The spring diet of badgers in two contrasting habitats in the Netherlands

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Abstract: In Northern Europe the badger (*Meles meles*) uses earthworms as a primary food source and is sometimes described as an earthworm specialist. In the Mediterranean, badgers tend to be generalists, and insects and fruits make a larger contribution to their diet. In this study we test the hypothesis that the proportion of earthworms in badger's diets is enhanced by a higher availability of earthworms. We do so by comparing the composition of the spring diet of badgers in two habitats with differing earthworm availability (biomass earthworms; 74.9 kg ha^{-1} vs. 7.3 kg ha^{-1}). The dietary composition was determined by fecal analysis. Between March and May 2007 fresh fecal samples were collected on a weekly basis from an earthworm-rich (*Veluwezoom* National Park; *n*=85) and earthworm-poor habitat (*Hoge Veluwe* National Park; *n*=79) in the Netherlands. The main food classes observed were earthworms, fruit, insects, larvae, amphibians and other vertebrates. Samples collected from Veluwezoom showed a relatively higher volume of earthworms than those from Hoge Veluwe (46.4% against 36.0%). However our results show that the badgers in the earthworm-rich habitat eat only 30% more earthworms, despite earthworms being ten times more available in this habitat. Earthworms are the primary food for badgers in both habitats and are supplemented with seasonal (beetles, larvae) and local (rabbits) resources, depending on their availability. The trophic niche of the Hoge Veluwe provided a more varied diet (B_A = 0.79) than that at Veluwezoom (B_A = 0.41) and badgers feeding from the earthworm-rich habitat, Veluwezoom, (C_H = 0.80±0.19) had less varied diet than those feeding from the Hoge Veluwe, an earthworm-poor habitat (C_H = 0.55±0.31). Although badgers are more generalist feeders than specialists, they do seem to prefer earthworms to other food.

Keywords: badger, diet, *Meles meles*, earthworms, biogeography.

Introduction

The badger (*Meles meles*) shows a trend of specialising on different prey in different areas throughout its range (Martin et al. 1995). In northern Europe, earthworms (Lumbricidae) are the main food source (Skoog 1970, Kruuk & Parish 1981, Madsen et al. 2002), covering between 50% and 80% of the total diet (Kruuk 1989, Goszczyński et al. 2000). In southern Europe a few studies have found similar results, particularly in wet areas (Balestrieri et al. 2004, Virgós et al. 2004). In southern Spain, however, badgers have been reported to specialise in rabbits (Martin et al. 1995) and, in Hungary, on amphibians (Lanszki 2004). Close to the southern edge of their European distribution, where earthworms are less available, badgers tend to feed more on insects and fruit and earthworms make a smaller contribution, occasionally up to 20% of the total diet (calculated from Kruuk & De Kock 1981, Boesi & Biancardi 2002, Marassi & Biancardi 2002). The badgers in the drier southern regions have

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been described as generalist feeders (Del Bove & Isotti 2001) with an opportunistic feeding strategy (Marassi & Biancardi 2002). Feng et al. (2013) studied badger diets in relation to a range of geographical and environmental factors. They found a clear latitudinal gradient in the dietary composition, with a higher intake of earthworms in northern regions and a greater consumption of insects and reptiles in the south. They concluded that the badger is not an earthworm specialist as such but that foraging tactics are mainly driven by food abundance.

In this study we compare badger diets in two contrasting habitats at the same latitude and with the same precipitation regime. The composition of the habitats differs, as does earthworm availability. We expected that the diet of badgers in the earthworm-rich habitat would contain more earthworms than in the earthworm-poor habitat. As dietary niche-breath generally increases with decreasing resource availability (Pianka 1994, Feng et al. 2013), we also expect that badgers in the earthworm-rich habitat will have a narrower food niche-breadth than those the earthworm-poor habitat.

