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Use of Forest Tracks by Commuting or Foraging Bats in a Forest-lake Landscape: A Case Study in the Wigry National Park, Poland

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Abstract: Studies on the use of forest tracks by bats were carried out in the forest-lake landscape of the Wigry National Park (NE Poland). Netting was performed in July and August 2023 at 14 sites situated near water bodies and at 14 sites remote from waters. In total, 396 individuals belonging to 11 species were caught. Tracks were most often used by *Eptesicus serotinus*, *Myotis daubentonii* and *Pipistrellus pygmaeus* (55% of all caught bats). *Eptesicus serotinus* and *Barbastella barbastellus* were more numerous on tracks remote from waters. The group of species known to feed over waters or in riparian habitats (*M. daubentonii*, *N. noctula* and *Pipistrellus* spp.) was represented more frequently on tracks near waters. Forest tracks in the studied landscape are important feeding grounds and corridors for commuting to feeding grounds for many bat species.

Key words: Chiroptera, land use, linear elements of landscape, bat netting, north-eastern Poland

Introduction

Forests and thickets are important feeding grounds for bats in temperate climatic zone (Furlonger et al. 1987, Walsh & Harris 1996, Brooks & Ford 2005). Many species of bats, especially those of shorter range of echolocation, use the linear elements of landscape when migrating and feeding (Limpens & Kapteyn 1991, Verboom & Huitema 1997). Inside large forest complexes, such elements are mainly formed along river valleys, partition lines and on roads cross-cutting forests. The importance of forest tracks for bats in Central Europe was documented in both large forests (Kowalski et al. 1996, Rachwald et al. 2021) and in small forest patches (Lesiński et al. 2007). It was demonstrated that large forest complexes may be not uniformly penetrated by bats with a greater intensity near shoreline zones (Lesiński et al. 2011). The reason of such behaviour is that the forest edge is visited by bats typical of the forest interior but also by such that fly from non-forest sites e.g. those using daily roosts in buildings situated in settlements outside the forest.

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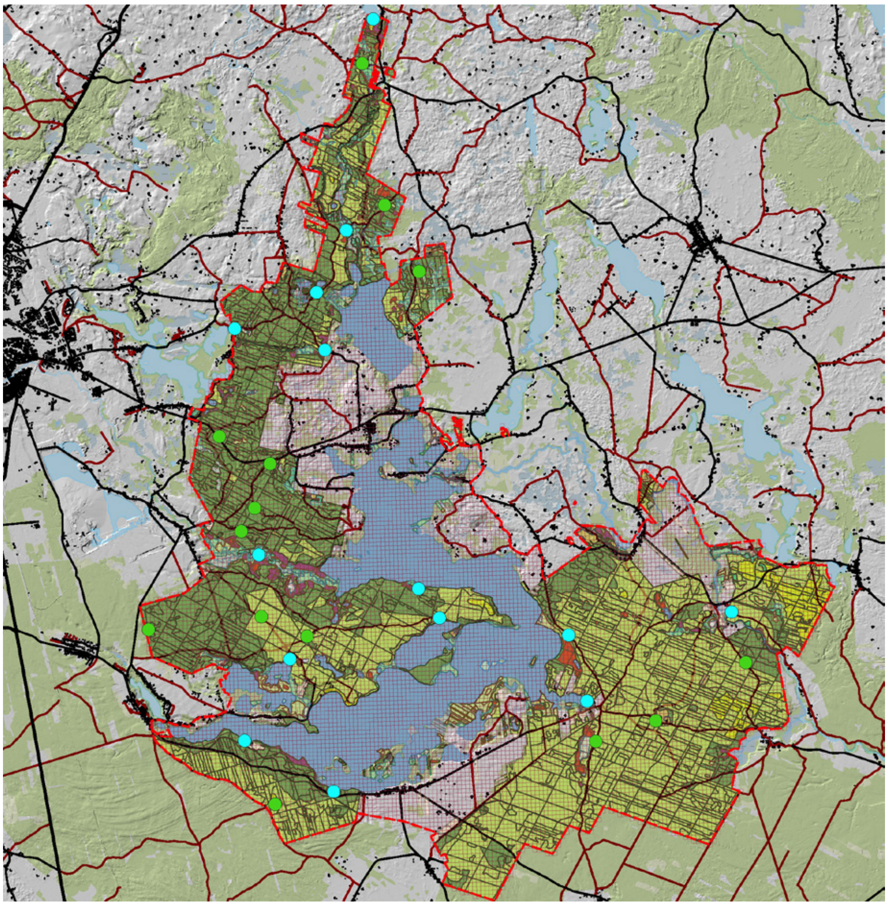

Fig. 1. Distribution of sampling sites in the Wigry National Park. Blue dots – near waters, green dots – sites remote from waters, red line – the boundary of the Wigry National Park, rivers and lakes are shown in blue, forests – in various shades of green and built-up areas – in black.

