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Phenology, diet, and ectoparasites of Leisler's bat (*Nyctalus leisleri*) in the Western Carpathians (Slovakia)

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In the Western Carpathians (central Slovakia), we recorded *Nyctalus leisleri* in six foraging habitats. The body condition of foraging females and young varied during the season (May to August). Parturition occurred about mid-June and the first flying young were captured in the first half of July. The ectoparasites were recorded in 56.5% of examined bats and comprised seven arthropod species of mites, fleas and flies; the most common were the mites *Spinturnix helvetiae* (55.4%) and *Steatonyssus spinosus* (31.3%). Pregnant females were the most infested. Ectoparasitic flies *Nycteribia latreillii* and *Nycteribia* (*Acrocholidia*) *vexata* were recorded for the first time in this species. Seven orders of insects were found in the faecal pellets examined. By frequency (F%) and volume (V%), the major food items comprised Lepidoptera (F = 100.0, V = 55.7) and Diptera (F = 91.5, V = 25.6). The four most abundant prey categories by volume varied significantly seasonally.

Key words: *Nyctalus leisleri*, diet, ectoparasites, parasite load, phenology, roosts

INTRODUCTION

Leisler's bat *Nyctalus leisleri* (Kuhl, 1817) is a typical European forest bat. It is distributed over most of Europe except for much of Scandinavia and northern Russia, stretching to North-West Africa and South-West Asia (Shiel, 1999; Bogdanowicz and Ruprecht, 2004). In Europe, the species ranges from low elevation floodplains (e.g., Ruczyński and Ruczyńska, 2000) up to montane forests (e.g., Hrúz *et al*., 2000; Spitzenberger and Bauer, 2001). Roosts are located exclusively in tree-hollows (Ruczyński and Bogdanowicz, 2005), except Ireland, where nursery colonies occupy roof attics (Shiel and Fairley, 1999). This medium-sized insectivorous bat (forearm length 39–47 mm, body mass 8–20 g — reviewed by Bogdanowicz and Ruprecht, 2004), specialises in aerial (or along vegetation) fast hawking. It hunts small to medium-sized insects (e.g., Nematocera, Trichoptera, Coleoptera, and Lepidoptera — Beck, 1995; Vaughan, 1997; Shiel *et al*., 1998, 1999; Waters *et al*., 1999; Fuhrmann *et al*., 2002).

Regarding ectoparasites of *N. leisleri*, some species-specific mites have been identified in Europe (Deunff *et al*., 1986; Estrada Peña and Sánchez Acedo, 1988; Fain *et al*., 2003; see also Bogdanowicz and Ruprecht, 2004). This species is also parasitized by some polyphagous mites (Andrejko, 1973; Estrada Peña *et al*., 1988; Haitlinger and Walter, 1997; Baker and Craven, 2003), fleas (Hopkins and Rothschild, 1956;

Beaucournu and Launay, 1990; Walter, 2004), and flies and bugs (Andrejko, 1973; Walter, 2004).

Our present knowledge of the ecology of *N. leisleri* comes mainly from western (e.g., Ohlendorf and Ohlendorf, 1998; Fuhrmann *et al*., 2002; Schorcht, 2002) and northern Europe (e.g., Shiel *et al*., 1998, 1999; Shiel and Fairley, 1999), where the forest environment has been considerably changed, which contrasts with the relatively natural conditions in the Western Carpathians. In this relatively undisturbed environment, there is an absence of data on the ecology of *N. leisleri* (cf. Danko *et al*., 2004). The purpose of this study is to broaden the scope of understanding about some selected aspects, including reproductive phenology, roosts, site fidelity, ectoparasites, parasite load, and food composition.

Materials and Methods

Data were collected in six localities across the mountains and basins of the Western Carpathians (Pliešovská kotlina Basin, Zvolenská kotlina Basin, Kremnické vrchy Mts. and Nízke Tatry Mts.; 48°28'–48°54'N, 19°02'–19°31'E, central Slovakia). *Nyctalus leisleri* was captured in various habitats (370–700 m a.s.l.) including: pastured oak woodland (locality 1), mixed forest-park stand (2), traditional farming area with a mosaic of habitat types (3), riparian stand (4), oak-beech forest (5) and mountainous fir-beech-spruce forest (6 — see Fig. 1).

