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Short communication

Winter diet of the stone marten (*Martes foina*) in central Bulgaria

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The dietary habits of various species of martens (*Martes* spp.) have been examined in detail, and it is known that they commonly eat mammals, birds, fruits and invertebrates, indicating a generalist diet (Zhou et al. 2011). Besides, each species has geographical variations in their dietary compositions and trophic diversity according to latitude and local climate (Zhou et al. 2011).

The stone marten (*Martes foina*) is widely distributed from Mongolia and the northern Himalayas to most of mainland Europe, and its habitat is known as variety of landscapes, forests, rocky areas, fields, pastures, villages and urban areas (Proulx et al. 2004). The food habits of the stone marten have been well studied mainly in western and central European countries, reported that it behaves as an opportunistic feeder (Rödel and Stubbe 2006), which principally feeds on small mammals, birds, insects and fruits (Bertolino and Dore 1995; Martinoli and Preatoni 1995; Lanszki 2003; Posłuszny et al. 2007). In central Europe, fruits are major component of its summer and autumn diet, while mammalian prey especially voles and mice makes up higher proportion of winter and spring diet (Lanszki et al. 1999; Baghli et al. 2002). In addition, trophic diversity of the stone martens from European countries correlated with variation in yearly precipitation (Zhou et al. 2011). However, this analysis has included few data from eastern Europe, especially lacked ones from the Balkan Peninsula because of unavailability of information; currently, the quantitative study of the stone marten diet in that region has only been conducted in a typical Mediterranean ecosystem in central Greece (Bakaloudis et al. 2012).

In this paper, we thus present the winter food habit data of the stone marten population in central Bulgaria, which is a part of the Balkan Peninsula. In addition, we also tackle with dietary differences between sexes, of which information on the species has yet to be accumulated.

Materials and methods

Study area

The study was conducted around Sarnena Sredna gora (42°24–34'N, 25°16–56'E), an area of ca. 520 km^2 of hilly terrain at an elevation of 350–800 m above sea level, central Bulgaria (Fig. 1). The climate in the area is transitional between moderate–continental and continental–Mediterranean (Köppen climate classification: Cfa). Average annual temperature ranges from 10 to 13°C depending on elevation with January temperatures around –1°C, and annual winter precipitation ranges from 130 to 200 mm (Velev 2002). The area is mainly cultivated but is partly covered with oriental hornbeam (*Carpinus orientalis*) shrub and oak (*Quercus* spp.) forests. The land is primarily used for orchards, vineyards, pasture and fallow land, with several small farms for sheep, pig, cattle and poultry.

Sample collection

We collected stone marten stomachs in winters (November to March) of 1997–1998, 1998–1999, 2000–2001, 2001–2002, 2002–2003, 2004–2005, 2007–2008 and 2008–2009, through the cooperation of local hunters. Stomach contents were washed with water in a plastic tray or a petri dish to sort the food items and then examined by microscopy (magnification: 4× and 10×), with contents identified to the species level, or at least to the level of Family or Order, where digestion had degraded content integrity. We used hair and feather collections

