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# Diet of *Eptesicus serotinus* in an agricultural landscape

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**Abstract**. The diet of *Eptesicus serotinus* maternity colony was investigated in southern Moravia (Czech Republic) by means of faecal pellet analysis. Samples were collected from beneath the roost throughout the summers of 1993 and 1995. Coleoptera and Diptera were the most frequent items found in faeces. Samples from individual years did not differ (chi-square test, p=1.00). There were differences in insect prey consumed during particular months, with greatest diversity occurring in July. Opportunistic foraging was an important strategy used at certain times of the year.

**Serotine, maternity colony, prey composition, seasonal changes, Czech Republic**

## Introduction

Farming practices in industrialised countries changed fundamentally during the second half of the 20th century, with increased use of pesticides (particularly herbicides) and synthetic fertilisers. Such agricultural intensification has resulted in large-scale changes in the landscape and increasing pressure on biodiversity (Stahlschmidt et al. 2012). Agriculture has become the most important form of land use in Europe, with 34% of terrestrial area used for crop production and 14% as grassland (Verburg et al. 2006). Moreover, mathematical models indicate that the lowest ecosystem quality values are found in intensively used lowland agricultural areas (Reidsma et al. 2006).

Agricultural landscapes usually represent mosaics of human land-use and remnant natural systems. In some areas of Europe, such as southern Moravia (Czech Republic), open agricultural landscapes predominate. These so-called "agrocoenoses" are considered homogeneous matrices that offer suboptimal conditions for bats (Gaisler & Kolibáč 1992). Landscape elements such as linear hedgerows and tree lines or solitary trees, important for orientation of foraging bats (Verboom & Huitema 1997), are often missing. In addition, food availability has declined following a large-scale pesticide application.

The serotine bat, *Eptesicus serotinus* (Schreber, 1774), is a widespread species found all over Europe and is one of the most common bats in the Czech Republic (Anděra & Hanák 2007). It occurs mainly in warm lowland regions, including agricultural landscapes. *Eptesicus serotinus* establishes maternity colonies in buildings and other human structures and is among the most abundant urban species (Hanák et al. 2009).

The flight of *E. serotinus* is highly manoeuvrable and the species is recognised as one of the slow aerial hawkers, species that forage during slow flight (approx. 15 km/h) at a height of 5 to 10 metres above the ground (Norberg & Rayner 1987). Gleaning of prey from leaves and the ground has also been registered as an additional strategy (Catto et al. 1996). Its loud echolocation signals, with maximum energy at 24–27 kHz, are readily distinguished in the field by means of bat detectors (Řehák 1999). *Eptesicus serotinus* forages in a wide range of habitats, including rural habitats (mainly around village streetlamps), gardens, forest edges, tree lines and meadows;

and even over water or rubble sites (unpubl. data, Catto et al. 1996). Foraging bats can opportunistically switch between habitats, not only during a season but even during one night (unpubl. data, Bartonička & Zukal 2003).

Data on *E. serotinus* foraging behaviour and diet in Europe are limited, there having been only one similar study undertaken in agricultural habitats typical of Central Europe (Gajdošík & Gaisler 2004). The latter study confirmed Coleoptera as the most important prey hunted in open uncluttered habitats. The main aim of this study was to investigate the trophic niche of *E. serotinus* in anthropogenically influenced south-Moravian habitats and to describe any variability over two seasons.

## Material and Methods

Faecal pellets were collected from polythene sheets spread beneath a known *E. serotinus* maternity roost (the colony consisted of about 35 females) in the loft of a church at Brod nad Dyjí (48° 52' N, 16° 32' E) in the summer seasons of 1993 and 1995. The locality is mainly surrounded by agrocoenoses (fields, windbreaks, vineyards and orchards) associated with the Svratka River valley. The Nové mlýny reservoir system (over 3000 ha total water surface) is an important landscape element in this region.

