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Feeding habits of two sympatric mustelid species, European polecat *Mustela putorius* and stone marten *Martes foina*, in the Czech Republic

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A b s t r a c t . Diet compositions of the European polecat (*Mustela putorius*) and the stone marten (*Martes foina*) were studied through macroscopic and microscopic analyses of 69 polecat and 120 stone marten stomachs dissected between 2000 and 2006 in Southern Moravia (Czech Republic). The diets of both mustelid species included a wide variety of prey species but were dominated by mammals and birds. Frogs were consumed only in winter. No reptiles were found in the diet of either species. Invertebrates were rarely present in the polecat diet but very common in the stone marten diet. In summer, the most common food for the stone marten was fruit. The stone marten consumed significantly more rodent species, especially rats (*Rattus norvegicus*), and songbirds and the food niche of the stone marten was broader than that of the polecat. The trophic niche overlap of both species, based on Pianka's index, was highest in winter. Stone martens appear to be an important food competitor of European polecats in the Czech Republic, mainly in winter when food resources are limited.

Key words: small mustelids, diet, stomach contents, niche overlap

Introduction

The European polecat (*Mustela putorius* Linnaeus, 1758) occurs throughout most of Europe, but it has either disappeared or its presence has declined in many countries in Central and Western Europe over the last 150 years (B a g h l i & V e r h a g e n 2003), including the Czech Republic. According to hunting statistics (Ministry of Agriculture of the Czech Republic, unpubl. data), no individuals are hunted at present, though 1.655 individuals were shot in 2.000 and more than 20.000 individuals have been shot since the beginning of the 1970s. On the other hand, stone marten (*Martes foina* Erxleben, 1777) abundance has increased since the last century and the numbers shot have risen from 2.000 individuals at the beginning of the 1970s to more than 18.000 individuals shot per year at present. These two carnivores are sympatric over much of their range (B a g h l i et al. 2002).

Habitat destruction, persecution by gamekeepers, and the introduction of American mink (*Mustela vison* Schreber, 1777) are considered to be the most important factors leading to the decline in European polecat numbers (J ę d r z e j e w s k i et al. 1993, S i d o r o v i c h et al. 1999, S i d o r o v i c h 2000, S i d o r o v i c h & M a c D o n a l d 2001). Other reasons may include deaths caused by traffic or interspecific competition for food with the stone marten, especially during the winter months (W e b e r 1989, S i d o r o v i c h 2000). Data on the food habits of the polecat and stone marten in Central Europe are limited (but see G o s z c z y ń s k i 1976, J ę d r z e j e w s k i et al. 1993, L o d é 1993). In the Czech

Republic, there have been several studies focusing on the diets of these two species (Kratochvíl 1952, Svatoš 1967, Svatoš & Dyk 1967, Holišová & Obrtel 1982, Šebela 1982).

The polecat diet mainly consists of rodents and amphibians, with lesser amounts of lagomorphs, birds and carrion (Kratochvíl 1952, Erlinge 1986, Lodé 1997). Other mammals, invertebrates, crayfish and fish are usually found only in small quantities (Lodé 1993, 1997). Polecats are food generalists (Brugge 1977, Lodé 1997), though there are a few populations known that have more narrowly defined diets consisting mainly of frogs (e.g. Weber 1989, Jędrzejewski et al. 1993) or rabbits (e.g. Birks & Kitchener 1999). The diet of the stone marten consists mainly of small and medium-sized mammals, birds, and fruit, especially in the summer months (Erlinge 1986, Serafini & Lovari 1993). Reptiles, amphibians and insects tend to form supplementary items (Romanowski & Lesiński 1991, Serafini & Lovari 1993, Genovesi et al. 1996).

The diet composition of polecats and stone martens depends on both habitat use (Lodé 1994, Lanszki 2003) and season (Kratochvíl 1952, Lanszki et al. 1999). Several authors have described competition among mustelids (e. g. Powell & Zielinski 1983, Erlinge 1986, Lodé 1993), but little is known about food competition between these two species (Baghli et al. 2002).