Altogether, 179 individual bats were captured and banded (under permission from the Ministry of Environment of the Slovak Republic) from early May to late August in 2003 and 2004. Bats were mostly caught in mist-nets (2.5 m high × 7–14 m wide) set over small pools or creeks during evening (71% of individuals). At two localities (Nos. 1 and 2) mist-nets were set regularly at two-week intervals (see also Kaňuch and Krištín, 2005). In the four other localities, mist-netting occurred irregularly. Additionally, 59 females (29%) were harp-trapped at a tree-hollow roost.

Captured individuals were sexed and their reproductive state (pregnant or lactating) was determined. Age was specified only for young in their first season. Young bats were distinguished by the presence of cartilaginous epiphyseal plates in their finger bones, visible when the wing was trans-illuminated (Anthony, 1988). Other individuals were classified as adults. Forearm length and body mass were measured in 172 individuals (owing to recaptures, 20 bats were measured twice and one three times — Table 1). Body condition of females and young was assessed with a Body Condition Index, which was calculated as body mass (g)/forearm length (mm), multiplied by 44.4 mm (the average forearm length of an adult female — Ransome, 1995).

The presence of ectoparasites was determined for 177 bats. All macroscopically found ectoparasites were sampled and stored in 96% ethyl alcohol. Mites were mounted in 'Liquid de Swan', fleas (after bleaching) in 'Canadian balsam', and were identified under a dissecting microscope (Whitaker, 1988). Parasite load was classified into three levels (1: 1–5; 2: 6–10; 3: > 10 individual parasites per bat without identification of parasite species). The parasite load was statistically assessed for three reproductive periods (pre-parturition, post-parturition, weaning time — separately for females and young) and also for individually recaptured females (pre-parturition versus post-parturition). Parasite load data were not normally distributed, and so we used non-parametric tests. The Kruskal-Wallis test was applied to determine if there were differences among reproductive periods. Once ie was determined that differences existed there, the Bonferroni post-hoc test was used for pair-wise comparison. A Wilcoxon matched-pairs test

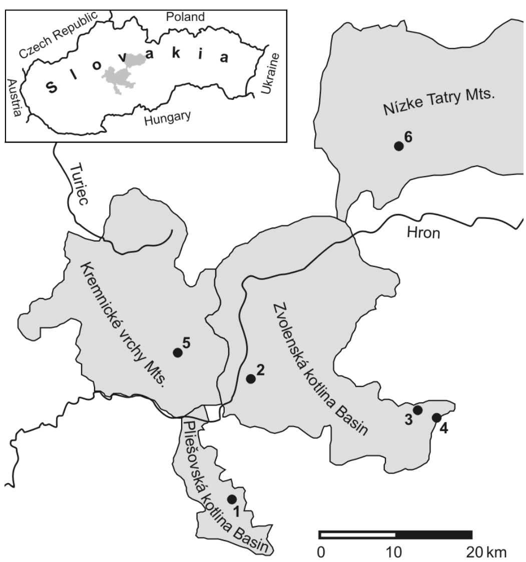

FIG. 1. Study localities of *N. leisleri* in the Western Carpathians in central Slovakia (1 — Gavurky, 2 — Sliač, 3 — Blato, 4 — Hriňová, 5 — Železná Breznica, 6 — Jasenie

TABLE 1. Body measurements according to sex and age category of *N. leisleri* from the Western Carpathians (n = 172; 20 of them were measured twice and one three times)

Category	n	Forearm length			Body mass		
		$\bar{x}$	SD	min–max	$\bar{x}$	SD	min–max
Males	2	43.10	1.60	41.5–44.7	15.05	0.55	14.5–15.6
Pregnant females	70	44.32	1.30	41.4–48.5	18.25	2.17	14.1–23.5
Lactating females	62	44.39	1.37	41.6–48.5	15.27	3.25	5.5–21.8
Non-reproducing females	17	44.75	1.22	41.3–46.8	15.32	1.73	10.8–18.0
Young males	13	42.87	0.84	41.7–44.6	14.04	1.83	10.6–16.5
Young females	30	43.87	0.91	42.1–45.9	14.17	2.13	10.6–17.8

was used to assess if there was a difference in parasite load between recaptured females.