Sampling took place in the morning, when the bats returned to the roost, at approx. monthly intervals during the first half of months in 1993 and the second half in 1995, with just one exception (22 July). From the pellets collected, 25 were taken as a main sample and further 25 as a spare sample; each of the samples being deposited in a separate plastic tube. In total, 250 *E. serotinus* pellets were analysed, of which 150 (6 samples) came from 1993 and 100 (4 samples) from 1995. The pellets were soaked in 96% ethanol for 24 h, and then teased apart (in glycerol) on a Petri dish underlain with a millimetre grid under a binocular microscope (Gajdošík & Gaisler 2004). The number of identifiable and unidentifiable items was determined and their percentage and frequency of occurrence estimated. Insect fragments were identified with the help of entomological books (e.g. Chinery 1981), previous papers focussed on bat diet (see Whitaker 1988), and a reference collection of whole insects trapped in the vicinity of the roost.

Variation in the diet between years was tested using the chi-square test. Pearson's correlation coefficient was used to explore the relationship between various food items and date of sampling. Trophic niche breadth was estimated from faecal samples on the basis of Levin's index (Krebs 1989). This index ranges from 0 to n, n corresponding to the number of prey categories (8 insect orders in this study). The statistics were performed using Statistica for Windows, StatSoft Inc., Tulsa, OK, USA (Zar 1998).

## Results

The diet of *E. serotinus* maternity colony under study consisted of eight insect orders (Table 1). Beetles (Coleoptera – Carabidae and Scarabaeidae) and small true flies (Diptera – Chironomidae) were dominant in the diet, making up from 40 to 90% of prey items. Opportunistic foraging on swarming insects (Hymenoptera – Formicidae and Ichneumonidae, and Heteroptera – Lygaeidae and Corixidae) was dependent on the time of the year. There was no significant difference in the insect prey types consumed between 1993 and 1995, neither by percentage occurrence nor percentage frequency (chi-square = 1.05; DF=19; p=1.00; and chi-square = 0.58; DF=19; p=1.00, respectively). Therefore, the data from both years were pooled for subsequent analysis.

The diversity of insect prey consumed increased significantly during the season ($r=0.69$; $p<0.05$), with the highest dietary diversity observed in July (Levin's index). The average number of consumed items continued to increase till September ($r = 0.93$; $p < 0.05$; Fig. 1). Small Diptera were most frequently caught in May and subsequently declined in importance (Table 2), while Heteroptera were dominant at the end of the season. Beetle fragments (Coleoptera) were most commonly found in August, as were remains of moths (Lepidoptera; Fig. 2). Opportunistic foraging on swarming insects was recorded as an important factor of foraging behaviour at different times of the year.

Table 1. Diet composition of an *Eptesicus serotinus* maternity colony at Brod nad Dyjí

