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Altitudinal distribution of bats in the Poľana Mts area (Central Slovakia)

Peter Kaňuch & Anton Krištín

Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, SK–96053 Zvolen, Slovakia; e-mail: kanuch@netopiere.sk, kristin@savzv.sk

Abstract: In May – August, bats were mist-netted along an altitudinal gradient of 350–1350 m a.s.l. in the Poľana Mts area, to verify the correlation of species number decrease and the increase in elevation, to find which species could be predictors of certain altitude levels and to compare the sexual occurrence of species in various altitudes. Seventeen bat species were recorded. The most abundant mist-netted species were *Myotis daubentonii* (16%), *M. myotis* (13%) and *M. mystacinus* (12%). Otherwise, the most frequently caught species were *M. mystacinus* (40%), *Eptesicus serotinus*, *M. myotis* (26%) and *Nyctalus leisleri* (23%). In this study at a local scale, from oak to spruce vegetation stages, decreasing number of species with increasing altitude was found. Species dominance of the individual altitudinal levels was significantly different (15 species up to 600 m a.s.l., six species over 1100 m a.s.l.). The results indicated that the occurrence of some bat species, due to their ecological adaptations, is more or less characteristic for higher or lower altitudes of the Western Carpathians. The "lowland" species were considered to be mainly *E. serotinus*, *Pipistrellus pipistrellus*, *N. noctula*, *N. leisleri* and *M. daubentonii*. In higher elevations (more than 850 m), the presence of reproductive females was not found, of all but one, *N. noctula*, of the "lowland" species which are breeding in the area. The "mountain" species were considered to be *E. nilssonii* and *Plecotus auritus*. The general occurrence and reproduction of *M. mystacinus* and *Barbastella barbastellus*, was not limited by elevation.

Key words: Bat assemblage, gradient analysis, mountains, mist-nettings.

Introduction

The most apparent altitudinal gradient of bat species diversity was observed in the tropics due to vegetation diversity. Analysis of capture records over a transect extending more than three kilometres in elevation showed that most bat species were distributed in the Amazon Basin with few montane endemics (Patterson et al., 1996). Relative species richness decreased with increasing elevation and fewer bat species were restricted to the highlands in Peruvian Andes (Graham, 1990).

In temperate zones, activity of bat species at different elevations were compared in several forested areas. Bat activity and capture rates were greater in lowland than upland areas (Grindal et al., 1999; Erickson & Adams, 2003). Likewise, species composition and relative occurrence of bats, with respect to roost-site availability, decreased with altitude in the Balkans and the Bavarian Alps (Pandurska, 1996; Holzhaider & Zahn, 2001). Considerable species diversity at low and medium elevations of Eastern Transcaucasia was determined by higher diversity of habitats there (Rakhmatulina, 1999). Spatial analyses, performed on field data from the Swiss mountains, confirmed the elevation as the most important predictor of bat community composition (Jaberg & Guisan, 2001).

Reproductive female bats are more constrained by thermoregulation than males and non-reproductive females, and constraints increase with elevation. There was found to be a significant negative relationship between altitude and relative abundance of reproductive females (Cryan et al., 2000; Holzhaider & Zahn, 2001). Likewise, sexual segregation according to elevation and prevalence of females in lower altitudes has been documented (Grindal et al., 1999; Russo, 2002; Baker & Lacki, 2004).

Many papers and studies evaluating local geographical distribution of bats (including also elevation data) have originated from Slovakia. However, detailed altitudinal distribution analysis is missing (cf. Uhrin & Polakovičová, 2000; Uhrin, 2006). The Poľana Mts, situated in the centre of Europe, represent high habitat diversity of the Western Carpathians. Up to 1999, only a few accidental or differently focused studies (diet of raptors) mentioned the occurrence of bats that originated from the area. Previous records as well the results of own chiropterological surveys were reviewed by Hrúz et al. (2000). At that time, 15 bat species were known to occur in the Poľana Mts and surrounding area. Data were collected mainly in loft and underground roosts,