In order to determine the relationship between the feeding habitats of these two sympatric carnivores, this study aims to analyse seasonal changes in the diet composition of polecats and stone martens, determine their feeding habits and establish whether a trophic niche overlap exists.

Materials and Methods

Diets of the polecat and stone marten were studied using analysis of stomach contents. In total, stomachs from 120 martens and 69 polecats were analysed from animals shot or killed on roads in Southern Moravia (Czech Republic) between 2000 and 2006. Stomachs dissected from collected animals were stored at -20°C prior to contents analysis.

Each stomach was defrosted and the contents measured in a graduated cylinder. The stomach contents were washed with water and passed through a range of sieves in order to separate the food remains. The cleaned stomach contents were then transferred to a Petri dish and examined under a binocular loupe according to Hammershøj et al. (2004). A combination of macroscopic and microscopic analyses enabled us to estimate the quantitative as well as qualitative composition of the diet. Using macroscopic analysis, stomach contents were classified into the main feeding groups, such as mammal, bird, fish, frog, carrion (considered as animals that were too big to have been killed by the stone marten or polecat), invertebrate, fruit, plant remains (leaves, twigs, grass, roots), and other (sand or human artefacts such as plastic or aluminium foil). The proportion of each feeding component in each stomach was estimated. When possible, individual components were classified into species, genus or family level using macroscopic or microscopic analysis. Various identification guides and reference materials were used to determine prey remains, such as teeth, paws, fur, bones, feathers, scales, pharyngeal teeth or other body parts (Gaffrey 1961, Brom 1986, Teerink 1991). No attempts were made to look for earthworm chaetae. Diptera larvae were excluded from the analysis as they could have developed within

the stomachs of dead animals or could have been ingested with carrion (Hammershøj et al. 2004). Hair, swallowed by the animal while grooming, was not considered as a dietary item.

Results are presented as a percentage volume (% V), indicating the volume of a particular food component as a percentage of the total volume of stomach contents, and as frequency of occurrence (% F), indicating the occurrence of a particular food component as a percentage of all the food components in the analysed stomachs. A chi-square test was used to test for differences in stomach contents in relation to season (winter (December-February), spring (March-May), summer (June-August) and autumn (September-November)), sex and species of mustelid (Table 1). Trophic niche diversity was expressed using the Shannon-Weaver index ($H' = - \Sigma x_i \times \ln x_i$), where x_i represents the percent of the i^{th} component in the diet of a species. Trophic niche width was calculated from % V using the Levins index (Levins 1968) with 10 taxonomic food categories. The total trophic niche overlap of both species was calculated from % F using Pianka's index (Pianka 1973), while the trophic niche overlap between seasons and species was calculated from % V using the Renkonnen similarity index (Losos 1980). The food-niche width index was calculated for each species according to Simpson's formula ($N_B = 1/\Sigma p_i^2$), where p_i is the proportion of feeding category *i* in the diet.

Results

From the total number of animals collected, 20 polecat (29%) and 12 stone marten (10%) stomachs were empty and, therefore, were excluded from further analysis. Of the 108 stone marten stomachs that contained food remains, 51 (47%) contained only a single dietary item, 42 (39%) contained two items and 15 (14%) contained three dietary items. Similar results were obtained for the 49 polecat stomachs containing remains, with 29 (59%) containing a single dietary item, 14 (29%) contained two items and six (12%) containing three dietary items. Very few stomachs were analysed from animals killed in summer (Table 1) and, therefore, the results from this season may be biased.

Table 1. The number of full stomachs analysed. MP = polecat; MF = stone marten.