| item | abundance | | | frequency [%] | | | occurrence [%] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1995 | total | 1993 | 1995 | total | 1993 | 1995 | total |
| Carabidae | 59 | 46 | 105 | 22.8 | 26.0 | 24.1 | 39.3 | 46.0 | 42.0 |
| Curculionidae | 1 | | 1 | 0.4 | | 0.2 | 0.7 | | 0.4 |
| Diversicornia | 1 | | 1 | 0.4 | | 0.2 | 0.7 | | 0.4 |
| indet. | 11 | 6 | 17 | 4.2 | 3.4 | 3.9 | 7.3 | 6.0 | 6.8 |
| Scarabeidae | 29 | 8 | 37 | 11.2 | 4.5 | 8.5 | 19.3 | 8.0 | 14.8 |
| Coleoptera total | 101 | 60 | 161 | 39.0 | 33.9 | 36.9 | 67.3 | 60.0 | 64.4 |
| Chironomidae | 90 | 51 | 141 | 34.7 | 28.8 | 32.3 | 60.0 | 51.0 | 56.4 |
| indet. | 2 | 1 | 3 | 0.8 | 0.6 | 0.7 | 1.3 | 1.0 | 1.2 |
| Muscoidea | 1 | | 1 | 0.4 | | 0.2 | 0.7 | | 0.4 |
| Diptera total | 93 | 52 | 145 | 35.9 | 29.4 | 33.3 | 62.0 | 52.0 | 58.0 |
| Corixidae | 6 | 11 | 17 | 2.3 | 6.2 | 3.9 | 4.0 | 11.0 | 6.8 |
| indet. | 8 | 1 | 9 | 3.1 | 0.6 | 2.1 | 5.3 | 1.0 | 3.6 |
| Lygaeidae | 9 | 26 | 35 | 3.5 | 14.7 | 8.0 | 6.0 | 26.0 | 14.0 |
| Pentatomoidea | 1 | 1 | 2 | 0.4 | 0.6 | 0.5 | 0.7 | 1.0 | 0.8 |
| Heteroptera total | 24 | 39 | 63 | 9.3 | 22.0 | 14.4 | 16.0 | 39.0 | 25.2 |
| Aphidoidea | 1 | | 1 | 0.4 | | 0.2 | 0.7 | | 0.4 |
| Cixidae | 1 | | 1 | 0.4 | | 0.2 | 0.7 | | 0.4 |
| Homoptera total | 2 | | 2 | 0.8 | | 0.5 | 1.3 | | 0.8 |
| Formicoidea | 8 | | 8 | 3.1 | | 1.8 | 5.3 | | 3.2 |
| Ichneumonidae | 9 | 7 | 16 | 3.5 | 4.0 | 3.7 | 6.0 | 7.0 | 6.4 |
| indet. | 4 | 1 | 5 | 1.5 | 0.6 | 1.1 | 2.7 | 1.0 | 2.0 |
| Hymenoptera total | 21 | 8 | 29 | 8.1 | 4.5 | 6.7 | 14.0 | 8.0 | 11.6 |
| Lepidoptera total | 17 | 17 | 34 | 6.6 | 9.6 | 7.8 | 11.3 | 17.0 | 13.6 |
| Caelifera | 1 | | 1 | 0.4 | | 0.2 | 0.7 | 0.0 | 0.4 |
| Orthoptera total | 1 | | 1 | 0.4 | | 0.2 | 0.7 | 0.0 | 0.4 |
| Psocoptera total | | 1 | 1 | | 0.6 | 0.2 | | 1.0 | 0.4 |
| total | 259 | 177 | 436 | 100.0 | 100.0 | 100.0 | 172.7 | 177.0 | 174.4 |
| no. samples | 150 | 100 | 250 | | | | | | |

Table 2. Seasonal changes in *Eptesicus serotinus* food structure. Explanations: Statistically significant Pearson's correlation coefficients ($p<0.05$) between food items and date of sampling are bolded

| item | frequency [%] | occurrence [%] |
|---|---|---|
| Coleoptera | 0.43 | **0.83** |
| Diptera | **–0.83** | –0.51 |
| Heteroptera | **0.72** | **0.77** |
| Homoptera | –0.20 | –0.20 |
| Hymenoptera | 0.29 | 0.39 |
| Lepidoptera | 0.56 | **0.71** |
| Orthoptera | 0.04 | 0.04 |
| Psocoptera | 0.55 | 0.55 |
| Levin's index | **0.69** | |
| average number of items | **0.93** | |

## Discussion

In most studies (e.g. Vaughan 1997, Andreas 2002, Gajdošík & Gaisler 2004, Whitaker & Karataş 2009), *E. serotinus* is described as a beetle forager, though Diptera are also frequently recorded (Kervyn & Libois 2008). Our results confirm a similar dietary structure in south-Moravian agricultural landscapes. In our material, Coleoptera were represented at a similar level as in samples netted at a nearby locality within the same region (see Andreas 2002). Interestingly, Gajdošík & Gaisler (2004) found less beetles (56.7% percentage occurrence and 24.9% percentage frequency) in samples collected from the same locality (Brod nad Dyjí) in 1997. A recent meta-analysis of *E. fuscus* diet, however, supports the hypothesis that foraging by this species is influenced by environmental factors thought to affect abundance of arthropods (Moosman et al. 2012). In this case, bats forage selectively where favourable summer climates result in greatest availability of volant arthropods, which could also explain the observed diet of *E. serotinus* at our locality.

