# Shifts in food availability and associated shifts in space use and diet in stone marten

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**Abstract:** Spacing patterns of mammals are commonly assumed to be influenced by changes in food availability, resulting in shifts in diet. However, there is a lack of detailed case studies proving this relationship. We present here such a study carried out on two stone martens (*Martes foina*). We collected data on individual space use by radio telemetry, measured the diet by faecal analysis, and assessed changes in food availability of some main food items. Overall, changes in space use were paralleled by changes in diet, and might have been the result of changes in local food availability. In one case the animal stopped being active in a part of its home range when the high local availability of fruit (cherries) decreased in late summer. This decrease in cherries within its diet was mostly compensated for by increased ingestion of other kinds of fruit and of small mammals. In another case, the animal temporarily ventured into an area outside of its usual range of activity during winter when the availability of its seasonal staple food, earthworms, was low. In the new area, it fed on the available fruits and small mammals.

*Keywords*: stone marten, *Martes foina*, feeding ecology, earthworms, home range, radio telemetry.

## Introduction

Spacing patterns of mammals are reported to be influenced by different factors such as sex, age, season, social interactions, anti-predator behaviour and resource dispersion (e.g. Powell 1994, Kats & Dill 1998, Zielinski et al. 2004). In particular food resources, or rather energy requirements related to food availability, often seem to be an important factor affecting home range size and habitat use (badger (*Meles meles*): Kruuk & Parish 1982, Johnson et al. 2001, Revilla & Palomares 2002; black bear (*Ursus americanus*): Powell et al. 1997; fisher (*Martes pennanti*): Zielinski et al. 2004; review on pine marten (*Martes martes*): Zalewski & Jedrzejewski 2006). Nevertheless, detailed information on the processes underlying the distribution and individual spacing behaviour of mammals within landscapes are rare. Individual case studies can make an important contribution to our knowledge on the proximate mechanisms which underlie the relationship between space use and food availability (e.g. Benhamou 1996). The stone marten (*Martes foina*) is a small carnivore which shows much flexibility in its diet. While this has been comprehensively studied (e.g. Waechter 1975, Delibes 1978, Skirnisson 1986, Ansorge 1989, Marchesi et al. 1989, Serafini & Lovari 1993, Lodé 1994, Bertolino & Dore 1995, Martinoli & Preatoni 1995, Genovesi et al. 1996, Rödel et al. 1998, Padial et al. 2002, Lanszki 2003) little is known about the interactions between space use, food availability and diet. Here, we present a study of two individual stone martens, where we describe such relationships.

## Material and methods

The study was conducted in the Hakel Forest, a wooded area in central Germany situated between Magdeburg and Quedlinburg, and the surrounding agricultural region over a period of ten months (June 1996–March 1997). For details on the study area see Stubbe (1971). We set wooden