Methods

The earthworm-rich habitat within *Veluwezoom* National Park (52°00'N 06°01'E) consists mainly of deciduous forest intermingled with agricultural fields and pastures (table 1). Four large badger setts were located, on average two kilometres apart. The earthworm-poor habitat within the *Hoge Veluwe* National Park ' (52°06'N 05°52'E) consists of heathland, mixed forest, deciduous forest and (open) pine forest (table 1). Some small patches of old pasture are scattered throughout the area. Five setts were located, on average 1 to 1.5 km apart. The study areas were 12 kilometers apart (at the closest point) and were linked through natural and artificial wildlife corridors (wildlife overpasses, wildlife tunnels).

In August 2007 the availability of earthworms in both study areas was measured. In both study areas, four habitat types were selected (grassland, arable land, forest and open field/heathland). Ten random soil samples (20x20 cm samples taken to a depth of 15 cm) were taken from each habitat type and the earthworms were hand sorted from these samples. The average wet weight of earthworms from each habitat was calculated from the wet weight of 40 individuals. A home range of approximately 300 ha (based on results from Elmeros et al. 2005 and Brøseth et al. 1997) was then created as polygon around each sett. The habitat cover for both study areas was estimated by superimposing a grid of known sizes onto a topographical map (1:25,000) of the area. The total area of each habitat type was multiplied by the average earthworm biomass (kg ha $^{-1}$) for each habitat type, which enabled us to calculate the earthworm biomass, across different habitat types, within each study area.

From March until May 2007, fresh badger faeces were collected on a weekly basis from latrines or single dung pits near setts or along trails located close to each sett. Each sample was stored in a polythene zip lock bag and kept frozen prior to analysis. In the laboratory the samples were defrosted overnight in a refrigerator and afterwards sterilised for 48 hours in a glass jar with FAA (10 parts-40% formalin, 85 parts-70% alcohol, 5 parts-glacial acetic acid) (Anthony & Smith 1974).

The analyses were performed following the procedures established by Kruuk & Parish (1981). We assumed that earthworm density in August was indicative for that in spring, at least in a relative sense. The sterilised samples were broken up and washed through a 1.3 mm mesh sieve. Water and particles passing through the sieve during the rinsing were collected in a 500 ml beaker. The solid material was allowed to settle for 15 minutes after which two samples were taken from the bottom of the beaker. These subsamples were washed separately in a Petri dish, stained with

Table 1. Estimated earthworm availability within 300 ha sites in the Veluwezoom and Hoge Veluwe National Parks based on samples taken in August 2007. Results from ten randomly selected, hand sorted 20x20x15cm soil samples for each habitat type. Habitat cover estimated from 1:25,000 topographical maps (Topografische Dienst 1997).

Veluwezoom				Hoge Veluwe			
Habitat type	Habitat cover ha	Earthworm kg/ha	Total earthworm kg	Habitat type	Habitat cover ha	Earth-worm kg/ha	Total earthworm kg
Grassland	139	631.1	87722	Grassland	30	136	4080
Deciduous forest	1153	12.4	9920	Deciduous forest	595	12.4	7378
Arable land	85	241.3	20510	Arable land	0	-	-
Other	200	0	0	Other	944	0	0
Total	1577		118152	Total	1569		11458
Mean earthworm biomass 74.9 kg ha^{-1}				Mean earthworm biomass 7.3 kg ha^{-1}			

picric acid and examined under a 40x binocular microscope for the presence of earthworm chaetae. The chaetae in ten 1 cm^2 areas within each dish were counted and the mean was calculated. These samples were scored as 0, or 1 (1-5 chaetae per field), 2 (6-10), 3 (11-20), 4 (21-30), 5 (31-40) or 6 (over 40 chaetae) per cm^2. The total number of earthworms was estimated from the regression $Y=9.1X - 1.3$, where Y = number of gizzard rings and X = chaetae score (Kruuk & Parish 1981). The macro-fragments were rinsed and examined under water in a large shallow white dish Six food categories were distinguished: insects, larvae, rabbits and birds, amphibians and fruit. The fruit category included all vegetable material (e.g. acorns, beech nuts, berries, roots). Grass and leaves were excluded from the analyses because it was assumed that these are incidentally ingested while feeding on earthworms or other food items, as opposed to being a food item in themselves (Wiertz 1976). Vertebrates also included carrion. A frequency-based, and a volumetric method, were used to analyse the composition of the badgers' diets (Zabala & Zuberogoitia 2003). For each scat, the total number of each type of prey was counted or extrapolated from the remains (Kruuk 1989). The composition of the diet was expressed as a percentage frequency of occurrence (FO) in the faeces and the estimated percentage volume of ingested biomass (EV) was calculated following the procedure proposed by Kruuk & Parish (1981). The relative volume (VT) was then calculated for six 2-week periods by the formula (FO x EV)/100.

