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Research Article

Diet composition of *Myotis myotis* (Chiroptera, Vespertilionidae) in western Poland: results of fecal analyses

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Abstract: The diet of greater mouse-eared bats (*Myotis myotis*) was investigated by analysis of 900 droppings taken from 8 different bat colonies in western Poland. Three taxonomic orders (Coleoptera, Lepidoptera, and Diptera) and representatives of 2 other groups of arthropods (Chilopoda: Lithobiidae and Arachnida: Araneae) were identified in the droppings. Coleoptera was the most abundant prey found in fecal samples in all seasons. Study sites differed significantly in the composition of prey, which probably reflects the local foraging conditions for *M. myotis*.

Key words: *Myotis myotis*, diet, fecal analysis, Chiroptera

Introduction

Foraging behavior has an important role in evolutionary biology and ecology since it is a major determinant of survival, growth, and reproductive success (Kramer, 2001). From a practical point of view, knowledge of foraging ecology is essential for the successful conservation of endangered or beneficial species. Bats are a group of animals with many endangered and declining species worldwide, and most bats are important components of natural systems, acting as predators or seed dispersers (Kalka and Kalko, 2006; Tang et al. 2008). Indeed, one of the crucial factors in understanding bat ecology and conservation is information about their diet (Sachanowicz et al., 2006).

Myotis myotis is one of the few European bat species specializing in preying on epigeic, flightless invertebrates, including ground beetles. The main component of the diet of greater mouse-eared bats is large beetles, especially species from the genera *Carabus* and *Pterostichus* (Drescher, 2000; Zahn et al., 2006; Boyles et al., 2007). They also eat large butterflies and their caterpillars, crickets, mole crickets, centipedes, spiders, and occasionally some dipteran and dermapteran species (Beck, 1995; Sachanowicz et al., 2006). *M. myotis* is a "surface-gleaner," which means that it collects its prey from the ground or from plant surfaces in forested areas (Bauerová, 1978; Arlettaz, 1996; Arlettaz et al., 2001). It flies 30-70 cm above the ground and locates its prey by listening, not by echolocation, and its wide wings are a morphological evolutionary adaptation to this kind of foraging (Russo and Jones, 2002). After locating the prey, it hovers for 2-5 s, catches the prey, rises in the air, and eats the item. Because of its foraging behavior and the sensory basis of

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its prey detection, *M. myotis* is an ideal subject for investigation of the role of sensory ecology in prey choice (Siemers and Güttinger, 2006).

The diets of bats differ both spatially and temporally (Rakotoarivelo et al., 2007; Bontadina et al., 2008), and thus several studies are usually necessary to understand the diversity of diet composition. In East Europe, information about the diet composition of this bat species is scant and originates from only one site at Sulejów in central Poland, inhabited by a nursery colony (Jaskuła and Hejduk, 2005).

The main aim of the current work was to identify and analyze the seasonal variation in the components of the diet of *M. myotis* on the basis of fecal analysis, and thus establish how the species responds to seasonal variations in trophic resources.

Materials and methods

The material was collected from 4 breeding colonies and 4 autumn colonies. The breeding colonies were located in the attics of buildings in Sieraków (52°39´N, 16°04´E), Jaglice (53°04´N, 16°12´E), and Skwierzyna (52°35´N, 15°30´E). Droppings from these colonies were collected in the summer months (July, August, and September) of 2007 and 2008 (details in the Table). We also collected droppings from a colony near Kopanki (52°17´N, 16°18´E). However, this colony was sampled in 2007 and 2008 from May to September. The autumn droppings were collected from a summer or an early autumn colony in an isolated bunker in a forest close to Czołowo village near Kórnik (52°14´N, 17°05´E) (September) and from a temporary colony in the Międzyrzecz Fortified Region (Boryszyn) (52°21´N, 15°26´E) (October).

Bat droppings found in bat-boxes were collected from 2 locations near Antonin in the eastern part of the Milicz Valley (52°36´N, 16°50´E) in June, July, August, and September of 2007 (Antonin A) and 2008 (Antonin B).

All investigated colonies were located near forest complexes where bats hunted for prey. These forests had typical Polish forest plant communities with a predominance of pine, i.e. a *Dicrano-Pinion* alliance, mainly *Leucobrio-Pinetum* and *Cladonio-Pinetum*. Additional trees growing in forests near bat colonies included beech and oak.

From each location (8 in total), 100 droppings were taken at random and analyzed individually.

Table. Prey remains in the droppings of *M. myotis* at different study locations. The months of data collection are given in parentheses.