Diet was determined by analysing faecal pellets. Captured bats were kept for about 10 minutes in cloth bags until they defecated. Arthropod fragments in bat droppings were identified using a method similar to McAney *et al*. (1991). Qualitative and quantitative structure of food composition was estimated through the volume of prey category in one dropping (V%) and frequency of occurrence in faecal pellets (F%) (according to Rydell and Petersons, 1998). In total, 154 droppings from 47 individuals captured at three localities (Nos. 1, 2 and 5) were collected. One-way MANOVA was used to determine if diet composition varied with season (May–August). Due to irregular dropping sampling and small sample size no comparison was performed between study localities.

RESULTS

Reproductive Phenology

Body condition of foraging females and young varied during the season (Fig. 2). Body mass of pregnant females increased from May to the end of June (maximum body mass 23.5 g — Table 1). Based on the occurrence of already-lactating and still-pregnant females, we conclude that parturition occurred between mid- and late June (the first lactating females were captured on 16 June). After parturition, the body mass of reproductive females decreased (by up to 5.5 g), in contrast to the average body mass

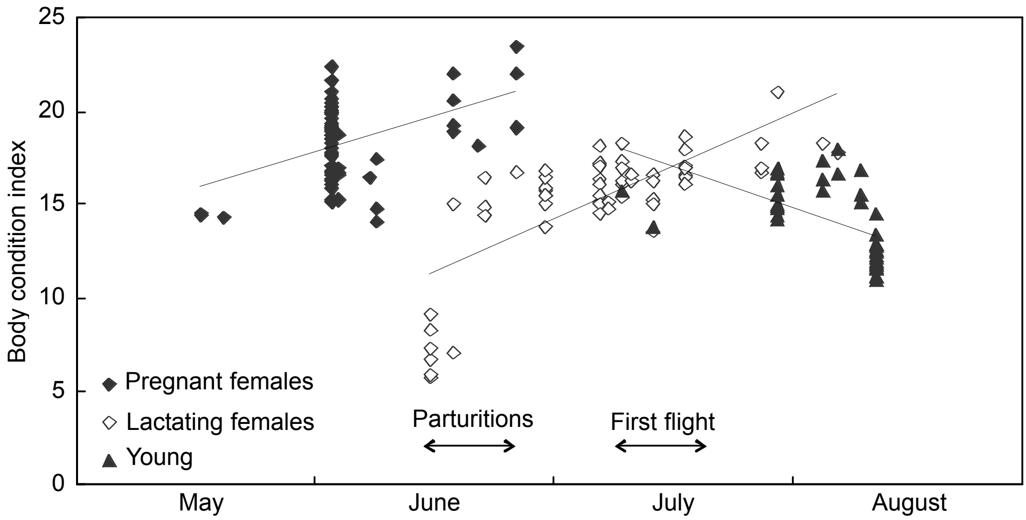

FIG. 2. Variation of body condition index of adult females (according to reproduction stage) and flying young of *N. leisleri* with time of parturition and first flights of young during the season (70 pregnant ♀♀, 62 lactating ♀♀, 43 young)

of non-reproductive adult females (15.3 g). Over the course of the season, body mass of the lactating females increased, whereas the body mass of young slightly decreased at weaning (between the first flights and last suckling). On average, the body mass of volant young was similar to that of adults (Table 1). The first flying young were caught in 11 July 2003. Except females and young, only two adult males were captured during the study, both at locality 1 in 11 July 2003 and 27 June 2004.

Roosts and Site Fidelity

In the study area, two roosts of *N. leisleri* were found randomly in 18 July 2002 and 3 June 2003. Both were located in tree-hollows: first in natural crevice (in ash *Fraxinus excelsior*, 10 m above ground, in locality 2 — see Fig. 1), and second in woodpecker hollow (in oak *Quercus robur*, 5 m above ground, in locality 1). They are the first known nursery roosts in the Western Carpathians. In the first case 43 individuals of *N. leisleri* left during the evening emergence (at this time, flying young had been mist-netted). The second roost contained at least 67 *N. leisleri* (50 pregnant and nine non-pregnant females were harp-trapped but at least eight other bats avoided the trap). One adult male *N. noctula* roosted in the tree with these females, but no male *N. leisleri* was present. Prior to the bat occupation, a pair of European starlings *Sturnus vulgaris* had bred in the tree-hollow.

At the two regularly mist-netted localities (Nos. 1 and 2), 20 adult females were recaptured once and one female twice in the two study years. Half of the recaptures occurred the summer after banding. All bats were recaptured at the former locality (19 ♀♀ at locality 1, one at locality 2). None of the 24 young banded in the first year of study were recaptured in the second year.

