Special Issue: A tribute to FJT

A collection of papers honouring Dr František J. Turček

Selected papers included in this Special Issue of *Folia Oecologica* were presented at the conference FJT100, organised on the occasion of centenary of the first Slovak ecologist František Jozef Turček (1915–1977) on December 11–12, 2015 at Technical University in Zvolen. This scientific meeting was attended by around 160 mainly Slovak ornithologists, mammalogists and ecologists from various research or nature conservation institutions. Manifold community of professionals and amateurs (such partition is not autotelic here, because Turček was gifted self-made man who had not completed his secondary-school education but later defended dissertation thesis and became one of the most cited Slovak ecologists), presented altogether 38 oral papers and 17 posters. In this editorial note, we could not afford to evaluate astonishing Turček's biography or his significant contribution to scientific knowledge as it was already done elsewhere (SLÁDEK, 1992, 1993; also see conference abstracts at the end of this issue). Surely, more comprehensive analysis is highly needed; however, it would require an extensive historical and library research.

Nevertheless, selection of eight peer-reviewed research papers and three short communications published in this issue, serves us as useful probe into the level of progress in ecological research since Turček's pioneering period in this small central European territory. Similar to his wide-ranging focus in animal ecology, also conference participants presented different topics from ecology of species, communities, through evolutionary and behavioural ecology to biological conservation and management. Whether we push forward or not the frontiers of science, almost forty years since his passing, it must assess the wise readers.

Please read and enjoy

Peter Kaňuch & Anton Krištín
Editors of the Special Issue: A tribute to FJT

Along with the conference, a commemorative plaque for F. J. Turček – the first Slovak ecologist – was unveiled at the Institute of Forest Ecology of the Slovak Academy of Sciences in Zvolen. The author was maestro Zbigniew Nišponský.

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Phylogenetic status of endemic *Chionomys nivalis mirhanreini* in the Western Carpathians

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Abstract

Dorková, M., Kocianová-Adamcová, M., Pristaš, P., Klinga, P., 2016. Phylogenetic status of endemic *Chionomys nivalis mirhanreini* in the Western Carpathians. *Folia Oecologica*, 43: 3–11.

The Snow vole has a fragmented distribution restricted to the mountain and rocky regions from the southwestern Europe to the Caucasus and the Middle East. Several subspecies have been described on the basis of dental characters. In this study we provide more detail insight into phylogenetic status of the Snow vole *Chionomys nivalis* occurring in the Western Carpathians compared to its populations within Eurasia. We analysed 588 bp fragment of mtDNA cytochrome *b* gene in samples collected in the two isolated populations within the High Tatras and Low Tatras Mountains. Our results indicate Western Carpathians as the long term isolated refugia for *C. nivalis* and support the subspecies status of *C. n. mirhanreini* in the Western Carpathians. The European populations are formed by two southern phylogenetic lineages – the first originates in Iberian Peninsula and the other expanding from Balkans to the Eastern Carpathians is also visible.

Keywords

haplotypes, post-glacial recolonization, phylogenetic lineage, Rodentia

Introduction

The European biota was strongly influenced by climatic fluctuations during the last two million years of Pleistocene (Castiglia et al., 2009), while the environmental changes in the last 20,000 years were probably the most dramatic for mammalian fauna. Pleistocene glaciatio affected the movement of several species (Moravcová, 2010). In the peak of glacial period, most species areas were fragmented into isolated glacial refugia. The European refugia were located in the Iberian, Apennine and the Balkan Peninsula and Great European Plain (Schmitt and Seitz, 2001).

The genus *Chionomys* is represented by only three species that exclusively inhabit mountainous regions of Europe, Asia Minor, and parts of Western Asia (Nadachowski, 1991) and these are: *Chionomys gud* (Satunin, 1909), *Chionomys roberti* (Thomas, 1906) and *Chionomys nivalis* (Martins, 1842). The first indisputably identified fossils of Snow vole, *C. nivalis,* are recorded from the island of Chios in Greece probably dates from the Middle Pleistocene (Storch, 1975) and their number is increasing in the upper Pleistocene (Nadachowski and Baryshnikov, 1991). Older fossils traditionally attributed to this species actually included *Microtus agrestis* and *Microtus oeconomus* (Nadachowski, 1991).