live-traps, baited with chicken eggs, in the forest and in a small wood situated within an agricultural area. Two stone martens were trapped and fitted with radio-collars (38 g, Wagener Telemetrieanlagen, Köln, Germany). Animal 1, an adult female, was trapped in the small wood in mid June 1996 and tracked until late November 1996. Animal 2, an adult male, was trapped in the forest in early September 1996 and tracked until late March 1997. The home ranges of the two animals were located in different parts of the study area and were several kilometres apart. The age class of both animals was assessed by their body mass (animal 1, female: 1300 g, animal 2, male: 1800 g; cf. Stubbe 1993). On most days the animals' day-time resting sites were located, and fresh faeces was collected from around these sites. It is assumed that these faeces stemmed from the tracked individuals. Due to our regular sampling pattern, we could assure that the faeces collected were at most ten days old. Faeces of unknown age, which we sometimes found when we located a daytime-resting site for the first time, were discarded. We located the animals once or twice a night while they were active (i.e. outside their day resting sites), resulting in $n_{fixes}$=65 for animal 1 and $n_{fixes}$=76 for animal 2. Exact positions were determined by triangulation, and we tried not to approach closer than 100 m (estimated by the intensity of the radio signal) to the animals, to avoid disturbances. Home range contours were determined using the minimum convex polygon method (Mohr 1947) that includes 100% of the tracking data points. The diet of the two focal animals was assessed by faecal analysis. In total, we collected 123 faecal samples from animal 1, and 86 from animal 2. After collection, we stored the faeces separately in plastic bags and froze them. In the laboratory, the faeces were washed with water over a fine-mesh screen. Undigested fruit remains were identified by the use of a reference collection. Remains of mammals were identified by hair analysis as described by Day (1966) and Teerink (1991). The presence of earthworm remains (Lumbricidae) was determined by the occurrence of earthworm bristles (chaetae; in most cases together with large amounts of turf substrate). All samples were soaked in water before washing and the solution was examined under a low power dissecting microscope in order to identify the earthworm bristles by their specific shape and light reflection. The composition of the diet was expressed by the frequency of occurrence, calculated as the number of faeces with presence of the particular food item per total number of faeces collected. Information on the general pattern of the seasonal changes in the availability of small mammals was derived from published data on small mammal population dynamics in the study area (Stubbe & Stubbe 1991). Every two weeks, we mapped the availability of fruits within the home ranges of our focal animals. To estimate the availability of earthworms, we calculated the percentage of 'worm nights' per month as described by Kruuk & Parish (1981). During a 'worm night' the temperature should not fall below 0 °C and there had to have been at least 2 mm rain during the previous 72 hours. Weather data were provided by a nearby meteorological station (Heteborn). The availability of other invertebrates and of birds was not assessed.

## Results

For animal 1 (female), a decrease in the availability of its temporary main food item, cherries (*Prunus avium*), was paralleled by a decrease in the activity range. From June to August 1996, the estimated home range size of this animal was around 15 ha. It comprised the small wood, the adjacent cherry grove, and the hedge row connecting these locations (see figure 1A). Our tracking data revealed that the animal mainly used the hedge row for passing between both forested areas. The animal used day-time resting sites in the small wood as well as in the cherry grove. During this period, when ripe cherries were freely available in the cherry grove, these fruits were the animal's most frequently eaten food item (occurring in 84% of the faeces, see figure 2A). Moreover, most of the faeces that

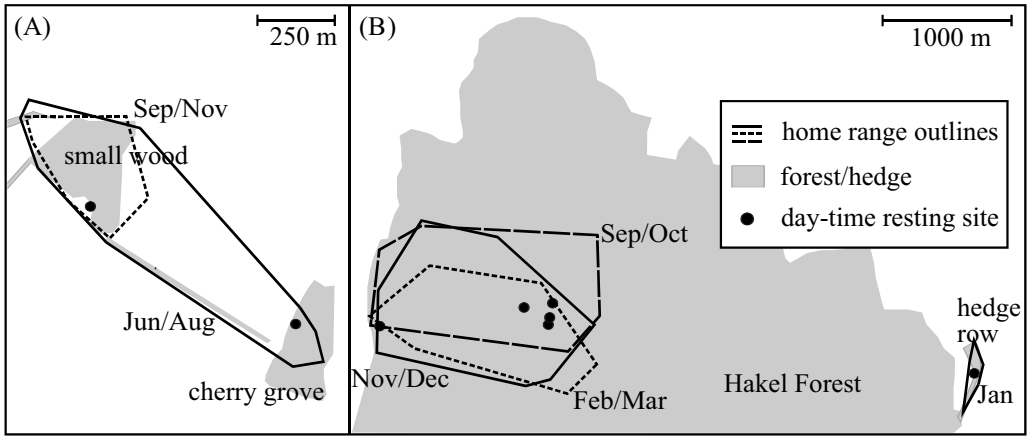


Figure 1. Home range estimates, calculated as minimum convex polygons (100% of fixes). Home range areas of (A) animal 1 (female) during June-August ($n_{fixes}$ = 40) and September-November ($n_{fixes}$ = 25), and (B) of animal 2 (male) during September-October ($n_{fixes}$ = 22), November-December ($n_{fixes}$ = 22), January ($n_{fixes}$ = 13), and February-March ($n_{fixes}$ = 19). Note that we only included fixes when the animals were outside their day resting sites.