Season	MP female	MP male	MF female	MF male
Spring	2	10	9	5
Summer	3	0	2	2
Autumn	5	4	2	9
Winter	13	12	39	40

Diet composition of the European polecat

The diet of the polecat included a wide variety of prey species, with mammals (mainly Rodentia and Lagomorpha) and birds (mainly Galliformes) dominating (Table 2). In total, ten mammal species were identified. Rodents were a common component of the diet throughout the year, with *Apodemus* sp. being the genus most preyed upon. No reptile was found in the diet.

In autumn and winter, birds were the most common food of polecats (Figs 1, 2). Invertebrates (beetles and earthworms) were rarely present, appearing in stomachs

during spring and autumn only. In spring, polecats consumed more rodents, hares (*Lepus europaeus)*, fish and earthworms than in autumn and winter ($p<0.05$). On the contrary, they consumed more beetles and birds (gallinaceous) in autumn than in spring ($p<0.01$). In winter, they consumed more mice, pine voles (*Microtus microtus*), and fewer white-toothed shrews (*Crocidura suaveolens*), birds and roe deer carrion (*Capreolus capreolus*) than in spring and autumn ($p<0.05$). According to the Levins index, trophic niche diversity and width were highest in spring and, surprisingly, in winter (Table 3).

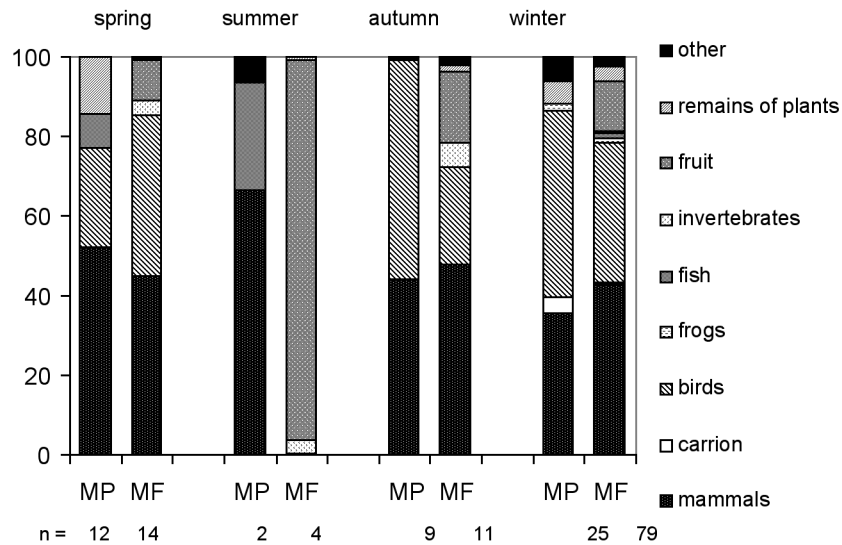

Fig. 1. The proportions (% V) of nine of the main feeding categories in the diets of polecats (MP) and stone martens (MF) in each season.

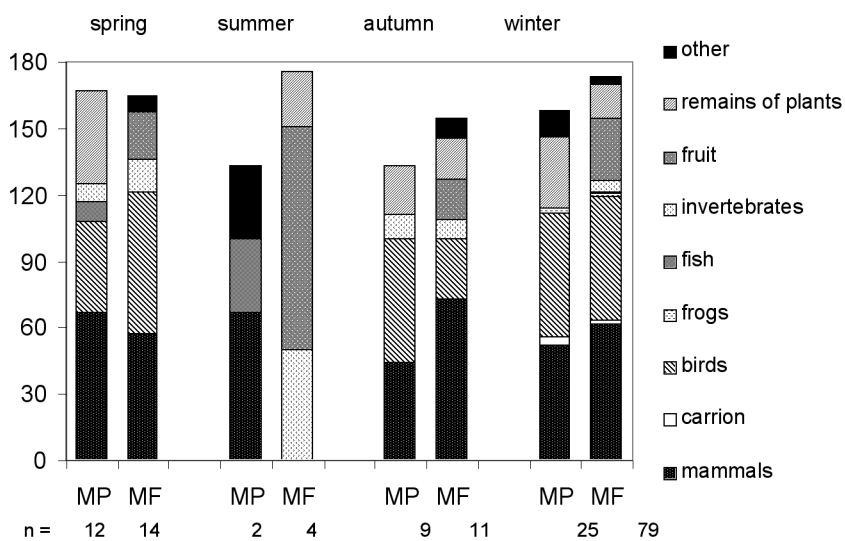

Fig. 2. The frequency (% F) of nine of the main feeding categories in the diets of polecats (MP) and stone martens (MF) in each season.