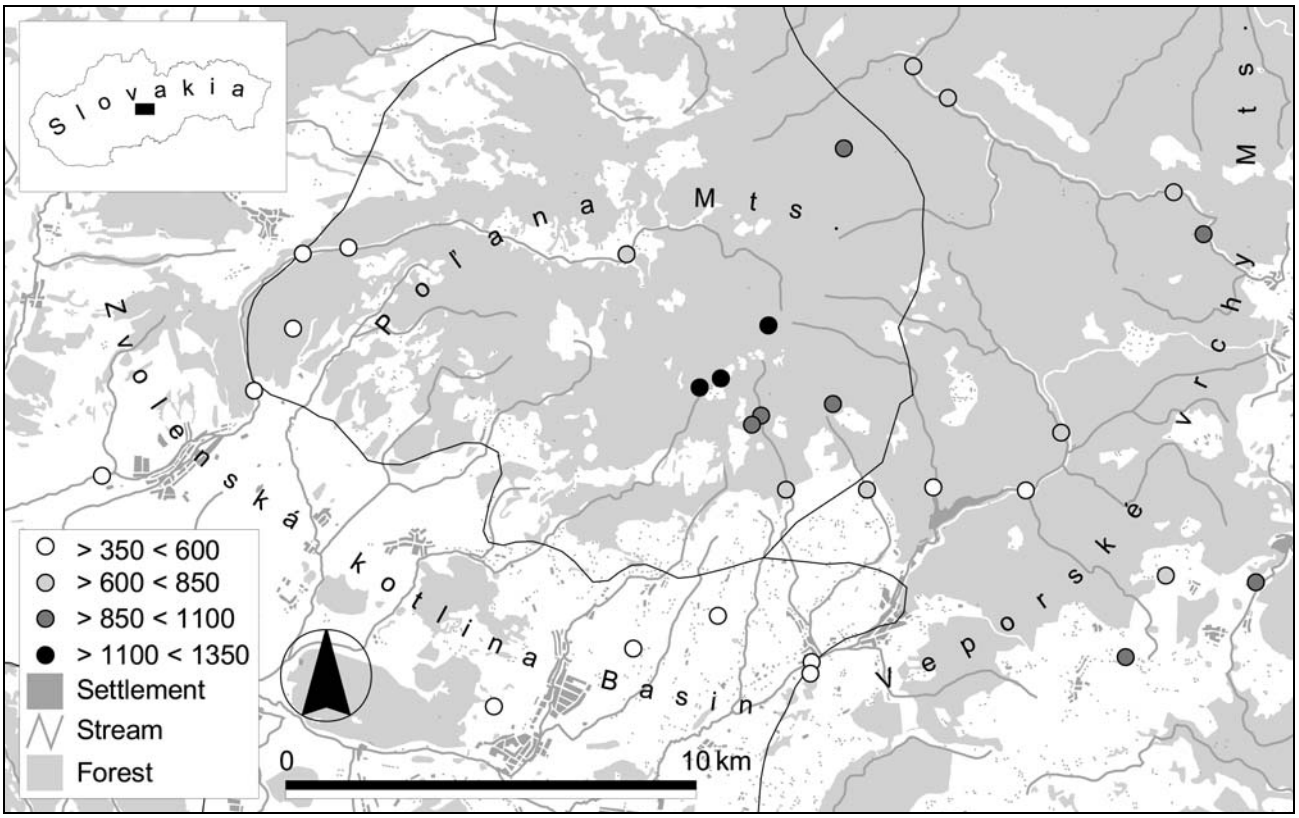

Fig. 1. Distribution of mist-netting sites (circles) in the Poľana Mts area, C Slovakia. Graduated colour of circles indicates altitudinal level (in m a.s.l.).

thus the most frequent were *Rhinolophus hipposideros* (Bechstein, 1800), *Myotis myotis* (Borkhausen, 1797) and *Plecotus auritus* (L., 1758).

The aims of the present study were: (i) to verify the correlation of species number decrease in foraging bat assemblages and the increase in elevation; (ii) to find which species could be predictors of certain altitude levels and (iii) to compare the sexual occurrence of species in various altitudes, in a small area located in the Western Carpathians.

Study area

The study area comprised the Poľana Mts, the southward adjacent part of the Zvolenská kotlina basin and part of the Veporské vrchy Mts from the east (48°33–42′ N, 19°14–39′ E, Western Carpathians, C Slovakia). Poľana Mts is the highest extinct volcano in C Europe. The elevational diversity of the area represents various climatic conditions (average annual temperature 8.0–2.5 °C, dependent on altitude). In a relatively small area (ca 450 km^2), it is possible to observe the changes in various vegetation stages, the density of settlements and intensity of the nature exploitation.