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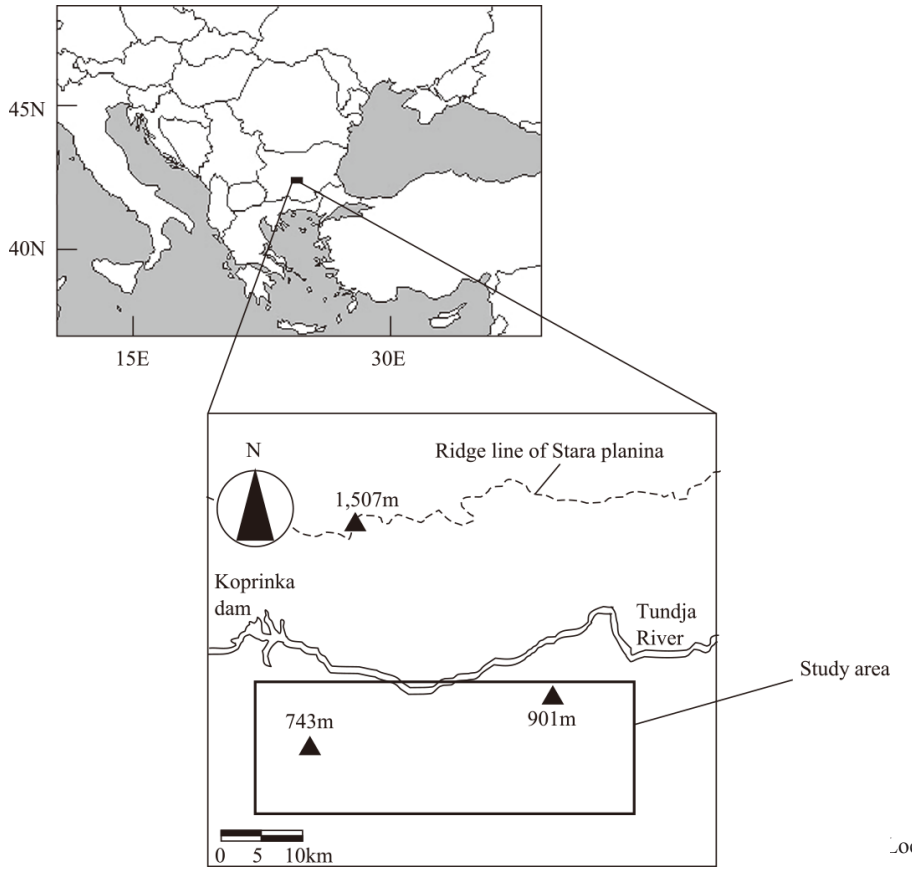

Location of the study area in central Bulgaria.

from the Laboratory of Zoology and Anatomy at Trakia University for reference. A staff of the Botanical section of Trakia University assisted with the identification of the plant materials.

Data analysis

Stomach contents were divided into ten categories: seven animal food categories, i.e. rodents, hare, other mammals (wild ungulates and carnivore), wild birds, insects, reptiles and fish; two plant food categories, i.e., fruits and other plants (twig or grass); and artificial materials (such as fragments of plastic bags or the remnants of human meal containers). Since the samples were composed entirely of stomach contents, subject to differing extents of digestion, it was not possible to measure sample weights, or relative content weights precisely. The stone marten diet was thus expressed as the number of each food item from sampled stomachs (n) and the relative frequency of occurrence (RFO; the number of occurrences of each food item/the total number of food items × 100). We tested if there was a significant correlation in the prey occurrence rank between males and females, using Spearman's rank correlation coefficient. The analysis was conducted by the statistical software, R (ver. 2.13.2.). We calculated trophic niche breadth by the Levins' standardized equation (Krebs 1989), and also Pianka's similarity index (Pianka 1973) between males and females to determine the dietary overlap. Both values were calculated at the level of the rough ten categories mentioned above.

Results and discussion

Overall winter food of the stone marten in central Bulgaria

A total of 64 stomach samples were collected, from which non-empty stomach rate was 78.1% (50 from 64; Table 1). We detected 66 prey items in the stomachs, inclusive of 16 species or genera, and unidentified items in the order of rodents, insects, birds, brown hare (*Lepus capensis*), other mammals and fruits, artificial materials, reptiles and other plants and fish (Table 1). Dietary niche breadth of the stone marten pooled across the studied years and sexes was 0.30 (Levins' index).

Table 1. Sample size (*n*) and the relative frequency of occurrence (RFO) of food items of the stone marten in central Bulgaria between 1997 and 2009