*Eptesicus serotinus* belongs amongst those bat species foraging in open habitats and having a higher aggregative response to insect abundance than edge-habitat and closed-habitat foragers (Müller et al. 2012). Moreover, the influence of vegetation density and temperature are of similar or even more importance for this guild than prey abundance. Our results support utilisation of opportunistic foraging by *E. serotinus*, the influence of which is clear in both the representation of other insect items in the diet (Gerber et al 1996) and seasonal variation in diet structure. The unusually high representation of Chironomidae (Diptera) in our samples probably reflects the existence of large water bodies close to our sample locality; foraging activity being recorded there by ultrasound detectors (Gajdošík & Gaisler 2004, unpubl. data). Lepidoptera were selectively caught by the bats throughout the season, most probably around village street lamps. Swarming insects (Hymenoptera, Heteroptera, Trichoptera, Neuroptera, etc.) are foraged for by aerial hawking at a wide range of habitats throughout the season (Sologor 1980, Labee & Voute 1983, Robinson & Stebbings 1993, Catto et al. 1994, Andreas 2002, Gajdošík & Gaisler 2004, Kervyn & Libois

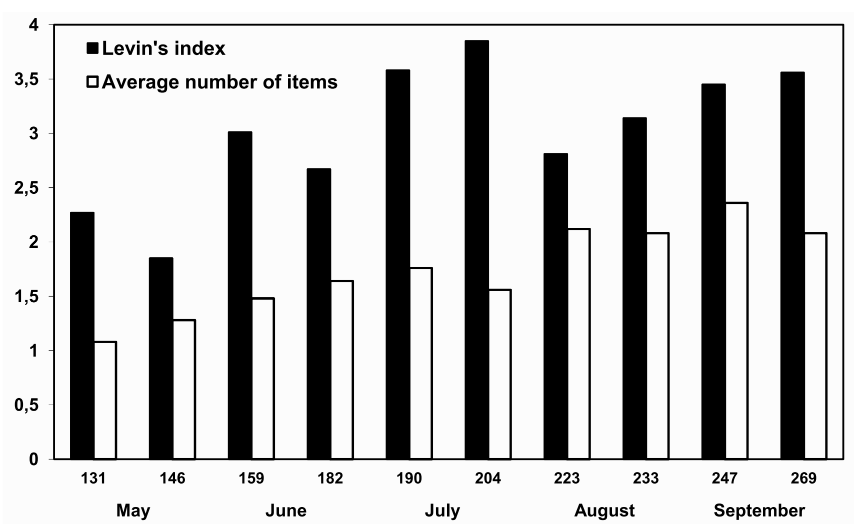


Fig. 1. Seasonal changes in prey diversity and prey niche breadth of *Eptesicus serotinus*. Explanations: x axis = serial number of a night starting from 1 January.

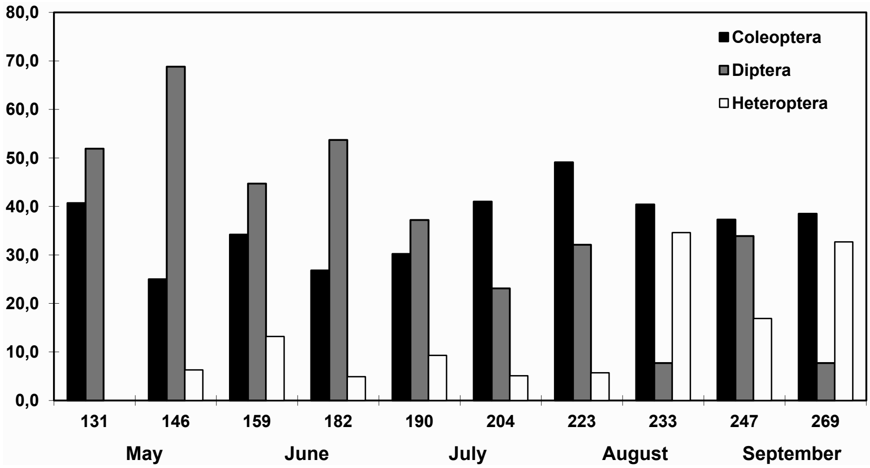


Fig. 2. Seasonal changes in frequency of the most important prey items of *Eptesicus serotinus*. Explanations: x axis = serial number of a night starting from 1 January.