On the other hand, bats when feeding may cover distances longer than 10 km from roosts (Catto et al. 1996, Limpens et al. 1999, Shiel et al. 1999). A small summer colony of *Eptesicus serotinus* (less than 20 individuals) was estimated to have hunting grounds of an area of several tens of square kilometres (Robinson & Stebbings 1997). Most of the country bat species are able to freely penetrate relatively large forests.

The character of tree stands decides upon species composition and densities of small invertebrates – the food base of bats in moderate climate zone. Densities of feeding bats were found to be higher in older tree stands (Thomas 1988). Various water bodies play an important role in feeding grounds of bats. They are both watering and feeding sites and for some species (like e.g. *Myotis daubentonii* and *M. dasycneme*) are the main food sources (Bogdanowicz 1994, Limpens et al. 1999). The neighbourhood of waters is the favourable feeding site for species such as *Nyctalus noctula* (see Rachwald 1992, Gebhard & Bogdanowicz 2004) or some species of the genus *Pipistrellus* (see Nicholls & Racey 2006, Ciechanowski et al. 2009).

The present study aimed at estimating bat species, for which the forest tracks in forest-lake landscape of the Wigry National Park (NE Poland) are most important as commuting routes or feeding grounds. A hypothesis was also tested whether forests situated close to water bodies are penetrated in different way by particular bat species compared with forests remote from lakes. We expected that tracks situated near waters (contrary to those in the forest interior) are exploited by more species and individuals and that species feeding above water surface or in riparian habitats are more abundant there.

Materials and Methods

Study area

The study was carried out in the Wigry National Park, north-eastern Poland (Fig. 1). The park of an area of 15,085 ha was declared in 1989 on the Lithuanian Lakeland at the northern edge of Augustów Primeval

Forest, representing the largest compact forest complex in lowland Europe. The study area was covered in c. 63% by forests. The Scotch pine and spruce were the main tree species there. Rare occurrence of the hornbeam in habitats typical of this species and permanent presence of the spruce in almost all forest communities were typical for these forests. Mixed leafy forests and mixed coniferous forests dominated. Aquatic ecosystems were diverse. In total, they occupied 2,732 ha i.e. 19% of the park area. Lake Wigry was the largest (2,118.2 ha) and deepest (73 m) water body. Small rivers formed the riverine network connecting numerous lakes. The Czarna Hańcza – tributary to the Niemen – was the longest river that carries most water. Non-forest habitats together with settlements of almost exclusively rural character constitute 18% of the park area. The park was characterised by most severe climatic conditions in lowland Poland. Winter usually started in the third decade of November and lasted until the first decade of April. Mean monthly air temperature in winter varied from –6.7 do –2.7^{o} C. Summer started in the middle of June and lasted until the third decade of August, with mean monthly air temperature of 16–18^{o} C. Mean annual sum of atmospheric precipitation was about 580 mm.

Bat capturing

Bats were caught in bat nets set up on forest tracks in July and August 2023. Sampling sites were localised by the crossroads so as to cross two tracks (the main and the side one) with two nets. Nets were set up under the canopy of tree branches leaving a free space near substratum 1 m high. In total, there were 28 sampling sites, 14 situated no more than 100 m from waters and 14 sites situated from 700 to 1000 m apart from waters (Fig. 1). In every site, bats were caught during three hours after the sun set. After catching and determination of species and sex, all caught individuals were immediately released in the same place. Authors had respective permissions for short-term catching of bats.

Statistical analysis

Proportions in the number of caught individuals between sites situated at different distance from waters were compared with the Chi^2 test (table 2 x 2) and differences in the number of caught individuals between these sites were compared with the U Mann-Whitney test at the significance level of p=0.05. Calculations were made with the use of Statistica, ver. 13.3 software.

Results

In total, 396 individuals belonging to eleven species were caught. In that number, 171 (43.2%) individuals were caught on tracks near waters and 225 (56.8%) – on tracks remote from waters. All sampled species were noted in sites close to water bodies while in sites remote from water bodies four species (*Myotis nattereri, Myotis brandtii, Eptesicus nilssonii* and *Nyctalus leisleri*) were missing. The four mentioned species were not abundant – median values were 0 (Table 1). The most frequent in catches were: *Eptesicus serotinus* (remote from waters – median 5.5 individuals per site), *Myotis daubentonii* (near waters – median 4 individuals per site) and *Pipistrellus pygmaeus* (median 2.5 individuals per site situated near waters) (Table 1). These three species combined constituted about 55% of all caught bats.