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Since then, in some areas Snow vole recognized gradual changes in the construction of teeth, while in other areas the development is not observed (Chaline and Graf, 1988). Climatic fluctuations in mid and late Pleistocene played an important role in changing the geographical distribution of the species (Janeau and Aulagnier, 1997). When most of the mountains were covered by ice, *C. nivalis* moved from mountains to adjacent lowland areas (Terzea, 1977). After the retreat of glaciers, the area of Snow vole has become fragmented into isolated populations, while in the smallest changed dramatically (for example, population in the Tatras can be considered as distinct species based on different dental morphology; Nadachowski, 1992). During Würmian glaciation, *C. nivalis* was widespread in Central and Western Europe especially during the coldest periods. At the end of the Würm suitable rocky habitats occurred only sporadically (Terzea, 1977). Recent distribution of Snow vole has relict character and it is occurring in the mountains of Europe, from southwest Europe in the Pyrenees and the Alps, through Southeast Europe to Turkey, Israel, Lebanon, Palestine, Syria, Iran, and South Caucasus to mount Kopet-Dagh (Corbet, 1978). Thus its distribution is fairly fragmented, mainly because of habitat requirements. Although *C. nivalis* is often found in mountainous conditions, this species is not physiologically suitable for cold environments (Bienkowski and Marszalek, 1974). Rather, it is suited for micro-environments with medium humidity in rocky habitats, specifically the stone and rubble piled boulders, cracks in the rocks, cliffs, cave entrances and slots in rock substrate (Luque-Larena et al., 2002), regardless of the altitude (Kryštufek and Kovačić, 1989).

In isolated populations of *C. nivalis* significant morphological divergence was identified (Amori, 1999) what resulted in large number of morphologically described subspecies. Corbet (1978) recognizes four subspecies, while Krapp (1982) distinguishes thirteen, Ellerman and Morrison-Scott (1966), similarly like the Kratochvíl (1981) indicate sixteen subtypes and Nadachowski (1991) in his most comprehensive review suggests eighteen of them. Somatic variability in European populations revealed an alpine branch (subtype) and branches including populations of Italy, Spain and France (Graf, 1982). Generally, the "North mountain" population group (Alps, Carpathians and Balkan Peninsula, but also the Caucasus and even Kopet-Dagh), is formed by *C. nivalis* and *C. mirhanreini*. Their territories were colonized relatively late, in most cases, after the retreat of glaciers (Janeau and Aulagnier, 1997). "Southern populations" group comprise *lebrunii*, *cedrorum* and s*piizenbergerae* which occupy lower altitudes and areas that have never been covered by glaciers. It is noteworthy that southern populations, except *C. n. hermonis* (southernmost population in the Lebanese mountains, which is classified as *C. n. nivalis*) are the most primitive. They are preserved primitive features characteristic of *C. nivalis* dates from the Middle Pleistocene. During cool periods, these populations were not forced to change their habitat contrary to mountain populations that emigrated. (Nadachowski, 1991).

Phylogeography of *C. nivalis* and its evolutionary history in relation to closely-related species was recently inferred using independent molecular markers (Yannic et al., 2012). However, this almost comprehensive study did not have included the northernmost population in the Western Carpathians where significant morphological differentiation was recorded in several traits (Luque-Larena et al., 2002). Therefore in this study, we attempt to elucidate phylogenetic status of Western Carpathians population of Snow vole based on analysis of mtDNA cytochrome *b* gene fragment.

Material and methods

Sampling

Within the Western Carpathian population we sequenced four samples from trapped individuals in Nízke Tatry Mts – Chopok (48°56´32.2″N, 19°35´15.5″E), Kráľova Hoľa (48°52′59″N, 20°08′21″E) and Tatry Mts – Roháče (49°12′26″N, 19°44′44″E) during 2002–2014. Tissue samples were stored in 96% ethanol. We also retrieved 35 sequences covering whole *C. nivalis* range from the GenBank (Table 1).

