Thus, an item with a high frequency of appearance together with a poor volumetric importance (e.g. insects in this study) indicates that it is eaten very often but in small quantities. In contrast, items for which both values are high (e.g. earthworms and fruit in our study) were eaten frequently and in large amounts which indicates their overall importance. Items with low frequencies of appearance and low volumetric values are eaten rarely and then only in small quantities, e.g. invertebrate larvae at the UBR. Finally, there exists the possibility of low frequencies of appearance and high volumetric values, which would indicate that a given item is rarely eaten but that then it is eaten in large amounts. Therefore, combining different methods gives a more accurate representation of the diet, whilst using a single one may enlarge or reduce the relative importance of some items. This is more important when dealing with the animal's ethology or its trophic plasticity, as using a single method may lead to incorrect conclusions.

Finally, we advise the use of more than one method when assessing badger's diet. The best choice would be to use frequency of occurrence expressed as a percentage of the total number of scats, combined with one or two volumetric methods (e.g. estimated relative volume of ingested biomass following the procedure put forward by Kruuk & Parish (1981) or measured dry weight of remains modified by correction factors). The first method is easy, requires little time and has been widely used, while the other is more time consuming but is more accurate. A combination of such methods not only gives a better representation of badger diets, but has also been widely used and therefore allows more precise comparisons to be made between studies. We also advise against using the following methods: frequency of occurrence expressed as percentage of the total number of occurrences of all food items and estimated relative volume in faeces; this is because their results are difficult to interpret.

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