All data were checked for normal distribution and equal variances. A General Linear Model (GLM) was used to test for differences in dietary composition between the two study areas. The study area and the month were taken as fixed factors and the relative volume of the different food items in the total diet as the dependent variable. The diet composition of the two study areas was compared by calculating the standardised Levins' index of food niche breadth (Range= 0 to 1):

$$B_A = \frac{B-1}{n-1}$$ according to Hurlbert (1978),

$$B = \frac{1}{\sum P_j^2}$$ (Levins 1968) where Pj= the proportion of each food item. The composition of the two groups of badgers' diets was determined and the level of diversity between the two was compared. This was calculated for all combinations of the results of the relative volume for the six 2-week periods using the simplified Morisita index of similarity (C_H) (Horn 1966);

$$C_H = \frac{2\sum X_{ij}X_{ik}}{\left[\left(\sum X_{ij}^2/N_j^2\right)+\left(\sum X_{ik}^2/N_k^2\right)\right]N_jN_k}$$

where X_{ij},X_{ik} = number of individuals of species *i* in sample *j* and sample *k*, $N_j = \Sigma X_{ij}$ = total number of individuals in sample *j* and $N_k = \Sigma X_{ik}$ = total number of individuals in sample *k*. A Mann-Whitney test was performed to test for differences in diet similarity between the study areas. All statistical analyses were carried out using SPSS version 14.0.

Results

The two study areas differed greatly in terms of habitat composition and earthworm availability (see table 1). The earthworm-rich habitat had 10 times as many earthworms as the earthworm-poor habitat. A total of 159 faecal samples was analysed (Veluwezoom: *n*=85, Hoge Veluwe: *n*=74).

The samples from Veluwezoom showed a high frequency of occurrence (FO) of earthworms and vegetable material (94.1 and 83.5%) as did those from Hoge Veluwe (86.5 and 89.2% respectively; figure 1) where insect imagos were also eaten frequently (90.5%). In both areas the FO of the other dietary components was lower (ranging from 68.9 to 28.2%). Earthworms and vegetable material made up the bulk of the diet in both areas. The relative volume (VT) of earthworms in the diet at Veluwezoom (46.4%) was higher than at Hoge Veluwe (36.0%; GLM,