Ectoparasite Load

The ectoparasite taxa found on *N. leisleri* in the study area comprised seven arthropod species from three orders: mites — *Steatonyssus spinosus* (family Dermanyssidae), *Macronyssus flavus* (Macronyssidae), *Spinturnix helvetiae* (Spinturnicidae); fleas — *Ischnopsyllus intermedius*, *I. variabilis* (Ischnopsyllidae); and flies — *Nycteribia latreillii*, *N.* (*Acrocholidia*) *vexata* (Nycteribiidae). A hundred (56.5%) of all examined bats (n = 177) were infested by at least one ectoparasite individual. Ectoparasite samples were collected from 72 individuals. Only 15.3% of the ectoparasite-positive individuals had two ectoparasite species; most had only one. The most frequent ectoparasite found were the mites *S. helvetiae* (55.4%) and *S. spinosus* (31.3%). Fleas and flies were rare (Fig. 3).

Relating parasite load to various periods, significant differences were found (Kruskal-Wallis test; $H_3 = 55$, $n = 177$, $P < 0.001$). Parasite load was caused mainly by permanent parasites (two most frequent mite species). The most heavily infested were pregnant females (pre-parturition). During the suckling period (post-parturition), there was a distinct decrease in the parasite load of adult females (Bonferroni's pairwise comparison; mean difference ± SE = 0.72 ± 0.10, $P < 0.001$). Consecutively, there was found an increase in the parasite load of weaned young (mean difference ± SE = -0.69 ± 0.17, $P < 0.001$) (Fig. 4). The same trend was evident for recaptured individuals. All recaptured females (n = 18) had the same or lower parasite load post-parturition in comparison with pre-parturition (Wilcoxon matched pairs test; $Z = 3.29$, $P < 0.001$).

Diet composition

Seven orders of insects were identified (n = 154 faecal pellets). Altogether nine

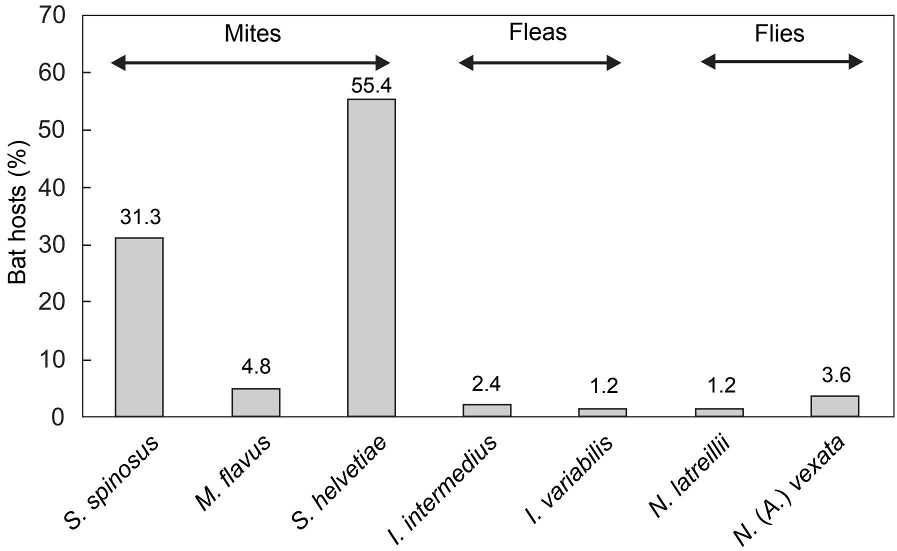

FIG. 3. Occurrence (frequency %) of individual ectoparasite species in *N. leisleri* (n = 72 parasitized bats)

taxonomic groups of insects were found; Aphididae (Homoptera), Heteroptera, Chrysopidae (Neuroptera), Coleoptera, Ichneumonidae and Formicidae (Hymenoptera), Lepidoptera, Nematocera and Brachycera (Diptera). Based on frequency and volume, the principal prey of *N. leisleri* comprised Lepidoptera (F = 100.0, V = 55.7) and Diptera (F = 91.5, V = 25.6); the proportions of the other insect groups were relatively similar (apart from Homoptera — see Fig. 5). All insect groups identified presented flying stages. Comparison of the volumes in pellets for the four most abundant prey categories exhibited a significant seasonal trend (one-way MANOVA; Wilks' λ = 0.579, $P < 0.05$). During the summer (May–August), the volume of Diptera, Hymenoptera and Coleoptera increased in contrast to a decrease in Lepidoptera (Fig. 6).