Order	Family	Genus or species	Kopanki (May-September)	Antonin A (July)	Antonin B (August)	Jaglice (August)	Sieraków (July)	Kórnik (September)	Boryszyn (October)	Skwierzyna (September)
Coleoptera	Carabidae	*Carabus auronitens*	+			+	+			+
	Carabidae	*Carabus violaceus*	+	+	+	+	+	+	+	+
	Carabidae	*Calathus* spp.	+	+	+	+		+	+	+
	Carabidae	*Pterostichus* spp.	+	+		+		+	+	+
	Carabidae	*Abax* spp.	+			+	+		+	
	Carabidae	*Cychrus caraboides*				+	+			
	Scarabaeidae		+	+	+					+
	Cerambycidae		+	+	+	+	+	+	+	+
	Curculionidae		+		+			+		
	Silphidae	*Necrophorus* spp.	+							
Lepidoptera	Noctuidae		+							
	Unidentified		+	+	+	+				
Diptera	Unidentified		+				+			
Chilopoda	Lithobiidae	*Lithobius forficatus*	+		+	+	+	+	+	+
Araneae	Unidentified		+	+	+	+	+		+	+

We collected fresh droppings only, and thus the date of collection reflected recent diets. Fecal samples were soaked in water, then completely dissected with a needle and tweezers and searched for taxonomically recognizable fragments (Beck, 1995). The analysis was done using a stereoscopic microscope with 6-24× magnification. The identification of beetles was done on the basis of beetle legs, antennae, and fragments of elytra. Members of the order Coleoptera were usually identified to the family level using published identification guides (Mroczkowski, 1955; Smreczyński, 1972, 1974, 1976; Stebnicka, 1978; Trautner and Gaigenmüller, 1987) and specimens collected from the bats' foraging grounds. The remaining groups of arthropods were identified to the order level (Lepidoptera, Diptera) from wings using their venation and identification keys (Trojan, 1957; Pławilszczikow, 1972), or by using another part of the body (Araneae, Chilopoda) (Prószyński and Staręga, 1971; Kaczmarek, 1979). Results are expressed in terms of relative frequency of occurrence, which represents the percentage of fecal pellets containing each prey type.

Results

Representatives of 3 insect orders (Coleoptera, Lepidoptera, and Diptera) occurred at all locations. In Coleoptera, 5 families (Carabidae, Silphidae, Cerambycidae, Curculionidae, and Scarabaeidae) were identified. At least 6 ground beetle species or genera from the family Carabidae were recorded in the present study: *Carabus auronitens*, *C. violaceus*, *Calathus* spp., *Pterostichus* spp., *Abax* spp., and *Cychrus caraboides*. Of these, *C. violaceus* was present at all locations and *Calathus* spp. at 7 locations. The other 4 species or genera occurred in smaller quantities. Other groups of invertebrates, including Lepidoptera (Noctuidae) (0.5% of all droppings), Lithobiidae (*Lithobius forficatus*) (2.8%), and Araneae (4.2%), were also detected in the droppings (Table and Figure 1). On average, Coleoptera constituted 88.1 ± 8.2% (mean ± SD, n = 8 locations) of prey detected in the droppings. Statistically significant differences (G-test, G = 15.93, P = 0.024) in the frequency of types of prey were found among study locations (Figure 2). There were seasonal differences in the choice of prey species (Figure 3). The proportion of Coleoptera (mainly carabids) in the diet of *M. myotis* fluctuated and was highest in May and September (Figure 3).

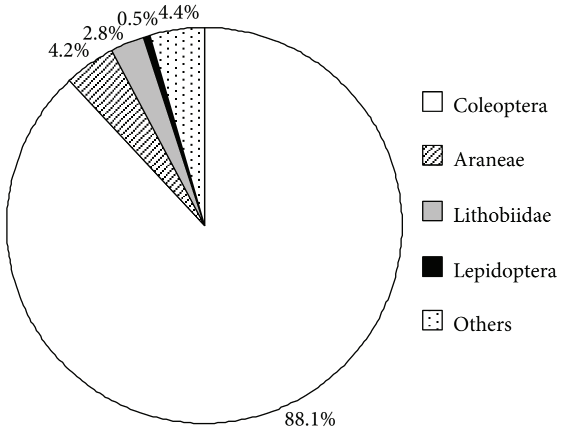

Figure 1. Frequency of invertebrate groups in the diet of *M. myotis* in summer and autumn.

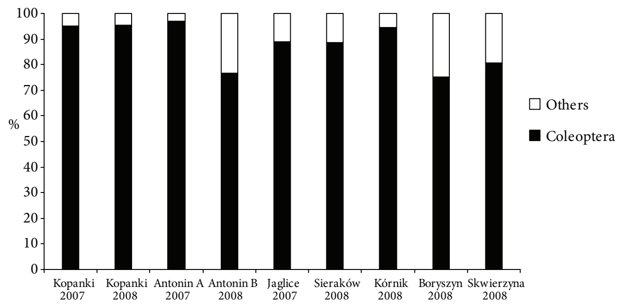

Figure 2. Variation of the main prey found in the diet of *M. myotis* at various locations. The "others" category includes invertebrates from the Araneae, Lithobiidae, Lepidoptera, and Diptera taxonomic groups.