Mosaic, extensively used farmland with settlements and sparse tree vegetation (small local stands of oaks *Quercus* spp., hornbeam *Carpinus betulus* and black locust *Robinia pseudoacacia*) was typical for the first altitudinal level (350–600 m a.s.l.). Over the 600 m of elevation, forest stands comprised mostly beech *Fagus sylvatica* (with low undergrowth), partly hornbeams and some oak growth; higher than 850 m a.s.l., beech stands were often mixed with spruce *Picea abies* and fir *Abies alba*, occasionally with maple *Acer pseudoplatanus* and elm *Ulmus glabra* (mixed Carpathian mountain beech forest). The highest level (1100–1350 m a.s.l.) was characterised almost entirely by pure spruce forests with admixture of beech, rowans *Sorbus* spp. and maple *A. pseudoplatanus*. Small open sites – meadows and peat bogs diversified this altitudinal level.

Material and methods

In May – August (2002–2005, sporadically from 1991), the bats were mist-netted (mist-net size 2.5 × 7–14 m, according to the mist-netting place) over small water sites – artificial ponds, garden fishponds, periodical pools, springs (maximally up to 200 m^2), brooks and forest paths (also in combination with water pools). Mist-nettings were performed mostly after warm days, during non-rainy weather, and conducted a minimum of three hours afters sunset. Mist-netted species were classified into two categories: 1 – adult males, 2 – adult females or young. Captured bats were immediately taken away from the mist-net and consequently released. Data which are older than 2002 (2.7%, $n = 261$) have already been published in Hrúz et al. (2000). Frequency of occurrence (F) and dominance (D) were calculated in individual species. Final values of the frequency of occurrence were calculated as a percentage of positive mist-nettings of species in four altitudinal levels separately.

Analysed mist-netting sites were distributed along an altitudinal gradient of 350–1350 m a.s.l. The lowest site was

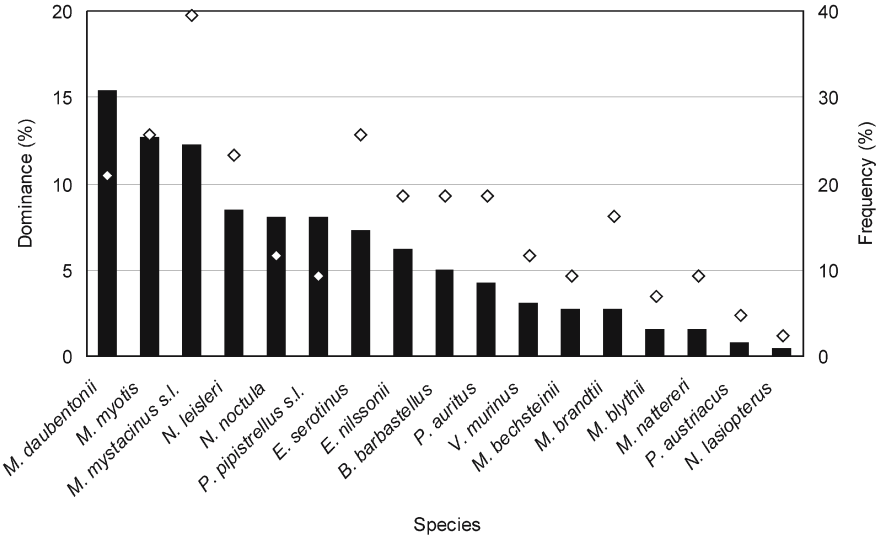

Fig. 2. Species dominance (black columns) and frequency of occurrence (white diamonds) of mist-netted bats ($n = 261$).

near Očová village and the highest in Zadná Poľana National Nature Reserve, 16.6 km apart as the crow flies. It provides suitable conditions for an altitudinal gradient study. The elevational gradient was divided into four intervals of 250 m, in which there were 43 positive mist-nettings (at least one individual caught) in a total of 30 sites (Tab. 1). General differences in species dominance regarding altitudinal levels were tested by the Kruskal-Wallis test. If the sample size was more than 10 individuals, the one-sample Kolmogorov-Smirnov test (*K-S* test) was used to test the differences in the abundance of bat species among altitudinal levels (SPSS for Windows, 10.0.7 version). Decreasing numbers of locations as well as mist-netting at increased elevation resulted in fewer potential opportunities for bat mist-netting. In addition, the area of highest altitudes was reducing.