Table 3. Trophic niche width (Levins index and the Shannon-Weaver index (in parentheses)), and trophic niche overlap (Renkonnen index) between stone marten and polecat diets.

Season	Polecat	Stone marten	Overlap
Spring	2.75 (1.90)	2.66 (2.15)	21.65
Summer	1.92 (0.27)	1.10 (0.99)	0.00
Autumn	2.01 (1.19)	3.09 (1.82)	36.36
Winter	2.80 (2.24)	3.25 (2.67)	37.33

Male polecats consumed more mammals (hares, rodents), invertebrates and plant material than females ($p<0.05$). On the contrary, female polecats fed significantly more on carrion and fish ($p<0.05$). In winter, males consumed more house mice (*Mus musculus*), pine voles, amphibians, and invertebrates ($p<0.05$) than females, while females consumed more voles (*Microtus arvalis*) and carrion than males ($p<0.05$).

Diet composition of the stone marten

As with the pine marten, mammals (mainly Rodentia and Lagomorpha) formed the greater part of the stone marten's diet (Table 2). Fifteen mammal species were identified to species level. The rodent species most preyed upon were the wood mouse (*Apodemus* sp.), house mouse, brown rat (*Rattus norvegicus*) and pine vole. Rodents were present in the diet in all seasons except summer. Birds (mainly Galliformes and Passeriformes) were again the second most important dietary item. Fish and frogs were consumed only in winter. No reptiles were found.

Fruits and invertebrates (Annelida, Lepidoptera, Diptera and Dermaptera) were consumed frequently in each season (Figs 1, 2). In summer, stone martens showed a distinct preference for fruits such as Amygdaloidae, Malaceae and Rosaceae (F = 100%, V = 96%). The index of diversity was lower in summer (only four stomachs analysed) and autumn and higher in winter and spring (Table 3). In spring, stone martens consumed significantly more squirrels (*Sciurus vulgaris*), hares, rodents, birds and butterflies than in autumn ($p<0.05$), and more squirrels and butterflies than in winter ($p<0.01$). Water voles (*Arvicola terrestris*) and earthworms were consumed significantly more often in autumn than in spring and winter ($p<0.01$). In winter, the diet of stone martens included significantly more hares and birds (Galliformes, Passeriformes and Columbiformes) than in autumn ($p<0.01$).

A high Renkonnen index of similarity between males and females (Re = 96.18) indicated a large overlap in their trophic niches. In winter, however, males fed significantly more on hares ($p<0.05$), while females fed more on rodents ($p<0.001$). According to the Levins and Simpson's indices, trophic niche diversity of female stone martens was highest in spring and highest for males in autumn and winter. Surprisingly, when all animals (both male and female) were analysed together, highest trophic niche diversity was determined to be during winter.

Comparison of European polecat and stone marten diets

Pianka's index indicated that the trophic niche overlap for both species was high (O_{jk} = 0.87). When considering the effect of different seasons on the diet of the mustelid species, trophic niche overlap was highest in winter (P_{ij} = 37.33). The stone marten, with more food categories, had a wider food niche (B = 11.5, N_B = 1.95) than the polecat (B = 10.6,

Table 2. Feeding components identified in polecat (MP) and stone marten (MF) food, their percentage frequency (% F) and percentage volume (%V), and values for trophic diversity (H') and equability (J'). Total = sum of dietary items.