DNA extractions and amplifications

DNA was extracted from tissues using a QIAmp Tissue Extraction Kit (Qiagen), following the manufacturer's instructions. For the phylogenetic study, the mitochondrial cytochrome *b* gene was amplified using primers L14841 and H15915 (Kocher et al., 1989; Irwin et al., 1991). The PCR mix of 25 µl total volume contained 50–100 ng DNA, 1 × PCR buffer, 0.4 µM each primer, 200 µM dNTPs, 1.5 mM $MgCl_2$ and 0.5 U Taq polymerase (Qiagen). The PCR reaction was performed in an Eppendorf Thermal Cycler with the following steps: 95 °C for 4 min, 40 cycles at 94 °C for 30 s, 58 °C for 1 min and 72 °C for 2 min, and a final elongation step at 72 °C for 10 min (Yannic et al., 2012). PCR products were checked in 1.6% agarose gel. Products were analysed on ABI PRISM 3100 capillary DNA sequencer (Applied Biosystems).

Alignment and analyses of mtDNA sequences

The sequences were aligned using ClustalW (Larkin et al., 2007) and manually edited in BioEdit (Hall, 1999). The total length of the alignment was 558 bp.

Table 1. Genetic diversity indices based on mtDNA cytochrome *b* sequences for the Snow vole *Chionomys nivalis*. Number of analysed individuals (n), number of haplotypes (Nh), number of segregating sites (S), nucleotide diversity (π) and haplotypes diversity (Hd) ± standard deviations

Population	Subspecies *C. nivalis*	n	Nh	S	π	Hd
Western group		23	23	63	0.024 ± 0.013	1 ± 0.034
Alps & Apennines	*nivalis*	12	12	28	0.015 ± 0.009	1 ± 0.034
Western Carpathians	*mirhanreini*	3	3	4	0.005 ± 0.004	1 ± 0.272
Balkan	*aleco, wagneri, malyi*	4	4	16	0.014 ± 0.010	1 ± 0.177
Pyrenees, Sierra de Gredos	*abulensis*	4	4	14	0.014 ± 0.010	1 ± 0.177
Eastern group		12	12	45	0.031 ± 0.017	1 ± 0.034
Anti-Lebanon	*hermonis*	3	3	5	0.006 ± 0.005	1 ± 0.272
Taurus	*cedrorum*	2	2	1	0.002 ± 0.002	1 ± 0.500
Caucasus	*trialeticus*	3	3	5	0.005 ± 0.005	1 ± 0.272
Khorasan	*dementievi*	4	4	5	0.004 ± 0.003	1 ± 0.177

Intrapopulation genetic characteristics such as number of samples per haplotype n, number of haplotypes Nh, nucleotide diversity π and haplotype diversity Hd were estimated in Arlequin 3.1 (Excoffier et al., 2005). We divided the populations into different groups based on their geographical ranges and environmental condition where they occur: a European group (Eastern Carpathians, Western Carpathians, Alps, Appenines, Dinarides, Baba, Rila) and an Asian group (Khorasan, Anti Lebanon, Saleh, West Toros, Caucasus). The matrix of pairwise genetic distances θ_{ST} (Nei and Li, 1979) with their corresponding P values was computed in Arlequin 3.1 with 10,000 MCMC iterations (Excoffier et al., 2005). To test the statistical significance of genetic differentiation between populations we used Fisher's exact test with 10,100 permutations. The AMOVA implemented in Arlequin 3.1 (Excoffier et al., 2005) was employed with 10,000 permutations.