Results and discussion

Diversity and structure of the bat assemblage

Using mist-nets, 17 bat species (61% of Slovak fauna) were recorded in the Poľana Mts area: *Myotis myotis*, *Myotis blythii* (Tomes, 1857), *Myotis bechsteinii* (Kuhl, 1817), *Myotis nattereri* (Kuhl, 1817), *Myotis mystacinus* (Kuhl, 1817), *Myotis brandtii* (Eversmann, 1845), *Myotis daubentonii* (Kuhl, 1817), *Vespertilio murinus* L., 1758, *Eptesicus serotinus* (Schreber, 1774), *Eptesicus nilssonii* (Keyserling et Blasius, 1839), *Pipistrellus pipistrellus* (Schreber, 1774), *Nyctalus noctula* (Schreber, 1774), *Nyctalus leisleri* (Kuhl, 1817), *Nyctalus lasiopterus* (Schreber, 1780), *Plecotus auritus*, *Plecotus austriacus* (Fischer, 1829) and *Barbastella barbastellus* (Schreber, 1774). *M. mystacinus* and *P. pipistrellus* were identified only to *sensu lato* (because their new cryptic sibling species would need genetic determination). The most abundant mist-netted species were *M. daubentonii* ($D = 16\%$), *M. myotis* (13%) and *M. mystacinus* (12%). High capture rate of *M. daubentonii* was caused by its typical foraging over water habitats, which could have overestimated our results. Otherwise, the most frequently caught species were *M. mystacinus* ($F = 40\%$), *E. serotinus* and *M. myotis* (26%) and *N. leisleri* (23%, Fig. 2). The rarest species in the area is considered to be *N. lasiopterus* (record details of this species will be referred to elsewhere; Kaňuch et al., 2005). The high occurrence of *M. mystacinus* corresponds with observations in Bavarian Alps, where it is the most abundant species; *M. mystacinus* and *M. brandtii* together make up an average of 70% of all bats at higher altitudes (Holzhaider & Zahn, 2001). Similarly, frequent records of *N. leisleri* indicate the common occurrence of this species in some parts of the Western Carpathians (Kaňuch et al., 2006). *Pipistrellus nathusii* (Keyserling et Blasius, 1839), cited as reaching elevations of up to 1260 m a.s.l. of Poľana Mts (Turček, 1953), very probably incorrectly identified the species as *M. mystacinus*. Ascertained present composition and species dominance in the bat assemblage is in stark contrast with previous knowledge from the area. Such discrepancy is related to different methods of data collection (cf. Hrúz et al., 2000).

Altitudinal distribution of species and sexes

A monotonic decline in species richness and density with increasing elevation has often been considered a general pattern, but recent evidence suggests that the dominant pattern is hump-shaped with maximum richness occurring at some mid-elevation point (Colwell et al., 2005; Herzog et al., 2005). In our study at a local scale from oak to spruce vegetation stages (350–1350 m a.s.l.) we found decreasing number of species with increasing altitude. Species dominance of the individual altitudinal levels was significantly different (Kruskal-Wallis test, $\chi^2 = 93.31$, df = 9, $P < 0.001$). In the lowest level (up to 600 m a.s.l.) 15 species were found, and in the highest (over 1100 m a.s.l.) only six (Tab. 1). A similar trend was also presented by Pandurska (1996), Grindal et al. (1999) and E-

Table 1. Parameters of mist-nettings in four altitudinal levels of Poľana Mts area.

Altitudinal level (m a.s.l.)	Total number			Species/mist-netting			Individuals/mist-netting		
	Sites	Mist-nettings	Bat species	Mean	Max	±SD	Mean	Max	±SD
350–600	12	14	15	3.5	7	2.1	10.1	30	10.5
600–850	8	11	13	2.5	5	2.5	3.7	8	3.7
850–1100	7	11	11	2.4	9	2.4	4.8	21	4.8
1100–1350	3	7	6	2.4	4	2.4	3.7	8	3.7

RICKSON & ADAMS (2003). The highest mean number of mist-netted species as well as individuals per single mist-netting was in the lowest altitudes; for all that the variability of mist-nettings was evidently high (Tab. 1). Different species' ability to avoid the mist-nets certainly distorts the results. Full absence of *R. hipposideros* in our results, in contrary to data from loft and underground roosts, confirms this possibility (cf. HRÚZ et al., 2000). Therefore it would be profitable to combine mist-netting method with ultrasound bat-detectoring (KUENZI & MORRISON, 1998). However, it is also species selective method, especially in the forest habitat. Low number of species in the highest altitudes can be partly explained also by the lower number of localities at which bats were caught. Also the importance of wind and predatory shelter for good mist-netting sites could be considered in the methodological design and data interpretation. ZAHN & MAIER (1997) found higher bat activity at streams and ponds situated in forest or lined by trees and bushes than without surrounding vegetation.