		MP		MF	
	ITEMS	% F	% V	% F	% V
Mammals	*Crocidura suaveolens*	2.04	0.41		
	Talpa europea			0.91	0.02
	Cricetus cricetus			1.82	1.82
	Clethrionomys glareolus			2.75	0.81
	Arvicola terrestris			0.91	0.02
	Ondatra zibethicus			0.91	0.74
	Microtus subterraneus	2.04	2.04	4.59	1.93
	Microtus arvalis	4.08	2.68		
	Apodemus sylvaticus			2.75	1.06
	Apodemus flavicolis	6.12	4.56	2.75	1.41
	Apodemus sp.	6.12	5.92	9.18	4.98
	Rattus norvegicus			5.5	4.68
	Mus musculus	2.04	0.2	6.42	2.63
	Sciurus vulgaris			0.91	0.91
	Rodentia sp.	8.16	6,57	10.08	6.89
	Lepus europaeus	2.04	0.23		
	Oryctolagus cuniculus	2.04	2.04	2.75	2.31
	Lagomorpha sp.	4.08	5	0.91	0.93
	Cervus elaphus			0.91	0.46
	Capreolus capreolus	2.04	2.04		
	Mammalia unidentified	14.29	18.88	7.06	10.65
	Total	55.09	44	61.11	42.25
Birds	Podicipediformes	2.04	2.04		
	Charadriiformes	2.04	2.04		
	Columbiformes			1.83	0.56
	Galliformes	24.49	22.05	21.1	12.92
	Passeriformes	4.08	2.49	12.84	8.19
	Aves unidentified	16.35	12.17	15.61	11.48
	Total	49.00	40.79	51.38	33.15
Amphibians	Total (*Bufo bufo*)	2.04	1.43	0.91	0.91
Fish	Total	4.08	3.67	0.91	0.91
Invertebrates	Annelida	2.04	0.02	0.91	0.65
	Dermaptera			0.91	0.05
	Lepidoptera			2.75	0.51
	Diptera			1.83	0.37
	Coleoptera	2.04	0.03	1.83	0.07
	Total	4.08	0.05	8.23	1.65
Fruit	Malvidae			15.6	8.03
	Prunidae			4.59	3.44
	Rosaceae			5.5	3.18
	Vitaceae			1.83	0.91
	Total			27.52	15.56
Plant material	Total	30.61	7.64	13.76	2.88
unidentified	Total	6.12	2.42	5.5	2.69
H`(J`)		2.396 (0.763)		2.685 (0.744)	

N_B = 4.96). Only stone martens consumed fruit and rats, and they consumed significantly more rodents and songbirds ($p<0.05$) than did polecats. Furthermore, female stone martens consumed more mice and invertebrates ($p<0.05$) than polecat females.

Discussion

In the present study, mammals dominated in the diet of polecats, as in a number of other European countries (e.g. in France Lodé 1993, in Italy Marins & Agnelli 1996, in Luxembourg Baghli et al. 2002, and in Hungary Lanszki & Heltai 2007). Similarly, mammals comprised the main constituent in the diet of stone martens, which is in agreement with studies from Spain (Delibes 1978) and Luxembourg (only during winter months) (Baghli et al. 2002). For the stone marten, the wood mouse (*Apodemus*) was the most preyed upon rodent species in both our study and others (Serafini & Lovari 1993, Genovesi et al. 1996). The second most important rodent species was that of rats, despite their being rather difficult to catch (Lodé 1999). Mammal consumption was high in the stone marten diet in winter, though almost no voles were present. It has been argued, however, that voles are not available to martens during winter, as they spend most of their time under the snow (Powell & Zielinski 1983, Storch et al. 1990). *Apodemus* spp. spends less time under snow cover, and thus they are probably easier prey for the marten to catch (Storch et al. 1990). Insectivores appeared rarely in the diet of both species, as was also found by Goszczyński (1976), Weber (1989) and Genovesi et al. (1996). Both polecats and martens generally avoided shrews, probably because of the scent glands present on their flanks (Moors 1975). The presence of hair from large mammals in the stomachs of both mustelids in winter indicates their ability to consume large mammal carrion as a food source (see also Weber 1989, Jędrzejewski et al. 1993, Genovesi et al. 1996, Baghli et al. 2002).

