Insect prey of the Long-eared bat *Plecotus auritus* (L.) (Chiroptera: Vespertilionidae) in Central Russia

Насекомые в добыче ушана *Plecotus auritus* (L.) (Chiroptera: Vespertilionidae) в Центральной России

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КЛЮЧЕВЫЕ СЛОВА: *Plecotus auritus*, энтомофагия, Lepidoptera, Noctuidae, Geometridae.

SUMMARY: Diet composition of *Plecotus auritus* in the vicinity of the Zvenigorod Biological Station (Moscow Region) was analyzed by collecting insect remains under assumed feeding perches of bats. Of the collected fragments 99.4% belonged to 11 families of Lepidoptera, particularly Noctuidae (83.4% of samples), Geometridae (9.6%), Thyatiridae (2.3%), and Lymantriidae (2.3%). The dominant species (60.8% of the total sample) was *Anaplectoides prasina* (Den. et Schiff.), indicating that *P. auritus* feeds opportunistically on the most abundant prey items. However, the strong dominance of noctuids and other nocturnal moths over other insects and low Emlen's diversity index (D_v=0.6 to 0.9), despite the rather large number of prey species (35) indicated high prey selectivity of the Long-eared Bat. Foraging activity patterns and feeding tactics of *P. auritus* are discussed.

РЕЗЮМЕ: Состав кормовых объектов *Plecotus auritus* в окрестностях Звенигородской биостанции МГУ (Московская обл.) исследован путем сбора остатков насекомых под присадами летучих мышей. 99,4% собранных фрагментов принадлежали к 11 семействам чешуекрылых, в т. ч. Noctuidae (83,4% от всех проб), Geometridae (9,6%), Thyatiridae (2,3%) и Lymantriidae (2,3%). 60,8% от общей выборки составляла совка *Anaplectoides prasina* (Den. et Schiff), указывая на то, что ушан оппортунистично поедает наиболее многочисленные кормовые объекты. Однако отчетливое преобладание в пробах совок и других ночных бабочек и низкий индекс разнообразия Эмлена (D_v=0,6–0,9), несмотря на значительное общее число кормовых видов (35), указывают на высокую кормовую избирательность ушана, предпочитающего крупных бабочек. Обсуждены характер кормовой активности и кормовые тактики *P. auritus*.

Introduction

The Brown Long-Eared Bat *Plecotus auritus* (Linnaeus, 1758) occupies a somewhat remote position within the Central Russian bat community in displaying pronounced ecomorphological adaptations (large ears, low wing loading and Aspect Ratio) towards gleaning insects from substrates [Kruskop, 1998]. It is also capable of using perches to detect and consume its prey. This bat generally utilizes two foraging tactics: aerial and gleaning insectivory [Fenton, 1990; Anderson, Racey, 1993]. The latter foraging pattern could provide up to 56 % of food items [Anderson, Racey, 1991]. Despite the fact that the trophic biology of *P. auritus* is relatively well described for Western Europe, its feeding habits in the Easternmost Europe are poorly known.

The Brown Long-eared Bat is a resident species. Its hibernation sites were found in limestone caverns on the banks of Moskva River ca. 20 km upstream of the Zvenigorod Biological Station [Borissenko, Kruskop, 1997; Borissenko et al., 1999], and apparently it uses nearby woodlands as summer foraging sites. However to date no data are available on its trophic biology in the considered area. Herein we shall present some preliminary data on this subject.

Materials and methods

Study site

The work was conducted from 25 June to 4 July 1998 in the vicinity of the Zvenigorod Biological Station of

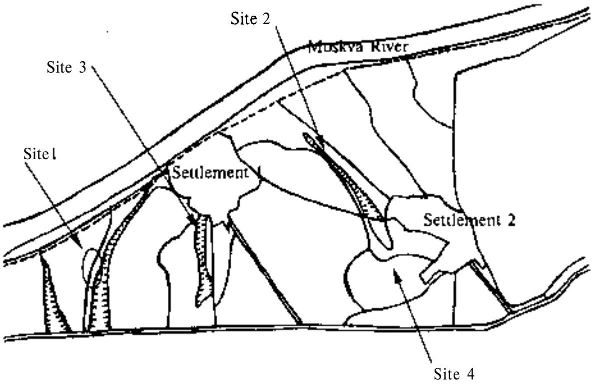

Fig. 1. The disposition of study sites in the vicinity of the Zvenigorod Biological Station.

Рис. 1. Расположение мест наблюдений в окрестностях Звенигородской биологической станции.

Moscow University (Moscow Area, Odintsovskii District, ca. 12 km W of Zvenigorod). Observations were conducted on right bank side of Moskva River on the ravined terraces above the flood-plain. The study site is covered with mixed spruce forest with limetree and oak. In several spots of the forest where the broad-leafed trees predominated, the undergrowth and forest floor were represented chiefly by nemoral elements.