FIG. 4. Parasite load ($\bar{x}$ + SD) in *N. leisleri* in three reproduction periods (71 ♀♀ in pre-parturition, 47 ♀♀ in post-parturition, 14 ♀♀ and 43 young during weaning)

DISCUSSION

In our study area, parturition in *N. leisleri* occurred at the same time as in neighbouring Austria (Spitzenberger, 1992). The first independently flying young were observed in early July, similar to Ireland (Shiel and Fairley, 1999). The marked difference (> 15 g, representing more than 100% of mean mass) between the body mass of near-term females and females immediately after parturition might be also due to two embryos (cf. Ohlendorf, 1983). Lactating females gained body mass steadily with time. The postnatal growth curves for bat young are similar to those of birds; a mass decline between the first flight and full weaning is common also in the vespertilionid bats (as reviewed in Tuttle and Stevenson, 1982). The rare occurrence of

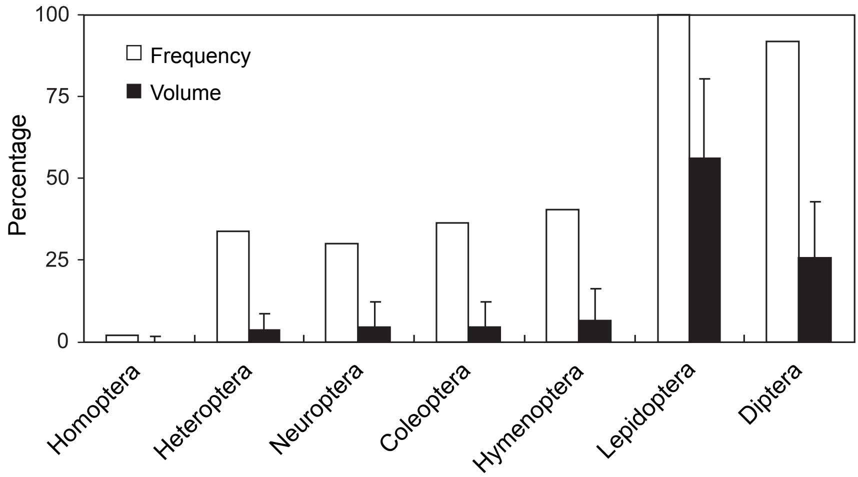

FIG. 5. Food composition of *N. leisleri* (154 pellets from 47 bats) captured in the Western Carpathians

adult males during the summer suggests that the sexes are separate at this time in the study area. As Ohlendorf and Ohlendorf (1998) noted, the sexes probably reunite just during mating period (late August and early September) in the resident areas.

Previously only 192 *N. leisleri* had been banded from 1948–2000 on the whole territory of the former Czechoslovakia, and only 12 recaptures had been reported (all within that area — Gaisler *et al*., 2003). Only one movement from Poland to Slovakia had previously been documented (Vachold, 1959). The different rates of recaptures in our two regularly mist-netted localities (locality 1 = 19.4%, n = 108; 2 = 1.9%, n = 54) may indicate that local population densities differ, but our methods could be biased (e.g., one-shot mass harp-trapping in locality 1).

The species-specific mite *S. helvetiae* (see Deunff *et al*., 1986) was discovered as the most frequent ectoparasite of *N. leisleri* in our study area. It has also been reported in adjacent Poland (Ferenc and Mysłajek, 2003). Other species-specific mites, such as *Steatonyssus balcellsi*, described from the Canary Islands (Estrada Peña and Sánchez Acedo, 1988), or *Macronyssus leislerianus*,