Food items	Male (*n* = 31)		Female (*n* = 19)		Total (*n* = 50)	
	n	RFO (%)	*n*	RFO (%)	*n*	RFO (%)
Mammals	25	59.5	11	45.8	36	54.5
Rodentia	16	38.1	10	41.7	26	39.4
Arvicola terrestris	1	2.4	1	4.2	2	3.0
Apodemus sylvaticus	0	0.0	1	4.2	1	1.5
Rattus norvegicus	2	4.8	0	0.0	2	3.0
Mus musculus	1	2.4	0	0.0	1	1.5
Unidentified	12	28.6	8	33.3	20	30.3
Lagomorpha						
Lepus capensis	5	11.9	1	4.2	6	9.1
Artiodactyla*						
Capreolus capreolus	2	4.8	0	0.0	2	3.0
Carnivora*						
Vulpes vulpes	1	2.4	0	0.0	1	1.5
Felis catus	1	2.4	0	0.0	1	1.5
Birds	6	14.3	2	8.3	8	12.1
Passeriformes						
Parus major	1	2.4	0	0.0	1	1.5
Fringilla coelebs	1	2.4	0	0.0	1	1.5
Turdus merula	1	2.4	2	8.3	3	4.5
Galliformes						
Perdix perdix	1	2.4	0	0.0	1	1.5
Phasianus colchicus	1	2.4	0	0.0	1	1.5
Unidentified	1	2.4	0	0.0	1	1.5
Reptiles	1	2.4	1	4.2	2	3.0
Squamata						
Elaphe longissima	1	2.4	0	0.0	1	1.5
Lacertidae sp.	0	0.0	1	4.2	1	1.5
Fish						
Cypriniformes						
Carassius gibelio	0	0.0	1	4.2	1	1.5
Insects	4	9.5	6	25.0	10	15.2
Orthoptera sp.	2	4.8	2	8.3	4	6.1
Coleoptera sp.	1	2.4	2	8.3	3	4.5
Hemiptera sp.	1	2.4	1	4.2	2	3.0
Unidentified	0	0.0	1	4.2	1	1.5
Fruits	4	9.5	0	0.0	4	6.1
Rosales						
Rosa canina	3	7.1	0	0.0	3	4.5
Prunus cerasifera	1	2.4	0	0.0	1	1.5
Other plants						
Twig or grass	1	2.4	1	4.2	2	3.0
Artificial materials						
Plastic envelop and raw garbage	1	2.4	2	8.3	3	4.5
Total number of food items occurring	42		24		66	
Proportion of non-empty stomach (%)	78.5 (31/40)		79.2 (19/24)		78.1 (50/64)	

* being considered as carcass.

Rodents, the primary prey for both males and females, are constantly available throughout the year although their populations more or less fluctuate (Zalewski 2007). This food category, therefore, seems to be an important energy source in winter, when alternative seasonal foods such as insects become less abundant and the period of ripe fruit is already over (Bakaloudis et al. 2012). Many studies in Europe also showed that rodents were the primary winter food of the stone marten (Lanszki et al. 1999; Carvalho and Gomes 2004).

Particularly males preyed on hare as well, especially in late winter (March). The stone marten in northern Italy had also consumed small amount of Lagomorpha (Bertolino and Dore 1995), however, reports of consumption of this food category have been quite few. Our result suggests that Lagomorpha, a medium-sized herbivore, also could be a meaningful prey for the stone marten when it is accessible. For other mammals, since roe deer (*Capreolus capreolus*) and red fox (*Vulpes vulpes*) are apparently large for the stone marten to hunt, they probably scavenged the carcasses.

Birds, insects and fruits also composed majority of the stone marten food accompanied with mammals. These three prey types commonly occurred in other European areas in winter, and many studies showed that fruits were more frequently occurred than insects and/or birds (Martinoli and Preatoni 1995; Baghli et al. 2002; Bakaloudis et al. 2012). In central Poland (Posłuszny et al. 2007) and northern Italy (Brangi 1995), moreover, fruits were the most frequently consumed food in winter. It is known that fruits become more available in the southern region of Europe during winter, hence, they are more frequently consumed by martens even during that period (Pandolfi et al. 1996; Zalewski 2004). In central Bulgaria, however, fruits occurred less frequently than insects and birds even though it is located on southern part of Europe.

Insects, which were particularly eaten by females, were the second dominant food of the stone marten in our study area. In central Greece, which is to the south of Bulgaria, insects occurred frequently as much as fruits did, surpassing mammals and birds (Bakaloudis et al. 2012). In south-western Portugal, moreover, insects were their most frequently consumed food (Santos-Reis et al. 2004). Those areas are considered to be milder in winter, thereby, insects may be still active even during that season.