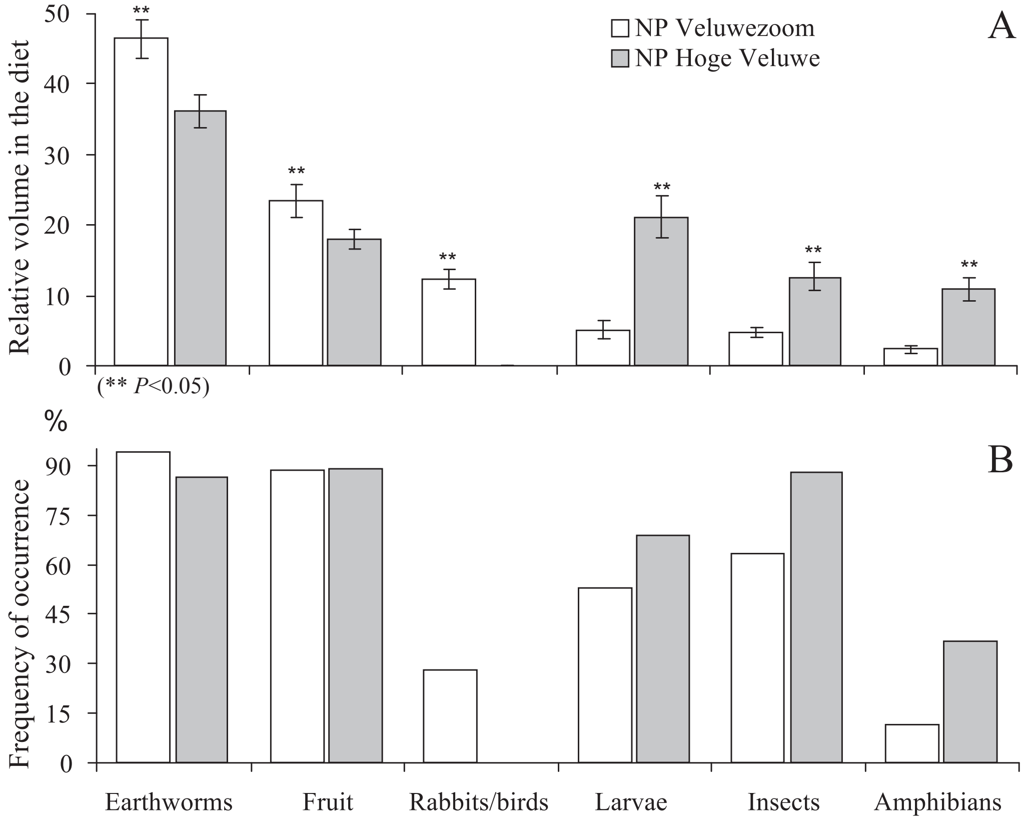

Figure 1. Difference in relative volume in the spring diet (A) and percent frequency of occurrence (B) of the six major food items in the spring diet (March-May) of badgers in the Veluwezoom (earthworm-rich) and Hoge Veluwe (earthworm-poor) National Parks.

Table 2. Food niche breadth and similarity index for the Veluwezoom and Hoge Veluwe National Parks calculated from relative volume of six major food items. Standardised index of food niche breadth, B_A (Hurlbert 1978), which varies from 0 (narrowest niche, specialist) to 1 (broadest niche, generalist). Simplified Morisita index of similarity, C_H, (Horn 1966), ranging from 0 (no similarity) to 1 (complete similarity).

Study area	No. of samples	B_A	C_H
		Levins' index (standardised)	Simpl. Morisita Index (mean ± SD)
Veluwezoom	85	0.41	0.80 ± 0.19
Hoge Veluwe	79	0.79	0.55 ± 0.31

F =15.964, *n*=12, *P*=0.016). Veluwezoom also showed both a higher VT of vegetable material (23.4%) and a higher mammal and bird content (12.3%) than Hoge Veluwe, which contained 18.0% vegetable material (GLM, *F*=32.119, *n*=12, *P*=0.005) and 0.0% mammal and bird content (GLM, *F* = 9.480, *n*=12, *P*=0.037). The VT of insect imagos in the diet at Veluwezoom (4.7%) was lower than at Hoge Veluwe (12.6%; GLM, *F*=220.979, *n*=12, *P*<0.001). Veluwezoom also showed a lower VT of both insect larvae (5.1%) and amphibians (2.3%) than Hoge Veluwe where the proportions where 21.1% (GLM, *F*=13.504, *n*=12, *P*=0.021) and 10.8% (GLM, *F* = 9.490, *n*=12, *P*=0.037) respectively.

The food niche-breadth, based on relative volume, of the diet at Hoge Veluwe was higher and had a more generalist character than that of Veluwezoom (table 2). Results from the simplified Morisita index of similarity showed that the spring diet of badgers feeding in the earthworm-rich habitat of Veluwezoom was more homogenous that of the badgers feeding from the earthworm-poor habitat (Mann-Whitney U-test, *U*=61.000, *n*=30, *P*=0.032) (see table 2).