Phylogenetic analyses were performed using neighbour-joining (NJ), maximum likelihood (ML), maximum parsimonious (MP) and Bayesian trees. Firstly the distance based NJ tree was constructed under Tajima-Nei distance model (Tajima and Nei, 1984) and Gamma distributed rate among sites. Gamma was set to one. The reliability of the NJ tree was assessed by 10,000 bootstrap replicates. A ML tree was constructed by implementing GTR+I model, inferred by the Nearest-Neighbour-Interchange heuristic method (NNI) with default set NJ/BioNJ initial tree and very strong branch swap filter. The phylogeny was tested by 10,000 bootstrap replicates. The topology of the tree was further investigated by Min-Mini Heuristic MP search method; search level three, max number of trees to retain was set to 10. A MP consensus tree was inferred from 10,000 bootstrap replicates in MEGA 5.2 (Tamura et al., 2011). The substitution model GTR+I and model frequencies A = 0.3308, C = 0.2722, G = 0.1098, T = 0.2872 were selected in jModeltest (Posada, 2008), based on the Akaike information criterion corrected for small sample sizes (AICc). Phylogenetic relationships between haplotypes were inferred by Bayesian inference using 1,000,000 the Markov Chain Monte Carlo (MCMC) starting from random tree and sampling every 1,000 generation (four chains, heating = 0.2) implemented in MrBayes 3.1.2 (Ronquist et al., 2011). Searches were performed using GTR model including proportion of invariant sites. The Bayesian 50% majority rule consensus tree was visualised in FigTree v1.4.2 (Rambaut, 2014). The most divergent *C. roberti* haplotypes were used to place a root in all phylogenetic trees. A haplotype distribution maps with interpolate values of nucleotide diversity and pairwise genetic distances (θ_{ST}) were constructed in ArcMap 10.2 (ESRI).

Results

Genetic diversity analyses

We analysed 588 bp long fragment of the mtDNA cytochrome *b* gene in 35 distinct haplotypes that were defined by 123 polymorphic sites, 97 were parsimony informative. In this set of analysed haplotypes, two were novel (GenBank Accession Numbers KX077599 and KX077600), obtained from sequences of four individuals sampled in Western Carpathians. Haplotypes were divided into two major groups: 1) the western group, 2) the eastern group (Table 1). Within 23 haplotypes of the western group we recorded 61 transitions and 6 transversion and 40 were parsimony informative. Within 12 haplotypes of the Eastern group we recorded 40 transitions and 7 transversions and 38 of them were parsimony informative. The western group included twelve haplotypes from Alps and Apennines, three haplotypes from the Western Carpathians, four haplotypes from Balkan area and four haplotypes from the Pyrenees. The Eastern group included three haplotypes from Anti-Lebanon, two from Taurus and three from Caucasus. We also analysed four haplotypes of *C. n. dementievi* from the Khorasan Mountains.

The Western group showed lower nucleotide diversity compared to the Eastern group. The highest value of nucleotide diversity was recorded in the Alps and Apennines followed by Balkan area, Pyrenees and the considerably low value was recorded in the Western Carpathians as representatives of the Western group. Generally, within the Eastern population units restricted to different mountain ranges, we recorded low nucleotide diversity values similar to value recorded in the Western Carpathians (Table 1, Fig. 1).