Table 1. Presence and median numbers of individuals per sampling site (LQ – lower quartile, UQ – upper quartile) on tracks situated near waters and remote from waters.

Species	Close to waters (N=14)				Remote from waters (N=14)			
	Presence	Median	LQ	UQ	Presence	Median	LQ	UQ
Myotis nattereri	+	0	0	0		0	0	0
Myotis brandtii	+	0	0	0		0	0	0
Myotis daubentonii	+	4	2	6	+	2	0	3
Eptesicus serotinus	+	0.5	0	2	+	5.5	3	14
Eptesicus nilssonii	+	0	0	0		0	0	0
Pipistrellus pygmaeus	+	2.5	2	5	+	2	2	3
Pipistrellus nathusii	+	0	0	1	+	0	0	0
Nyctalus noctula	+	0	0	1	+	0	0	0
Nyctalus leisleri	+	0	0	0		0	0	0
Plecotus auritus	+	0	0	0	+	0	0	1
Barbastella barbastellus	+	0	0	2	+	1.5	1	3

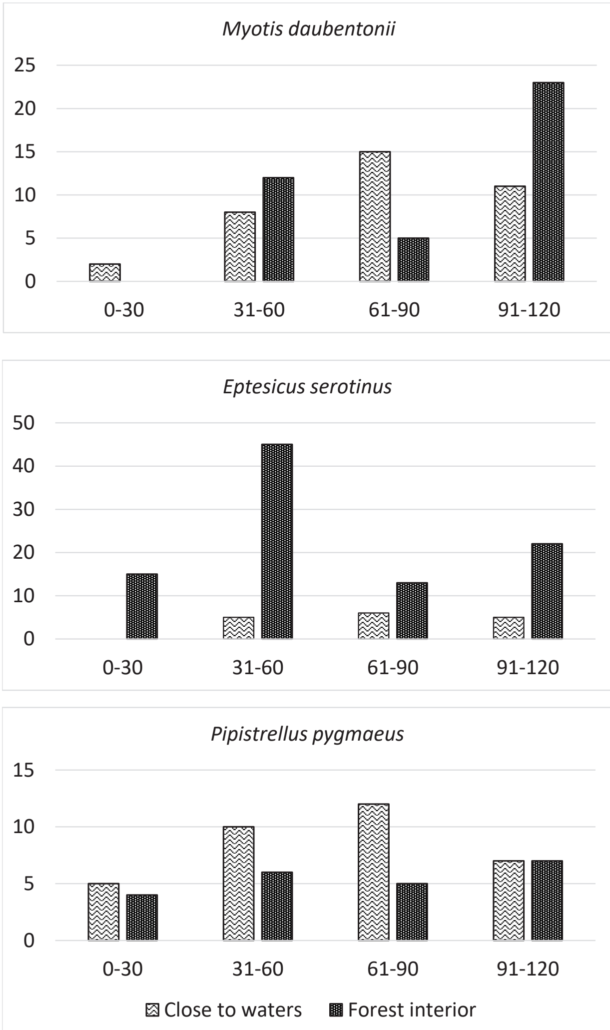

Fig. 2. Comparison of the distribution of catches in three species of bats in sites close to waters and in the forest interior during two hours after the sun set (in half-hour time intervals).

Statistically significant differences in the number of individuals caught in different distance from waters calculated for particular species was found for *E. serotinus* and *B. barbastellus* (both more frequent on tracks remote from waters). Significant differences were also noted for two groups of species: (1) associated with feeding grounds over forest tracks (*E. serotinus, P. auritus, B. barbastellus*), and (2) those feeding over waters or in riparian habitats (*M. daubentonii, P. pygmaeus, P. nathusii, N. noctula*). Representatives of the first group were distinctly more often caught on tracks remote from waters while the representatives of the second group were more frequently caught on tracks situated less than 100 m apart from larger water bodies (Table 2).

Catches of bats during two hours after the sun set (highest activity of bats) were analysed and their distributions were compared in half-hour intervals for sites close to waters and those far from waters (Fig. 2). The analysis of three species showed that the smallest differences were noted in *P. pygmaeus*. *M. daubentonii* appeared on tracks slightly later than the two other species. In greater numbers it was noted not earlier than half an hour after the sun set. The greatest differences between sites were recorded for this species in the second hour. In the time interval „61–90 min." it was more frequent on tracks near waters whereas in the interval „91-120 min." it was more frequent in the forest interior (Chi^2=7.0, df=1, p=0.01). *E. serotinus* was markedly less frequent on tracks near waters and appeared there about half an hour later than on tracks remote from waters. Noteworthy, this species was definitely more often caught in the forest interior in the time interval „31–60 min.".