Our results indicated that the occurrence of some bat species, due to their ecological adaptations, is more or less characteristic for higher or lower altitudes of the Western Carpathians. The "lowland" species (i.e., in our study area, species common in the first altitudinal level 350–600 m a.s.l.) were considered to be (in the order given) mainly *E. serotinus* (*K-S* test, $Z = 1.54$, $P < 0.05$), *P. pipistrellus* (*K-S* test, $Z = 2.47$, $P < 0.001$), *N. noctula* (*K-S* test, $Z = 2.35$, $P < 0.001$), *N. leisleri* (*K-S* test, $Z = 1.50$, $P < 0.05$) and *M. daubentonii* (*K-S* test, $Z = 3.29$, $P < 0.001$) (Fig. 3). It was identical to species composition in foraging grounds in the Východoslovenská rovina lowland (up to 200 m a.s.l.) where (among others) *E. serotinus*, *N. noctula* and *P. pipistrellus* also dominated (DANKO et al., 2000). Abundance and frequency of occurrence of the above-mentioned species noticeably decreased in our mist-nettings with the increase of elevation. These species are specialised in open-space hunting, in the vicinity of settlements, or over water. Such habitat opportunities were concentrated in the lower parts of the area. Due to foraging in open non-forested urban areas, JABERG & GUISAN (2001) identified *N. noctula*, *N. leisleri* and *P. pipistrellus* as species which should be altitudinal independent. Moreover, RACHWALD (1992) found very low activity of *N. noctula* in the coniferous and deciduous forests, in contrast to semi-open area. In *P. pipistrellus* and *N. noctula*, the frequency of mist-net captures was rather low in comparison to their abundance, i.e. there were few sites in which high numbers of individuals were caught (Fig. 3). In higher elevations (more than 850 m), the presence of reproductive females was not found, of all but one, *N. noctula*, of the "lowland" species which are breeding in the area. Likewise, in altitudinal sexual segregation of *M. daubentonii* in Italian Alps, females occurred only up to 880 m a.s.l. (RUSSO, 2002). Hence, we support the "constrained thermoregulatory" hypothesis in reproductive females (HOLZHAIDER & ZAHN, 2001) in our study area.

The "mountain" species were considered to be *E. nilssonii* (*K-S* test, $Z = 1.67$, $P < 0.01$) and *P. auritus* (*K-S* test, n.s.), and in spite of low sample size *V. murinus*, too. JABERG & GUISAN (2001) categorised this species as a low-altitudinal species. This discrepancy could be affected by the different ecology of breeding females which were not found in our area (cf. STRELKOV, 2000). This species showed a high occurrence in addition to *E. nilssonii* and *P. auritus* in summer mist-netting in the Tatra Mts (900–1060 m a.s.l., PJENČÁK et al., 2003). Missing records of *E. nilssonii* from the highest altitudinal level was probably caused by open-space foraging strategy of the species and no possibilities for a mist-netting site there (Fig. 3). Based on bat-detector records in the vicinity of chalets in Predná Poľana (ca. 1300 m a.s.l.), it is expected this species occurs here, too. *E. nilssonii* was also considered by JABERG & GUISAN (2001) as a unique high elevation species. Similarly in Bulgaria, where the Mediterranean species dominate, this northern species occurred only in the highest altitudes (PANDURSKA, 1996). Regular mist-nettings of *M. bechsteinii* reproductive females in only one site (1260 m a.s.l.) can be related to the rare occurrence of the species in the area.