Discussion

The bulk of the diet at Veluwezoom consisted of earthworms and fruit, which comprised over 73% of the diet with vertebrates playing a secondary role: Similar results have been found in diets analyzed in Scotland (Kruuk & Parish 1981). These three items made up a higher contribution to the spring diet of badgers in Veluwezoom than those in Hoge Veluwe. In a survey of badgers' feeding baits in the Dutch province of Limburg (done between January-April and April-July) Wiertz (1976) found that earthworms were the main food source (78-74%) and vertebrates a secondary item (12-14%). A similar study conducted in the province of Utrecht found the spring diet to consist of earthworms (59.1%), maize (16.1%), larvae (8.7%), fruit (7.8%), amphibians (4.4%), mammals (3.9%), birds (1.3%) and beetles (0.6%) (calculated from Wansink et al. 1996). The Hoge Veluwe diet contained more larvae, insects and amphibians than that in Veluwezoom. Similar results were found in an area of poor badger habitat in Essex (Skinner & Skinner 1988), with earthworm volumes of 33.2%, beetle volumes of 19.4% and larvae volumes of 13.3%. The contribution of amphibians, in this case frogs (*Rana* sp.), within the diets from both locations followed a similar pattern, with frogs contributing more to the diets in March than in April and May. Wiertz (1976) also found a higher volumes of frogs in badger diets during the first three months of the year. Our results for March showed the relative volume of amphibians was four times higher in Hoge Veluwe than in Veluwezoom. The Hoge Veluwe area contains several waterholes which are potential sources of frogs. While badgers are not specialised hunters (Neal & Cheeseman 1996) young individual rabbits (*Oryctolagus cuniculus*) are occasionally dug out from their burrows (Kruuk 1989). At Veluwezoom rabbits were abundant near the badger setts (personal observation) and older animals were taken as carrion, as evidenced by the presence of maggots in the faecal samples (Wiertz 1976) containing rabbit remains. Myxomatosis was reported in April at Veluwezoom which resulted in an increase in sick and dead rabbits and could explain the role of dead rabbits within the diet (Dirkmaat 1988). Infected animals do not attempt to run away when approached and therefore become an easy prey item (personal observation).

The earthworm-rich Veluwezoom contained 10 times more earthworms than the earthworm-poor area Hoge Veluwe. However, the diet of badgers in the earthworm-rich habitat contained only 1.3 times more earthworms (Veluwezoom 46.4%, Hoge Veluwe 36.0%). The relatively high overall contribution of earthworms in the diet at Hoge Veluwe (compared to their availability) could be the result badgers increasing their foraging efforts (i.e. increases in feeding distances and time spend outside the sett). Hence, earthworms are without any doubt an important food item. Kruuk & Parish (1982) found that badger numbers increase when there is more available earthworm biomass.

Badgers mainly feed on the larger earthworms, *Lumbricus terrestris* (>8 cm) and *L. rubellus* (Kruuk 1989) but, in the Netherlands, the species *Aporrectodea caliginosa*, *Allolobophora chlorotica* and *Aporrectodea longa* are the most commonly occurring grassland species (Eekeren et al. 2003). Because of the scarcity of large earthworms in both study areas, our calculations of earthworm availability were based on earthworms >4 cm. The presence of smaller earthworms could contribute to them making up a higher proportion of badger's diets.