Nightly temperatures were relatively stable throughout the study period, usually exceeding + 15°C. Relative humidity was around 70-80%. It rained on the following nights of 25.06, 29.06, 2.07 and 3.07.

Sampling of food remains

During the daytime search of insect remains (mostly moth wings) was conducted along established routes throughout the area under investigation. To minimize the risk of confusion with birds, a number of characteristics were used to identify these remains as belonging to *P. auritus*. We considered as such food remains that had a patchy (not solitary) spatial distribution, eventually forming aggregations under presumed perch sites (e. g., exposed branches), and appeared recurrently at least twice. Nearly all remains found during our study, were represented by wings of nocturnal moths; in several instances we found parts of the prothorax of noctuids with conjoined anterior wings and legs — a characteristic (although uncommon) type of food remains of the Long-eared Bat. The presence of such remains also confirmed our identification.

All encountered insect remains, attributable to *P. auritus*, were collected and assorted into samples, according to the date and precise location where they were taken. Only anterior wings were included in further analyses. The samples were subsequently identified with maximum precision, when possible, to the specific level. The number of anterior wings by species was calculated for each sample and tabulated. To assess the diversity of food types in each sample, Emlen's diversity index D_v was calculated Magurran, 1992]:

$$D_v = \sum_{p_i} p_i e^{p_i}$$

where is the proportion of individuals of species *i* (Table 1).

Table 1.
Number of anterior wings of insects of different families collected per sample.
Таблица 1.
Число собранных передних крыльев насекомых различных семейств по местам сбора.

Sampling site №	1							2		3	4	Total:	Proportion
Дата:	28 Jun	29 Jun	30 Jun	1 Jul	2 Jul	3 Jul	4 Jul	29 Jun	30 Jun	1 Jul	1 Jul		
Weather conditions			rain			rain	rain		rain				
Insect families:													
Noctuidae	66	50	11	41	89	4	3	5	5	9	13	296	83.4%
Geometridae	2	0	5	0	3	3	2	14	2	1	2	34	9.6%
Lymantriidae	0	0	0	2	5	0	0	0	0	0	1	8	2.3%
Sphingidae	0	0	2	0	0	0	0	0	0	0	0	2	0.6%
Cossidae	0	0	0	0	0	0	0	0	0	1	0	1	0.3%
Pieridae	2	0	0	0	0	0	0	0	0	0	0	2	0.6%
Notodontidae	0	0	0	0	0	1	0	0	0	0	0	1	0.3%
Hepialidae	0	0	0	0	0	0	0	1	0	0	0	1	0.3%
Thyatiridae	2	0	1	1	2	0	0	2	0	0	0	8	2.3%
Tabanidae	0	0	0	0	0	0	0	0	0	0	1	1	0.3%
Melolonthidae	0	0	0	0	0	0	0	0	0	1	0	1	0.3%
Total:	72	50	19	44	99	8	5	22	7	12	17	355	100.0%
Proportion	20.3%	14.1%	5.4%	12.4%	27.9%	2.3%	1.4%	6.2%	2.0%	3.4%	4.8%	100.0%	
D_v for each sample	0.6	0.7	0.8	0.6	0.6	0.8	0.8	0.9	0.7	0.8	0.8	0.7	

The data on spatial distribution and size of samples, their content and diversity of food items were used for indirect assessment of the intensity of foraging of *P. auritus* in different parts the study area.

Observations of foraging activity

Sites with most abundant and regularly appearing food remains were selected to conduct nightly observations of foraging activity of bats. These sites (Fig. 1, 1-4) represented segments of forest trails 100 to 200 m in length and their nearest surroundings. The acoustic activity of bats was monitored using a D-100 narrowband heterodyning ultrasound detector (Pettersson Elektronik AB, Sweden), tuned to 50 kHz. The echolocation signals of all detected bats were recorded using a dictaphone. Echolocation signals of *P. auritus* are heard at 50 kHz as dry clicks of low intensity and high interpulse interval [Ahlen, 1990]. The only other Central Russian bat with similar echolocation call design is *Myotis nattereri*, which has not been found at the Zvenigorod Biological Station or its surroundings. Hence we assumed that all signals matching the above characteristics belonged to the Long-eared bat. Further confirmation of the correctness of identification was made by comparing our detected signals with reference recordings, kindly provided by T. Stormark.

To make a quantitative assessment of bat activity we calculated the number of bat passes [Furlonger et al., 1987] recorded at each observation site, with respect to weather conditions.

Results and discussion

Food remains of P. *auritus* were most often encountered in parts of forest where broad-leafed elements predominated over spruce. In most of these places the food remains appeared recurrently for several nights. The well documented tendency of *P. auritus* to form piles of food remains under feeding perches [e.g., Kuzjakin, 1950; Panyutin, 1970; Kurskov, 1978; Botvinkin et al., 1998] was also confirmed in our study.