The general occurrence and reproduction of two species, *M. mystacinus* and *B. barbastellus*, was not limited by elevation (*K-S* test, n.s.) (Fig. 3). *M. brandtii* and *M. nattereri* were also considered to be altitude independent species in the Pol'ana Mts. The presence of these species will be mainly associated with the forest cover. Especially, *M. mystacinus* appears as the most typical forest bat. A very similar situation in altitudinal distribution of the above-mentioned species was also found in the Balkans (PANDURSKA, 1996). Based on our results, *M. myotis* could also be considered a broad altitudinal distributed species. Its occurrence in the higher

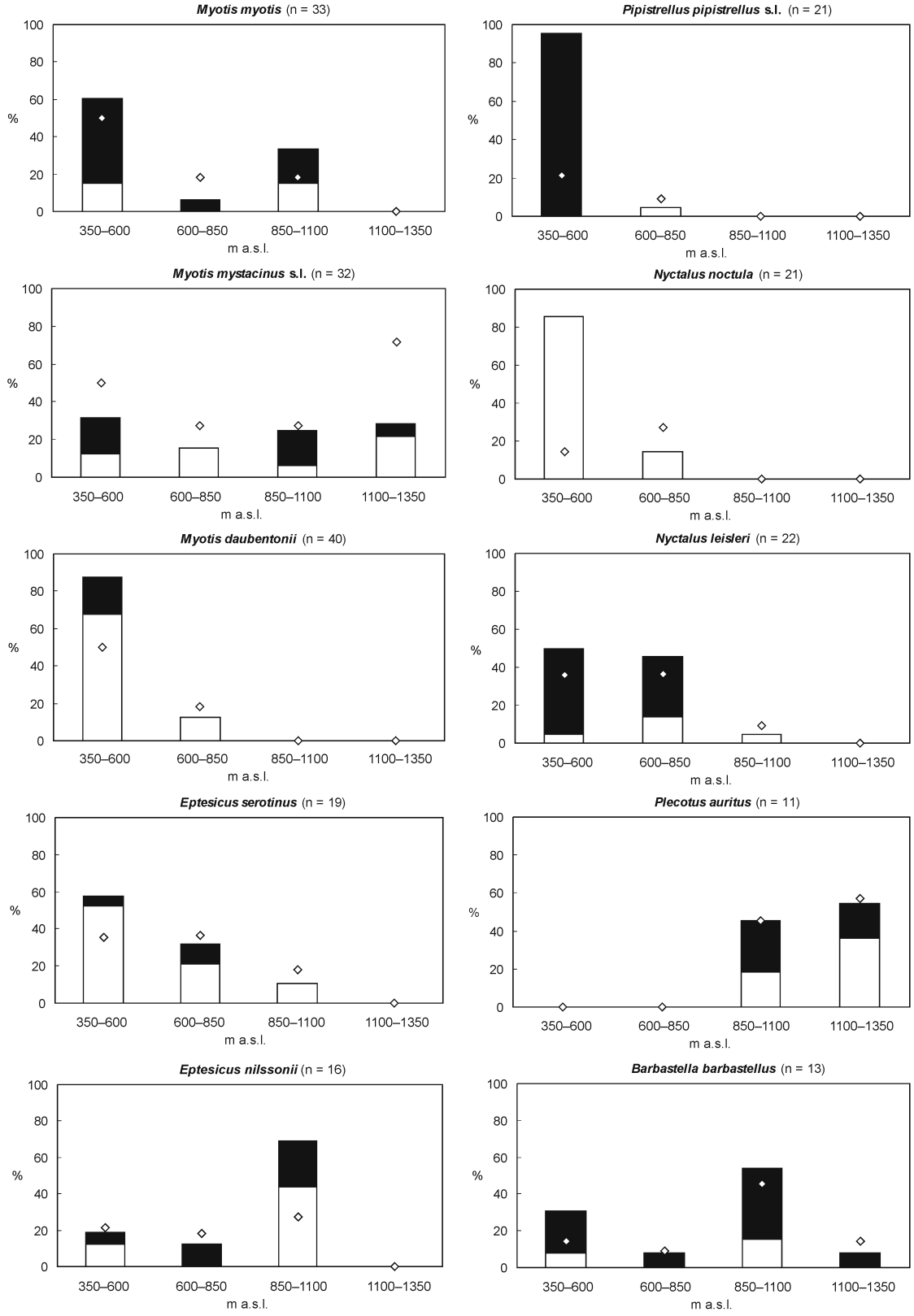

Fig. 3. Dominance (columns) and frequency of occurrence (white diamonds) of the ten most abundant mist-netted bats (white part of columns – adult males, black part of columns – adult females or young).

altitudes was ascribed to large foraging home-range in this species. Furthermore, nursery colonies were found only in lower elevations (Hrúz et al., 2000). Our results confirm that altitude is an important factor influencing

species richness and limit presence of bat species. The study of species' vertical distribution also has an importance in species and habitat conservation. Spatial estimation of the population size should be calculated with respect to the vertical character of the area (cf. CRYAN et al., 2000).

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