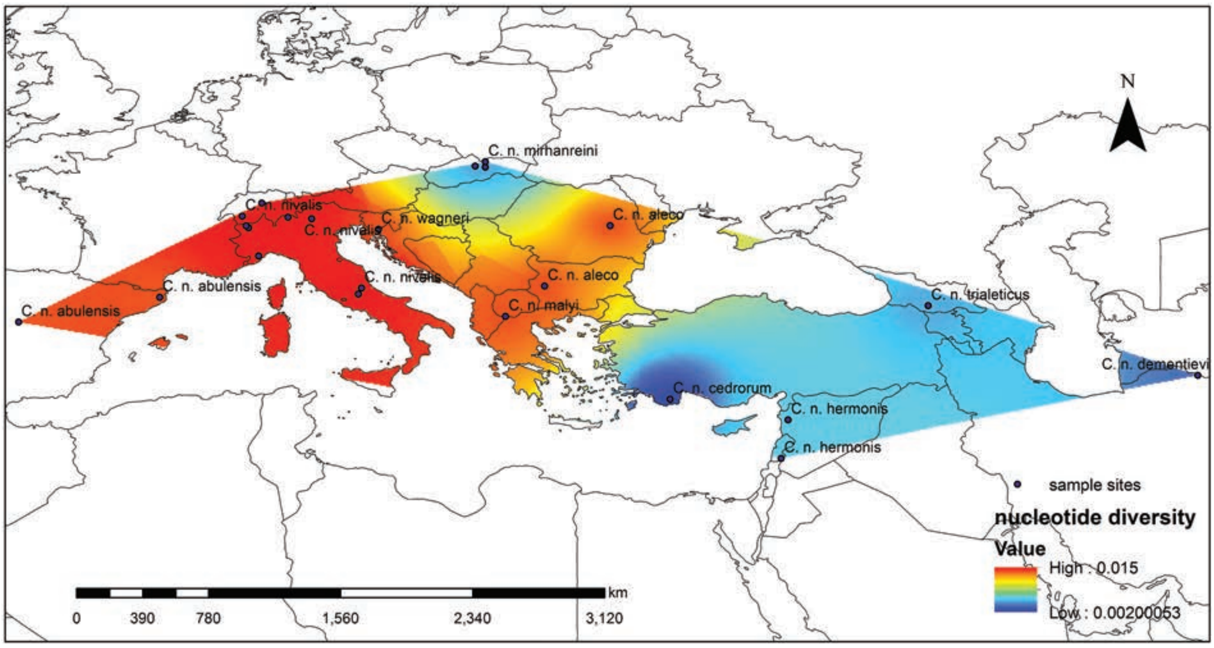

Fig.1. Map of interpolated nucleotide diversity (π) values among analysed subspecies.

Population differentiation

Interpolated θ_{ST} values clearly indicate lower genetic differentiation within the population on the West from the Western Carpathians than within the Eastern group (Fig. 2, Table 2). Genetic distances between pairs of populations (θ_{ST}) confirmed the highest differentiation of the Khorasan population (θ_{ST} = 0.80–0.93) where is assumed to be *C. n. dementievi*, very high differentiation of the Western Carpathian population from the other seven populations (θ_{ST} = 0.57–0.93) indicate the presence of *C. n. mirhanreini*. The lowest, differentiation was recorded between population of Alps, Apennines and Balkan population (θ_{ST} = 0.41). The genetic distance between the Western and Eastern group was θ_{ST} = 0.29. In the analysis of molecular variance (AMOVA) we calculated genetic variation among Western and Eastern group. The overall fixation index was 0.14 (P = 0.03) and 13.55% of the total genetic variation is due to differentiation between Western and Eastern group. Among populations within the Western and Eastern group the fixation index (F_{sc}) was 0.66 (P = 0.000) and 57.48% of total variation was due to differentiation among populations (Table 3).

Phylogenetic patterns

The evolutionary relationships examined in NJ, ML, MP and Bayesian trees had similar topology and only the topology of Bayesian inference is shown (Fig. 3). The phylogenetic reconstruction revealed strong support (99–100%) for dichotomy between *C. n. dementievi* and all other monophyletic subspecies. Poorly supported (<70% in all trees) were West (Pyrenees, Alps, Apennines, Western Carpathians, Eastern Carpathians, Rila, Baba, Dinarides) and East groups (Anti Lebanon, Saleh, Taurus, Caucasus). Within the Western group were well supported several geographic groups consistent with subspecies statuses of *C. nivalis*. Within the Western group additional sequences of *C. n. mirhanreini* created highly supported the Western Carpathians group (97–100%).

Discussion

Taxonomic status of the *Chionomys* genus was ambiguous for a long time (Nadachowski, 1991). Miller (1908) considered *Chionomys* as subgenus and