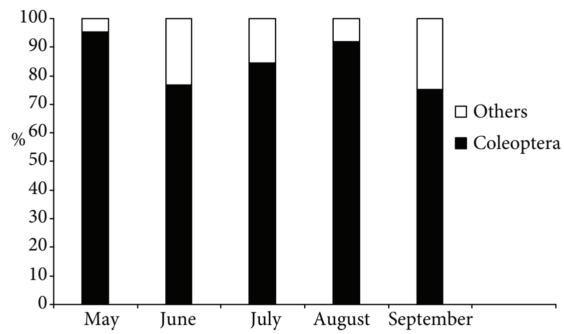

Figure 3. Seasonal variation of the main prey found in the diets of *M. myotis* at the breeding colony in Kopanki. The "others" category includes invertebrates from the Araneae, Lithobiidae, Lepidoptera, and Diptera taxonomic groups.

Discussion

The present investigation shows that ground beetles are the dominant insect group in the diet of *M. myotis* during all seasons. This confirms earlier studies focused on this species in other regions of Europe (Bauerová, 1978; Beck, 1995). The Carabidae are not only the most important beetle family, but they are also usually the most numerous group among all invertebrate taxa present in feces (Bauerová, 1978; Arlettaz, 1996; Arlettaz et al., 2001; Pereira et al., 2002; Jaskuła and Hejduk, 2005). The most probable reason for this phenomenon is the high level of noise made by large beetles moving on the ground, which is used by *M. myotis* for detection of its prey. This is confirmed by the high frequency in the diet of the larger (>20 mm long) species from the family Lithobiidae. Larger insects were frequently present in the diet because, in proportion to their size, they produce more noise and are easily detected by bats (Siemers and Güttinger, 2006). Furthermore, some investigators (Arlettaz, 1996; Pereira et al., 2002; Jaskuła and Hejduk, 2005) suggest that the high percentage of carabid beetles in the diet of *M. myotis* can be correlated with the high availability of these invertebrates and particular types of habitats preferred by the greater mouse-eared bat. It is also likely, in the analyzed forest locations, that Carabidae is one of the most abundant epigeic arthropod groups (Sienkiewicz and Konwerski, 2006). The occurrence of this type of prey in the diet of *M. myotis* can be further explained by the energy costs of hunting. Some small invertebrate groups are not consumed by the bat even if they are very abundant in the area (Pereira et al., 2002; Jaskuła and Hejduk, 2005) because they have a lower biomass, and hence lower energy content, compared to larger carabids. Consequently, the energy return for hunting small prey may not compensate for the costs of hunting. This hypothesis was also confirmed in the present study, since *Carabus violaceus*, recorded as the most numerous prey species in the diet of *M. myotis* populations, was also the largest carabid species recorded in the pellets. Other studies also found that, in the spring, the diet of the greater mouse-eared bat contained a huge quantity of insects such as mole crickets (*Gryllotalpa*) and butterfly caterpillars (Arlettaz et al., 1997, Ma et al., 2008). The sporadic occurrence of insects from the orders Dermaptera, Hymenoptera, and Hemiptera was also noted in other studies (Beck, 1995; Koteja et al., 2001; Whitaker and Karataş, 2009, 2010). The differences in the diet of *M. myotis* in various studies suggest that there may be a geographical pattern of diet choice related to habitat use by the bats or climatic conditions. This interesting problem requires further testing with a much larger sample of locations than in our study. While our study was focused on diet composition analysis, the results have some implications for the conservation of the studied species. The predominance of carabid beetles in the diet indicates that they might be the preferred insect prey for this bat species. When conservation actions for the bats are planned, such as hanging nest boxes, areas with a high abundance of large carabid beetles should be selected. Moreover, carabid beetles are regarded as a good indicator of other arthropod diversity (Rainio and Niemela, 2003); therefore, sites with a high abundance of carabids may also be good sources of other prey for *M. myotis*, but this hypothesis requires further study. However, this species is an opportunistic predator in Europe. Their diet is related to the abundance and detectability of prey. In other regions, as outlined above, *M. myotis* prefers not only carabids but also crickets, mole crickets, and spiders in their spring and summer diet (Pereira et al., 2002; Wolz, 2002; Whitaker and Karataş, 2009, 2010). Thus, knowledge of local food preferences is required for the successful conservation of this species.

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