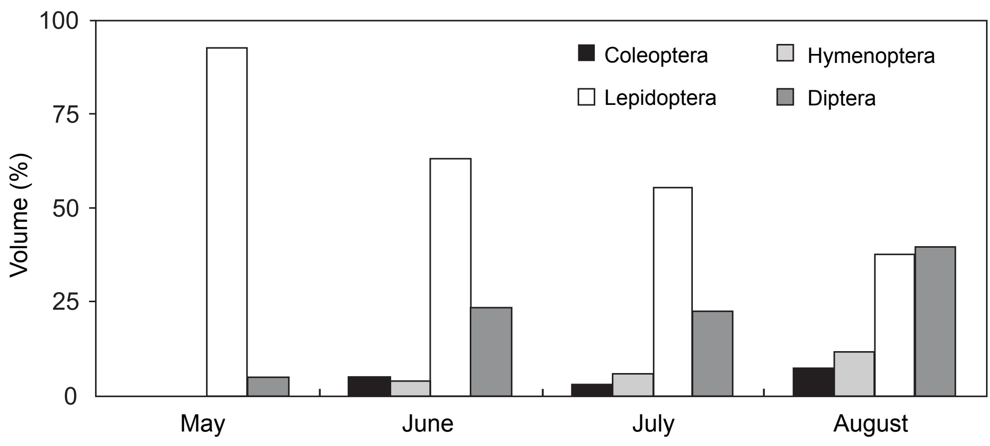

FIG. 6. Changes in composition of the four most abundant prey categories of *N. leisleri* during the season (n = 3 bats/10 pellets in May, 12/38 in June, 21/64 in July, 11/42 in August)

described from Germany (Fain *et al.*, 2003), were not discovered during the present study. Records of mites *S. helvetiae* and *M. flavus* were the first findings of these parasites in Slovakia.

The fleas *I. intermedius* and *I. variabilis* were less numerous — they occur similarly in other European countries (cf. Hopkins and Rothschild, 1956; Beaucournu and Launay, 1990; Walter, 2004; see also Bogdanowicz and Ruprecht, 2004). The flies *N. latreillii* and *N.* (*Acrocholidia*) *vexata* were recorded for the first time in this species (cf. Bogdanowicz and Ruprecht, 2004). Neither flies *Nycteribia kolenatii* and *N. pedicularia* nor the tick *Argas* (*Carios*) *vespertilionis* and bugs of the genus *Cimex* were discovered in Slovakia (cf. Andrejko, 1973; Estrada Peña *et al.*, 1988; Haitlinger and Walter, 1997; Bogdanowicz and Ruprecht, 2004; Walter, 2004).

Frequent switching between roosts is typical of tree-dwelling bats. One theory for this behaviour is that it serves to reduce parasite numbers (Lewis, 1995). The intensity of roost switching by the pallid bat *Antrozous pallidus* correlated positively with the parasite load of temporary parasite species (flies, ticks) at the roost (Lewis, 1996). We found a parasite load decrease in females after the parturition. Tree-dwelling females cluster in the largest aggregations prior to parturition (Červený and Bürger, 1989; Lučan, 2001), presumably for thermoregulatory reasons, but thereby incur a larger parasite load (cf. Tuttle and Stevenson, 1982). The increase in colony size due to newborns in a tree-hollow's limited space may compel bats to occupy new and parasite-free tree-hollows (cf. Lučan, 2001); and in case of permanent parasite species (mites), the parasites of females can switch onto their young during suckling. The increasing parasite load of young shortly afterwards (during weaning) could be explained by the parasite's natural development and higher attractiveness of young bats for blood-suckling parasites (Christe *et al.*, 2000).

Moths and flies are an important food component for *N. leisleri* also in other parts of its range (reviewed by Bogdanowicz and Ruprecht, 2004). Based on the size of insect body fragments in droppings, we surmise most prey are 10–20 mm long, thus confirming the bat as a specialist hunter of small and medium-sized insects (cf. Beck, 1995; Shiel *et al.*, 1998, 1999; Waters *et al.*, 1999; Fuhrmann *et al.*, 2002). In our study area, moths were the most important food by volume and frequency, although this may be an overestimate, because moth wing scales are a conspicuous component of bat faeces and represent a large volume share, despite bats consuming small numbers of moths (see Robinson and Stebbings, 1993). In contrast, the relatively low volume of small 'soft' insects (e.g., Homoptera) may be underestimated because they are more easily digested by bats. Caddisflies (Trichoptera), mentioned in Beck (1995) and Waters *et al.* (1999), were probably unimportant because water habitats were lacking. The increase in seasonal volume of flies, hymenopterans and beetles (and contrary decrease of moths) in *N. leisleri* food item composition probably only reflects the gradual increase in activity these insect groups as summer progresses, providing supplementary evidence of foraging opportunism of this fast-hawking bat species (cf. Fuhrmann *et al.*, 2002).

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