Diet composition

The bulk of the collected fragments (99.4%) belonged to Lepidoptera. The other two insect orders (Coleoptera and Diptera) represented in our samples formed only 0.3% each, and their allocation to food remains of *P. auritus* is not undoubtful, therefore we shall omit them from further consideration.

Eleven lepidopteran families were found in our samples, however, only four of them constituted more than 1% of the total sample (Table 1). The Long-eared Bat shows a strong preference to nocturnal moths, especially Noctuidae, which formed 83.4% of our samples, and also Geometridae (9.6%), Thyatiridae (2.3%), and Lymantriidae (2.3%). The devotion of P. *auritus* to noctuids as the dominant prey item has been previously reported from various parts of its distribution range [e.g., Kurskov, 1978; Anderson, Racey, 1991; Botvinkin et al., 1998].

On the specific level our samples contained 35 insect species, of which only nine represented more than 1 % of the total sample (Table 2). In all samples of sufficient size the dominant species (60.8% of the total sample) was *Anaplectoides prasina* (Den. et Schiff.) This medium-sized (weight ca. 0.3 g) forest species of noctuid belonging to the group of cutworms is confined to bush vegetation and is common from the second half of June through September [Koch, 1984; Zolotarenko, 1970]. All sites where food remains were collected had well-developed nemoral bush undergrowth. The other moth species regularly encountered are also confined to forest and are known to be present in July, around the time when the sampling took place. This finding indicates, that *P. auritus* feeds opportunistically on the most abundant prey items - a tactic considered to be characteristic of many bat species, particularly the Vespertilionidae [Fenton, 1990]. Similarly, Kurskov [1978] found that the composition of food remains of *P. auritus* was most similar to the sample made with an insect light-trap.

However, the strong dominance of nocturnal moths over other insects indicated high prey selectivity of the Long-eared Bat, as compared, for instance, with the other bat species inhabiting the surroundings of the Zvenigorod Biological Station [Borissenko et al., 1999]. Unfortunately, the extent of this selectivity cannot be established until fecal samples are analyzed, because insects of smaller size classes (hence not requiring perches to consume them) and with less conspicuous wings were undoubtedly overlooked in our study.

As could be seen in Table 1, the main differences observed between the four sites where samples of insect remains were taken is in the number of wings found. The bulk of them was collected in Site 1. Emlen's diversity index (D_v) varied between samples from 0.6 to 0.9 (0.7 on the average), indicating relatively low diversity, despite the rather large number of prey items (Table 2). This is consistent with the above notion that *P. auritus* feeds selectively.

Foraging behavior

Based on our data it was not possible to draw conclusions on the hunting behavior of the Long-eared bat, particularly whether aerial hunting or gleaning was the preferred tactic. However, we obtained indirect indications on the preferred modes of prey consumption. Many moth wings were found in more or less compact clusters (within 1 m in diameter) under small hanging branches which could presumably serve as perches during manipulations with prey. In some instances the wings were distributed rather evenly along parts of a trail and its surroundings. This may have resulted from the perches being located high in the canopy. The probability that the wings were detached from the prey in the air is less likely, due to relatively large prey size. The occurrence of wings directly under trees implies that the bat may also use tree trunks as perches.

In several instances in Site 1, wings, legs and parts of prothorax of moths were found on large horizontal logs

Table 2. Species of insects found among food remanis of P. *auritus*.
Таблица 2. Виды насекомых из кормовых остатков P. *auritus*.