2008). Occasional gleaning from the ground or other surface might also be expected; this being supported by findings of plant material and fine gravel in feaces and by telemetry studies (Kurtze 1982, Catto et al. 1996, Andreas 2002).

Overall, the diet of *E. serotinus* indicates the use of specific behaviour patterns to ensure optimum exploitation of its trophic niche (a wide variety of habitats and opportunistic foraging) and to minimise food competition with other bat species. A single foraging strategy (aerial hawking) tended to be preferred within the agrocoenosis studied; however, habitat preferences changed throughout the year (unpubl. data, Zukal et al. 1997), resulting in changes in diet structure. The ability of serotines to exploit buildings as roosts, street lamps as feeding sites, and its dependence on just a few insect groups associated with agricultural habitats has allowed this species to adjust to an environment undergoing anthropogenic change (Catto et al. 1996).

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## Literature

Anděra M. & Hanák V., 2007: *Atlas rozšíření savců v České republice. Předběžná verze. V. Letouni* (*Chiroptera*) *– část 3. Netopýrovití* (*Vespertilionidae – Vespertilio, Eptesicus, Nyctalus, Pipistrellus a Hypsugo*) [*Atlas of the Mammals of the Czech Republic. A Provisional Version. V. Bats* (*Chiroptera*) *– Part 3. Vespertilionid bats* (*Vespertilionidae – Vespertilio, Eptesicus, Nyctalus, Pipistrellus and Hypsugo*)]. Národní muzeum, Praha, 172 pp (in Czech, with a summary in English).

Andreas M., 2002: *Potravní ekologie společenstva netopýrů* [*Feeding Ecology of a Bat Community*]. Unpubl. PhD Thesis. Czech Agriculture University, Praha, 163 pp (in Czech).

Bartonička T. & Zukal J., 2003: Flight activity and habitat use of four bat species in a small town revealed by bat detectors. *Folia Zoologica*, **52**: 155–166.

Catto C. M. C., Hutson A. M. & Racey P. A., 1994: The diet of *Eptesicus serotinus* in southern England. *Folia Zoologica*, **43**: 307–314.

Catto C. M. C., Hutson A. M., Racey P. A. & Stephenson P. J., 1996: Foraging behaviour and habitat use of the serotine bat (*Eptesicus serotinus*) in southern England. *Journal of Zoology*, *London*, **238**: 623–633.

Gaisler J. & Kolibáč J., 1992: Summer occurrence of bats in agrocoenoses. *Folia Zoologica*, **41**: 19–27.

Gajdošík M. & Gaisler J., 2004: Diet of two *Eptesicus* bat species in Moravia (Czech Republic). *Folia Zoologica*, **53**: 7–16.

Gerber E., Haffner M. & Ziswiler V., 1996: Vergleichende Nahrunganalyse bei der Breitflügelfledermaus *Eptesicus serotinus* (Schreiber, 1774) (Mammalia, Chiroptera) in verschiedenen Regionen der Schweiz. *Myotis*, **34**: 35–43.

Hanák V., Neckářová J., Benda P., Hanzal V., Anděra M., Horáček I., Jahelková H., Zieglerová A. & Zieglerová D., 2009: Fauna netopýrů Prahy: přehled nálezů a poznámky k urbánním populacím netopýrů [Bat fauna of the Prague [Bat fauna of Prague: review of records with notes on the urban bat populations]. *Natura Pragensis*, **19**: 3–89 (in Czech, with a summary in English).