Table 2. Statistical differences in the numbers of selected species or groups of species in catches localised in sites close to waters (N=14) and in sites far from waters (N=14). U Mann-Whitney test – significant differences are shown in bold.

Species or group of species	Z	p
Myotis daubentonii	1.75	0.081
Eptesicus serotinus	**–3.26**	**0.001**
Pipistrellus pygmaeus	1.10	0.270
Pipistrellus nathusii	1.26	0.206
Nyctalus noctula	0.76	0.448
Plecotus auritus	–0.94	0.346
Barbastella barbastellus	**–2.46**	**0.014**
E. serotinus + *P. auritus* + *B. barbastellus*	**–3.94**	**<0.001**
M. daubentonii + *P. pygmaeus* + *P. nathusii* + *N. noctula*	**2.46**	**0.014**
All species	–0.71	0.476

Discussion

Three species, *E. serotinus*, *M. daubentonii* and *P. pygmaeus*, dominated in the study area. These species were often noted as dominants in local bat communities in NE part of Poland (Lesiński 2001, Rachwald et al. 2021, Thor et al. 2023). They also belonged to frequent and numerous bat species in earlier studies in the study area (Postawa & Gas 2003, Kmiecik et al. 2010). Similar abundant populations of *P. pygmaeus* are noted in some areas of northern Poland (e.g. Ciechanowski et al. 2024). Finding *N. leisleri* is remarkable since this species was rarely noted in NE Poland (Sachanowicz et al. 2006). Another species, *E. nilssonii*, may possibly be more numerous in the area than it could have resulted from its rare presence in netting. This species seldom uses forest tracks and usually flies at higher altitudes above ground when feeding (Rydell 1993).

Forest tracks are used by bats as linear landscape elements facilitating commuting from daily roosts to feeding grounds. This is particularly true for species, whose feeding grounds are above waters or in close vicinity of water bodies. This group of bats includes *M. daubentonii*, which feeds above water (Bogdanowicz 1994), pipistrelles *Pipistrellus* spp. and *N. noctula* feeding above water or in riparian habitats (Rachwald 1992, Nicholls & Racey 2006, Ciechanowski et al. 2009, Lundby & Montgomery 2010, Scott et al. 2010). Comparisons between these species did not reveal significant differences in relative densities in relation to the distance to waters (Table 2). However, slightly higher statistically significant density was noted close to waters when the whole group was analysed. This may be evidence of long distances covered by some individuals from daily roosts to feeding grounds. Such species usually inhabit tree holes, possibly situated far from water in the middle of forest interior (Encarnação et al. 2005, Ruczyński & Bogdanowicz 2008). Earlier studies in the Wigry National Park showed that in catches made over waters or in close vicinity, bats of this group constituted in total more than 90% of community (Postawa & Gas 2003, Kmiecik et al. 2010).

Results obtained in the study area confirm that for some bat species the forest tracks are not only the corridors for flights but also the basic feeding grounds. This conclusion pertains to *E. serotinus* (Baagøe 2001, Harbusch & Racey 2004) and *B. barbastellus* (Sierro & Arlettaz 1997), which were more often caught on tracks far from waters. The first species flies to forest feeding grounds mostly from outside since it inhabits the roosts in buildings (Tink et al. 2014). The second species finds both daily roosts in trees (usually behind the protruding bark – Russo et al. 2005, Gottfried et al. 2015) and feeding grounds (Sierro & Arlettaz 1997, Zeale et al. 2012) in large tree stands. *P. auritus* may behave the same way as *B. barbastellus* but too small number of caught individuals did not allow for statistical confirmation of similar pattern of the forest use.

No decreased densities of bats in the forest interior were noted in the forest-lake landscape which was the case in a large forest complex in central Poland (Lesiński et al. 2011). This is an evidence of a wider landscape penetration in the Wigry National Park.

Forest tracks in the study area are used by relatively rich bat assemblage including the presence of rare species (*N. leisleri*). The tracks constitute both linear elements facilitating migration to feeding grounds (e.g. *M. daubentonii*), and proper feeding grounds for *E. serotinus* or *B. barbastellus*. The time table of findings *M. daubentonii*, indicating frequent presence of this species far from waters in the end of the second hour after the sun set suggests that some part of individuals may in that time already return to roosts in tree holes (typical roosts of breeding colonies – Bogdanowicz 1994) situated in the forest interior. The obtained results clearly confirm that most mid-European bat species may freely penetrate even large forest complexes.

The assumed hypothesis was mostly confirmed. Slightly higher number of species noted near waters may result from the fact that apart from species feeding there, these sites are visited for watering by species otherwise feeding in the forest interior. According to hypothesis, the species feeding above water and in the riparian habitats were more frequent on tracks close to waters than in the forest interior. The assumption of their higher relative densities in forest near waters was, however, not confirmed.

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