In autumn and winter, birds (Galliformes) dominated in the polecat diet. Polecats often find and consume injured or dead pheasants (*Phasianus colchicus*) during the hunting season (personal obs.), which lasts from November 16 to January 31. Polecats, however, may also be actively hunting pheasant chicks during the day (Javůrek 1955, Lochman & Hanzal 1993). A relatively large number of arboreal bird species was identified in stone marten stomachs (except for in summer, when fruit dominated), possibly reflecting their greater climbing ability as compared with polecats (Šebela 1982, Blandford 1987, Baghli et al. 2002).

Toads (*Bufo bufo*) were found in the diet of both species (Weber 1989, Romanowski & Lesiński 1991, Baghli et al. 2002), but only during the winter months. Weber (1989) found that polecats could find and excavate hibernating frogs from up to 30 cm of soil, and locate them even with snow cover of up to 1 m thick. Over-wintering frogs, therefore, may be an easy prey for polecats. Toads often occur in significant amounts in the diet of polecats (Lodé 1997, Sidorovich & Pikulik 1997), which seem to prey on both frogs and toads with no clear selection, despite the toad's toxic glands.

Fish bones and scales were found in one polecat stomach in each spring and summer. This food source has been found in polecat stomachs by a number of authors (e.g. Jędrzejewski et al. 1993, Hammershøj et al. 2004). Fish appear to be a relatively rare dietary item for stone martens, on the other hand, as we identified fish remains in only one stone marten stomach and there seem appears to be only one other record in the literature (Lanszki 2003) of this dietary class being associated with the stone marten. An alternative

explanation for the presence of fish bones and scales in the stone marten's stomach may be that it was scavenging on human refuse. Both mustelid species have previously been reported as scavenging. A stick and a piece of plastic found in polecat stomachs during winter, and the presence of aluminium foil in winter samples and remains of apples in spring samples for martens, indicates the possible use of human refuse as a food source (Svatoš 1973, Holišová & Obrtel 1982).

No reptile was found in the diet of either species. Reptiles were, however, found in the diet of polecats in the Czech Republic by Kratochvíl (1952), as well as in the diet of stone marten in Italy (Lucherini & Crema 1993, Serafini & Lovari 1993), Romania (Romanowski & Lesiński 1991) and Spain (Delibes 1983).

According to our results, fruit represents an important food component for the stone marten, not only in summer and autumn but also in winter when they consumed apples and pears lying on the ground, sometimes digging them up from under snow cover (Goszczyński 1976, Posłuzny et al. 2007). No fruit was found in polecat stomachs. Nevertheless, fruit has been reported by Weber (1989) as being occasionally consumed by polecats.

The data obtained from stone marten stomachs indicates a more complex feeding pattern compared to polecats. Further, there were significant seasonal differences in the diet of stone martens. Stone martens, therefore, appear to show greater seasonal shifts in their food habits than do polecats. Baghli et al. (2002) stated that the trophic niche overlap between stone martens and polecats is low and appears only during the winter months. The present data, however, disagree with this statement, as a high trophic niche overlap was detected not only during winter but also in spring and autumn. During the summer months, stomach analysis indicated a low overlap in the diet of mustelids; however, only a small number of animals were available for analysis during this season and this will have biased the results. According to competition theory, the degree of overlap in diet between sympatric species should be higher when their key resource is abundant (Schoener 1982). Despite we don't have a data about potential food resources abundances in the area, this would explain the high trophic niche overlap observed between the two mustelid species in the present study. In spite of this conclusion stone martens should be an important food competitor of the Eastern polecat in South Moravia, when food resources are limited, e.g. in winter.

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