Levins' standardised index of food niche-breadth was higher in the earthworm-poor area (B_A = 0.79) than in the earthworm-rich area (B_A = 0.41). This followed our expectations that badgers in earthworm-poor habitats would compensate for the low abundance and accessibility to earthworms by using a wider range of food resources. Similar (year-round) indices have been found in the Italian Apennines in open habitat (B_A= 0.59) and wooded habitat (B_A = 0.33) (Asprea & de Marinis 2005) and in a north-western Italian agricultural riverine habitat (B_A = 0.47) (Balestrieri et al. 2004). A spring diet in the Italian pre-Alps showed B_A= 0.535 (Marassi & Biancardi 2002). In the diet from the earthworm-poor Hoge Veluwe larvae (mainly cranefly, Tipulidae spp.; Cockchaffer, *Melolontha* sp.), and insects (mainly dor beetles, *Geotrupes* sp.) made up a larger share of the diet than in Veluwezoom. During May, there was a noticeable higher presence of dung beetles observed in the field than in other months (personal observation). Larvae of the crane fly, fully grown just before pupation in late spring or early May, will feed above ground when the weather is warm and damp (Coyler & Hammond 1968) and tend to remain in batches of thirty individuals that can occur in densities of ten batches per square metre (Macfayden 1963). Kruuk & Parish (1981) mention an increase in the relative volume of insects in badgers' diets towards August. According to foraging theory we hypothesise that badgers in the earthworm-poor habitat utilised a wider array of other (sometimes less-favoured) food resources. We expected more variation in the diet in the earthworm-poor habitat (Hoge Veluwe), as a result of badgers' compensating for the low availability of earthworms. This was supported by the results of the simplified Morisita index of similarity, which showed more variation in the Hoge Veluwe diet. We did not expect that badgers would compensate for the lower availability of earthworms by preying on only one or two other food items which led to the diet in the earthworm-poor habitat being more similar to the earthworm–rich diet than we expected.

This study shows that the badger has a quite generalist feeding strategy, usually built around food availability. However, the less-than-expected difference in earthworms within the diets from the two contrasting habitats demonstrates that badgers do prefer earthworms. When earthworms become scarce badgers increase their effort to obtain this important food source. This finding has relevance for the conservation of badgers. If earthworm availability declines, this can lead to longer feeding distances which in turn can lead to an increase of the main cause of death among badgers' in the Netherlands: road accidents.

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Samenvatting

Het voorjaarsdieet van dassen in twee contrasterende habitats

In Noord-Europa zijn regenwormen het belangrijkste voedsel voor dassen (*Meles meles*) en soms worden ze beschouwd als echte regenwormspecialisten. In het Middellandse Zeegebied daarentegen zijn dassen meer generalisten met een groter aandeel insecten en vruchten in het dieet. In deze studie testen we de hypothese dat een lokaal hoger regenwormenaanbod een groter aandeel van regenwormen in het dieet mogelijk maakt door middel van het vergelijken van dieten in een regenwormarm en in een regenwormrijk habitat (biomassa van regenwormen respectievelijk 7,3 kg ha^{-1} en 74,9 kg ha^{-1}). De dieetsamenstelling werd bepaald via faecesanalyse. Van maart tot mei 2007 werden wekelijks verse mestmonsters in het Nationaal Park Veluwezoom (regenwormrijk, n=85) en het Nationaal Park De Hoge Veluwe (n=79). De belangrijkste voedselklassen waren regenwormen, vruchten, insecten, zooogdieren, vogels en amfibieën. Het gemiddelde dieet van de Veluwezoom bevatte een groter aandeel regenwormen (46,4% tegen 36,0%). De resultaten van deze studie laten eveneens zien dat het dieet in het regenwormrijke habitat slechts 1,3 maal zoveel regenwormen bevatte dan het regenwormarme habitat, ondanks een tien keer zo groot aanbod. Dassen in beide habitats gebruiken regenwormen als hoofdvoedsel en ze vullen, afhankelijk van beschikbaarheid, hun dieet aan met voedselbronnen die seizoensgebonden (kevers, larven) of lokaal (konijnen) beschikbaar zijn. De trofische niche-breedte was groter voor het regenwormarme Hoge Veluwedieet (B_A = 0.79) dan die voor het regenwormrijke dieet van de Veluwezoom (B_A = 0.41) terwijl de regenwormrijke Veluwezoom een hogere similariteit in de dieetsamenstelling had dan de regenwormarme Hoge Veluwe (C_H = 0.80±0.19 versus C_H = 0.55±0.31). Hoewel dassen eerder generalisten lijken te zijn dan specialisten, hebben ze toch een duidelijke voorkeur voor regenwormen boven andere prooitypen.

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