contained cherry remains consisted almost completely of indigestible parts of this fruit, suggesting that cherry was indeed the animal's staple food during this period of time. According to our tracking data, animal 1 restricted its activity solely to the area of the small wood from September 1996 until the end of the study period (circa 5 ha, figure 1A), when there were no more cherries available. Consequently, the frequency of these fruits in the animal's diet decreased, whilst fruits of the plum (*Prunus domestica*), blackthorn (*Prunus spinosa*), hawthorn (*Crataegus monogyna/laevigata*), crab apple (*Malus sylvestris*), mountain ash (*Sorbus aucuparia*), wild rose (*Rosa canina*) and common privet (*Ligustrum vulgare*) were increasingly in-

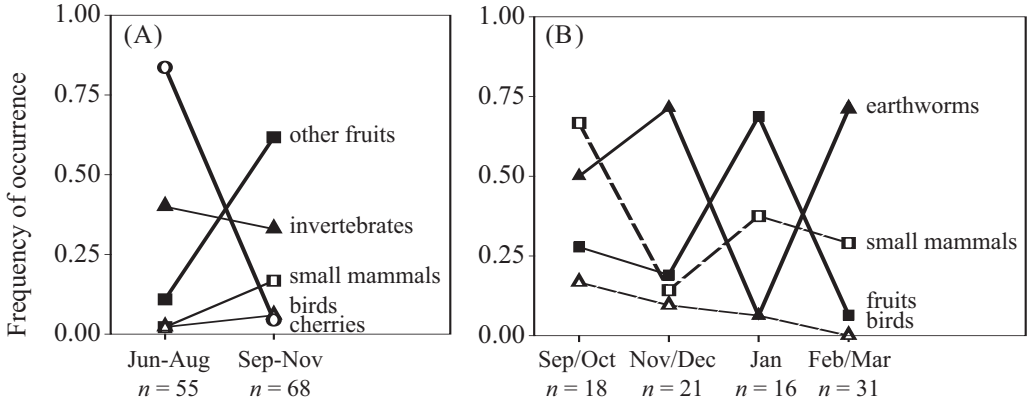


Figure 2. Changes in the frequency of occurrence of remains of different food categories in the faeces of (A) animal 1 and (B) animal 2. Note that in the case of animal 1, the invertebrate remains in the faeces mainly stemmed from earthworms. Bird remains did not occur in the collected faeces of animal 2. Numbers of analysed faeces per months are denoted in the graphs.

cluded in the diet. All of these fruits were available in the small wood until the end of the study period. The decreasing proportion of faeces including cherries was also paralleled by an increase in the frequency of invertebrates (mainly earthworms, Lumbricidae, and caterpillars, Hymenoptera, in one sample), small mammals (field mice (*Microtus agrestis* / *Microtus arvalis*), yellow-necked mouse / wood mouse (*Apodemus flavicollis* / *Apodemus silvaticus*), bank vole (*Clethrionomys glareolus*), rat (*Rattus* spp.), common shrew (*Sorex araneus*)), and a slight increase in the frequency of small birds (undetermined).