In central Bulgaria, some artificial materials such as the plastic envelope and raw garbage were even utilized by both sexes. Because our study area includes human settlements, we suppose it is easy for them to access such kind of materials. It is also reported that the populations in a Hungarian village (Lanszki 2003) and a mountainous zone in Italy (Brangi 1995) took advantage of some garbage related to human life.

Food difference between sexes

For males, 40 stomach samples were collected and non-empty stomach rates were 77.5% (31 from 40; Table 1). Dietary niche breadth was 0.32 (Levins' index). Rodents were the most frequently consumed food item by males (n = 16, RFO = 38.1%; Table 1). Next to rodents, they frequently fed on wild birds (n = 6, RFO = 14.3%) and the hare (n = 5, RFO = 11.9%), followed by insects (n = 4, RFO = 9.5%), fruits (n = 4, RFO = 9.5%) and other mammals (n = 4, RFO = 9.5%; Table 1). The least utilized preys by males were reptiles (n = 1, RFO = 2.4%), other plants (n = 1, RFO = 2.4%) and artificial materials (n = 1, RFO = 2.4%; Table 1). No fish occurred in the stomachs of males (Table 1).

For females, 24 stomach samples were collected and non-empty stomach rates were 79.2% (19 from 24; Table 1). Dietary niche breadth was 0.26 (Levins' index), slightly lower than males. For each food items, similar to males, females also consumed rodents the most frequently (n = 10, RFO = 41.7%; Table 1). Second, unlike males, they fed on insects (n = 6, RFO = 25.0%) followed by wild birds (n = 2, RFO = 8.3%) and artificial materials (n = 2, RFO = 8.3%; Table 1). The least utilized preys by females were hare (n = 1, RFO = 4.2%), reptiles (n = 1, RFO = 4.2%), fish (n = 1, RFO = 4.2%) and other plants (n = 1, RFO = 4.2%; Table 1). It is notable that any fruits and mammals except for Rodentia and Lagomorpha were not taken advantage of by females (Table 1).

In summary, some sexual variation in diet was observed and we found no significant correlation in the prey occurrence rank between males and females (Spearman's rank correlation test: S = 75.46, P = 0.33 > 0.05). This indicates that the food preference of each sex was not entirely the same even though dietary overlap between sexes was pronounced (Pianka's index: 0.88).

It is noteworthy that our results suggest the presence of the dietary differences between sexes as well; males preferred to prey on hare and birds next to rodents, while females fed on insects as the second preference. Brown and Lasiewski (1972) predicted that Mustelids reduce intersexual competition by exhibiting sexual size dimorphism in order to approach different size of prey. The

body size of the stone marten also differs between sexes: males are 430–590 mm and females are 380–470 mm of body length in Russia and central Europe (Heptner et al. 2002). Thereby, sexual dietary differences which we observed might partly attribute to this dimorphic phenomenon.

In addition, females consumed no large mammals (carcasses) and fruits in winter. Similarly, females of pine marten (*M. martes*) in Poland (Zalewski 2007) and fisher (*M. pennanti*) in northern United States (Giuliano et al. 1989) fed on carcasses and fruits less frequently than male martens: males could have a higher probability of finding such patchily distributed trophic resources by occupying larger home ranges than females (Giuliano et al. 1989; Zalewski 2007). As for the stone marten, it is known that home ranges of males tend to be larger than those of females since males usually mate with one or more females (Herr et al. 2009). Although we did not assess their home range sizes in central Bulgaria, it is assumable that the absence of those two patchy foods from female stomachs might be caused by the sexual difference of home range size. Besides, this assumption can well explain wider trophic niche breadth of males, exploring broader range to obtain various prey types.

Further sex-related studies on the diet of the stone marten by well-arranged analysis will enable us to estimate relative volumes of the food items, which is our urgent issue to be improved. Additionally, year-round data of food items combined with level of body size difference, prey availability, home range size and habitat selection will provide more constructive information on understanding of the ecology of their dietary habits.

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