Chinery M., 1981: Les insectes d'Europe en couleurs. Bordas, Nemours, 380 pp.

Kervyn T. & Libois R., 2008: The Diet of the Serotine Bat – a Comparison Between Rural and Urban Environments. *Belgian Journal of Zoology*, **138**: 41–49.

Krebs C. J., 1989: *Ecological Methodology*. Harper Collins Publishers, New York, 654 pp.

Kurtze W., 1982: Beobachtungen zur Flugaktivität und Ernährung der Breitflügel-Fledermaus *Eptesicus serotinus* (Schreber). *Drosera*, **82**: 39–46.

Labee A. H. & Voûte A. M., 1983: The diet of a nursery colony of the serotine bat *Eptesicus serotinus* (Schreber, 1774) in The Netherlands. *Lutra*, **26**: 12–19.

Moosman P. R. Jr., Thomas H. H. & Veilleux J. P., 2012: Diet of the widespread insectivorous bats *Eptesicus fuscus* and *Myotis lucifugus* relative to climate and richness of bat communities. *Journal of Mammalogy*, **93**: 491–496.

Müller J., Mehr M., Bässler C., Fenton M. B., Hothorn T., Pretzsch H., Klemmt H. J. & Brandl R., 2012: Aggregative response in bats: prey abundance versus habitat. *Oecologia*, **169**: 673–684.

Norberg U. M. & Rayner J. M. V., 1987: Ecological morphology and flight in bats (Mammalia, Chiroptera): Wing adaptations, flight performance, foraging strategy and echolocation. *Philosophical Transactions of the Royal Society of London B*, **316**: 335–427.

Reidsma P., Tekelenburg T., van den Berg M. & Alkemade R., 2006: Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Ecosystems and Environment*, **114**: 86–102.

Robinson M. F. & Stebbings R. E., 1993: Food of the serotine bat, *Eptesicus serotinus* – Is fecal analysis a valid qualitative and quantitative technique? *Journal of Zoology*, *London*, **231**: 239–248.

Řehák Z., 1999: Central European bat sounds. *Nietoperze*, **1**: 29–37.

Sologor E. A., 1980: K izučeniû pytaniâ *Vespertilio serotinus* [To the knowledge of feeding in *Vespertilio serotinus*]. Pp.: 188–190. In: Kuzâkin A. P. & Panûtin K. K. (eds.): *Voprosy teriologii*. *Rukokrylye* (*Chiroptera*) [*Questions in Theriology*. *Bats* (*Chiroptera*)]. Nauka, Moskva, 320 pp (in Russian).

Stahlschmidt P., Pätzold A., Ressl L., Schulz R. & Brühl C. A., 2012: Constructed wetlands support bats in agricultural landscapes. *Basic and Applied Ecology*, **13**: 196–203.

Vaughan N., 1997: The diet of British bats (Chiroptera). *Mammal Review*, **27**: 77–94.

Verboom B. & Huitema H., 1997: The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus*. *Landscape Ecology*, **12:** 117–125.

Verburg P. H., Schulp N., Witte N. & Veldkamp A., 2006. Landscape level impacts of change in European land use: high-resolution simulations with the CLUE model. *Agriculture*, *Ecosystems & Environment*, **114**: 1–6.

WHITAKER J. O. Jr., 1988: Food habits analysis of insectivorous bats. Pp.: 171–210. In: KUNZ T. H. (ed.): *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press, Washington & London, 533 pp.

WHITAKER J.O. Jr. & KARATAȘ A., 2009: Food and feeding habits of some bats from Turkey. *Acta Chiropterologica*, **11**: 393–403.

ZAR J. H., 1998: *Biostatistical Analysis*. *Fourth Edition*. Prentice Hall Inc., Upper Saddle River, 663 pp.

ZUKAL J., GAJDOŠÍK M. & ŘEHÁK Z., 1997: The diet and foraging strategy of *Eptesicus serotinus* in southern Moravian agrocoenoses. *Bat Research News*, **38**: 30–31.

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