In animal 2 (male), a temporary decrease in the availability of its main food item, earthworms, was paralleled by a temporary and local change in its home range use. From September to December 1996 and February to March 1997, we tracked this animal within an area of 115 ha, located in the forest (see figure 1B). During this time, when the availability of small mammals (see Stubbe & Stubbe 1991) and also of fruits decreased in the forest, animal 2 increasingly relied on earthworms. This food item was found in 72% of the faecal samples collected in November and December 1996. In some of the faeces containing earthworm remains, we also found remains of Carabidae. In January 1997, the severe winter temperatures caused a sudden decline in the availability of earthworms: according to the index proposed by Kruuk & Parish (1981), the percentage of 'worm nights' during this month was zero, whereas during all other months of the study period, it did not drop below 36%. In this month, animal 2 moved to a hedgerow outside the forest, about 2.8 km away from the border of its home range over the preceding months (figure 1B). During this period, all the tracking data (including the day-time resting site) that we obtained from this animal came from an area of 1.2 ha around this hedgerow. Fruits, in particular blackthorn and wild rose, were still available here and were the animal's most frequent food during this month. We found fruit remains from the above mentioned species in 69% of the faeces collected, whereas the proportion of faeces including remains of earthworms greatly decreased to about 6% (see figure 2B). Additionally, there was an apparent increase in the proportion of small mammal remains (*Clethrionomys glareolus*, *Apodemus flavicollis* / *Apodemus silvaticus*). In February 1997, when the cold period was over, and the estimated availability of earthworms increased to 43% of 'worm nights', the animal returned to its formerly used home range, and switched its diet: earthworms were again the animal's most frequent food item and only a small proportion of faeces included fruit remains. The importance of earthworms for animal 2 was also emphasised by the high proportion of earthworm remains within the total faecal volume collected: turf and earthworm bristles, contributed about 70% of the total volume of faecal remains in November / December 1996 as well as in February / March 1997.

## Discussion and conclusions

The results of the faecal analysis confirm the highly omnivorous diet of this small mustelid, ranging from small mammals and birds to invertebrates and fruits (see review in Clevenger 1994). In both animals studied, the changes in their use of space were associated with changes in food availability. We suggest that in the case of animal 1, the exhaustion of a temporarily available food source (cherries) was the reason for the observed reduction of the foraging area used by the animal. Animal 2 was strongly reliant on earthworms as a food source during autumn and winter. Compared to other published data on the diet of the stone marten (see Clevenger 1994), this appears to be quite unusual and might have been the consequence of the low densities of other small mammals during this period. We speculate that when adverse weather conditions limited the availability of earthworms, this animal left its former home range in order to search for alternative food sources. In conclusion, our findings strongly indicate, although only illustrated with two cases, that temporary and local changes in the availability of

food can cause changes in space use, such as the ones observed in this study.

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## Samenvatting

**Veranderingen in de beschikbaarheid van voedsel en daaraan gerelateerde veranderingen in ruimtegebruik en menu bij steenmarters**

Gewoonlijk wordt aangenomen dat patronen in de ruimtelijke verdeling van zoogdieren worden beïnvloed door veranderingen in het aanbod van voedsel, die weer leiden tot veranderingen in het menu. Echter, gedetailleerde studies die deze relatie ondersteunen zijn nauwelijks beschikbaar. Hier presenteren we een dergelijk onderzoek dat is uitgevoerd aan twee steenmarters (*Martes foina*). We verzamelden gegevens over het individuele ruimtegebruik met behulp van radiotelemetrie, bepaalden het menu door uitwerpselen te analyseren en gingen na hoe de beschikbaarheid van enkele belangrijke voedselcom- ponenten in de loop der tijd veranderde. Veranderingen in ruimtegebruik gingen in het algemeen gepaard met veranderingen in het menu en kunnen het gevolg zijn geweest van veranderingen in het plaatselijke voedselaanbod. In het ene geval hield de betreffende steenmarter op met haar activiteiten in een deel van haar home range toen daar de plaatselijk eerst in grote hoeveelheden aanwezige wilde kersen aan het eind van de zomer opraakten. De afname van kersen in het menu van dit dier als gevolg hiervan werd vooral gecompenseerd door een toename van andere vruchten en van kleine zoogdieren. In het andere geval verlegde het betreffende dier, toen tijdens de winter de beschikbaarheid van het voor dit seizoen gebruikelijke stapelvoedsel, regenwormen, laag was, tijdelijk zijn activiteiten naar een gebied waar het zich voedde met de hier beschikbare vruchten en met kleine zoogdieren.

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