Family	Species of insects:	Number of anterior wings	% total sample	Average number per sample
Noctuidae	*Abrostola trigemina* (Werneb.)	1	0.3	0.09
	Acronicta leporina (L.)	2	0.6	0.18
	Acronicta megacephala (Den. et Schiff.)	1	0.3	0.09
	Anaplectoides prasina (Den. et Schiff.)	216	60.8	19.64
	Apamea remissa (Hbn.)	2	0.6	0.18
	Apamea lateritia (Hfn.)	1	0.3	0.09
	Diarsia sp.	1	0.3	0.09
	Euplexia lucipara (L.)	1	0.3	0.09
	Hyppa rectilinea (Esp.)	2	0.6	0.18
	Lacanobia contigua (Den. et Schiff.)	1	0.3	0.09
	Lacanobia oleracea (L.)	1	0.3	0.09
	Lacanobia thalassina (Hfn.)	4	1.1	0.36
	Melanchra persicariae (L.)	13	3.7	1.18
	Polia bombycina (Hfn.)	2	0.6	0.18
	Polia hepatica (Cl.)	2	0.6	0.18
	Polia nebulosa (Hfn.)	22	6.2	2.00
	Pseudoips fagana (F.)	2	0.6	0.18
	Oligia latruncula (Den. et Schiff.)	12	3.4	1.09
	Oligia strigilis (L.)	1	0.3	0.09
	gen. sp.	9	2.5	0.82
Geometridae	*Alcis repandata* (L.)	3	0.8	0.27
	Biston betularia (L.)	1	0.3	0.09
	Cabera pusaha (L.)	9	2.5	0.82
	Hylaea fasciaha (L.)	1	0.3	0.09
	Lomographa temerata (Den. et Schiff.)	1	0.3	0.09
	Semiothisa alternaria (Hbn.)	4	1.1	0.36
	Xanthorhoe montanata (Den. et Schiff.)	2	0.6	0.18
	Xanthorhoe sp.	1	0.3	0.09
	gen. sp.	12	3.4	1.09
Lymantriidae	*Leucoma salicis* (L.)	1	0.3	0.09
	Calliteara abietis (Den. et Schiff.)	7	2.0	0.64
Sphingidae	*Hyloicus pinastri* (L.)	2	0.6	0.18
Cossidae	*Cossus cossus* (L.)	1	0.3	0.09
Pieridae	*Pieris napi* (L.)	2	0.6	0.18
Notodontidae	*Pheosia gnoma* (F.)	1	0.3	0.09
Hepialidae	*Hepialis humuli* (L.)	1	0.3	0.09
Thyatiridae	*Habrosyne pyritoides* (Hfn.)	2	0.6	0.18
	Theteela fluctuosa (Hbn.)	6	1.7	0.55
Tabanidae	gen.sp.	1	0.3	0.09
Melolonthidae	*Melolontha* sp.	1	0.3	0.09
Total:		355		

covered with moss. Apparently the insect was consumed directly on this horizontal substrate. This is advantageous in that the probability of prey loss during manipulations is minimal. Considering the plasticity of foraging tactics of *P. auritus*, it is possible that the bat could have descended to manage the insect it captured. There is another possibility that these moths could have been eaten by shrews (e.g., *Sorex minutus*), however, the remains of moths were found in rather exposed places ca. 0-5 m above the ground, which is not a characteristic foraging territory for shrews.

Observations of feeding captive *P. auritus* [Borissenko, unpublished] indicate that the bats utilize both horizontal and vertical substrates to manipulate with large insects, frequently preferring the latter to free hanging on perches. While on a vertical wall, they often turn right side up, their wings and interfemoral membranes forming a pouch to collect accidentally dropped prey. Unfortunately no direct observations of foraging behavior of free-living Long-eared bats were made in this study.

Foraging activity

P. auritus is known to have continuous nocturnal activity during the darkest period of the night [Rakhmatulina, 1998]. In our study the echolocation signals of this bat were registered as early as 23.15 (nearly 1 hour after sunset), and as late as 4.15 (ca. 35 min. before sunrise). Most passes were detected between midnight and 3.00. As indicated by ultrasound detection, bat activity was confined to places, where insect remains were found during the daytime. At Site 1, where most of the insect remains were found, registered activity was on the average 6 bat passes/hour, whereas at the remainder sites this parameter decreased by several times to as low as 1-2 passes per night or no activity at all. Thus ultrasound detection observations are consistent with the results of sampling insect remains in showing the strongly uneven pattern of habitat use by *P. auritus*. The number of passes per unit time decreased considerably during bad weather (heavy rain). This corresponds to the decrease in the number of moth wings collected after rainy nights at Site 1 (Table 1).

Considering that the Long-eared bat tends to forage in proximity of its day roosts [Rakhmatulina, 1998], our findings indicate that a colony of this species could have been residing nearby during the work period. The maximum number of anterior wings found after one night at Site 1 (50-99) corresponds to 25-50 moths consumed by the bats. This is undoubtedly underestimated, since we were unlikely to retrieve the remains of all captured moths (not to mention other insects). One individual *P. auritus* ingests a maximum of 1/3 of its own weight, or ca. 2.5-3 g. Omitting the non-edible parts, this should correspond to a maximum of 15 moths the size of *A. prasina*. Thus the number of individuals foraging at Site 1 each night could be estimated as at least 2-4. This is approximately the average number of breeding female *P. auritus* living in one day roost [Likhachev, 1980]. Site 1 has many trees potentially suitable as roosting sites for the Long-eared Bat, however a search for day roosts in the surrounding forest did not yield positive results.

It was approximately the same site that a nursing colony of 4–5 *P. auritus* was found by L.A. Lavrenchenko in early July 1973 in a wooden bird box. This is by far the only record of the Long-eared bat colony in the vicinity of the Zvenigorod Biological Station.

In late June and early July 1999 the same sites as in 1998 were searched for insect remains, and ultrasound detection was conducted for several hours. However, no insect remains were found and no signals definitely referable to *P. auritus* were detected. It is possible that the colony could have moved to an area with better foraging conditions.

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