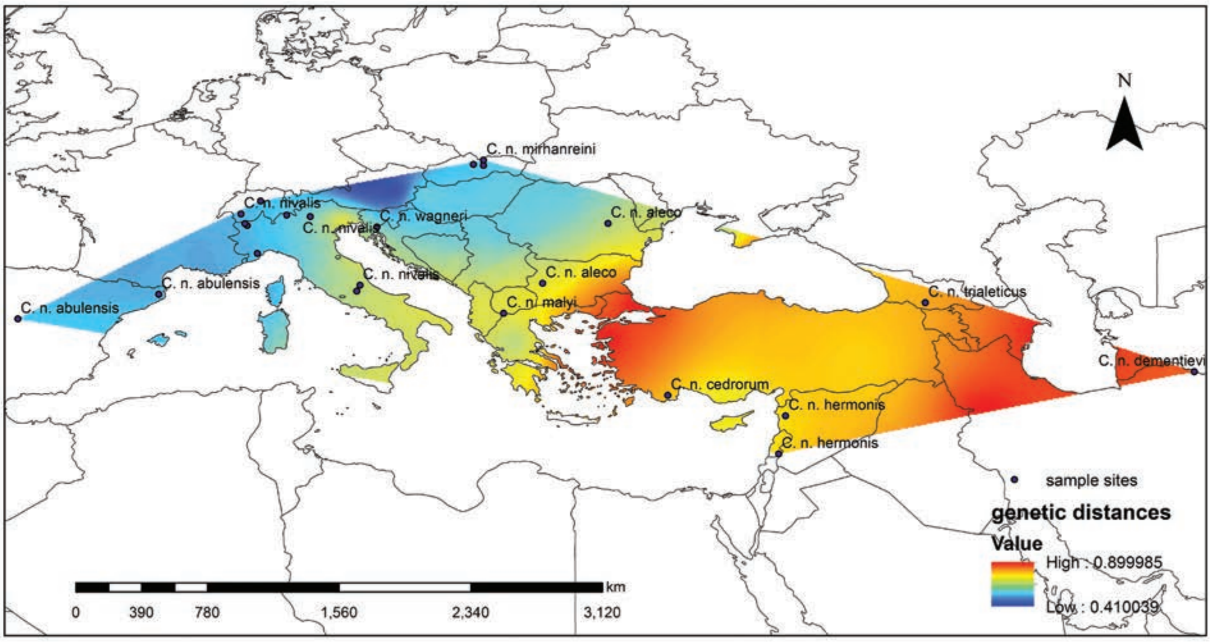

Fig. 2. Map of interpolated pairwisie genetic distances (θ_{ST}) among analysed subspecies. The red colour means high differentiation compared to low differentiation in blue.

Table 2. Pairwise genetic distances (θ_{ST}) among population groups of mtDNA haplotypes. *P*-values after 10,000 permutations are above the diagonal and θ_{ST} values are below the diagonal.

	Balkan	Alps & Apennines	Western Carpathians	Pyrenees	Anti Lebanon	Taurus	Caucasus	Khorasan
Balkan	0.000	0.001	0.029	0.029	0.029	0.063	0.029	0.027
Alps & Apennines	0.414	0.000	0.002	0.001	0.002	0.014	0.003	0.001
Western Carpathians	0.705	0.574	0.000	0.030	0.097	0.103	0.097	0.030
Pyrenees	0.520	0.495	0.730	0.000	0.029	0.070	0.031	0.026
Anti Lebanon	0.672	0.565	0.836	0.692	0.000	0.104	0.095	0.028
Taurus	0.663	0.594	0.904	0.684	0.735	0.000	0.099	0.063
Caucasus	0.680	0.621	0.878	0.713	0.773	0.780	0.000	0.027
Khorasan	0.799	0.747	0.926	0.818	0.898	0.924	0.907	0.000

many authors has accepted this view (Ellerman and Morrison-Scott, 1966; Corbet, 1978; Krapp, 1982). However, biochemical data support the hypothesis of separation of *Chionomys* from *Microtus* (Yannic et al., 2012). In addition, the genetic distance calculated between genera *Microtus* and *Chionomys* is even greater than between *Microtus* and *Arvicola* (Janeau and Aulagnier, 1997). Taxonomic studies based on morphological differences have led to the same conclusion (Gromov and Polyakov, 1992). Later, several other studies had tried using molecular markers to resolve the phylogenetic position of *Chionomys* in relation to the other species of *Microtus*. Based on cytochrome *b*, Jaarola et al. (2004) confirmed the genus *Chionomys* as distinct from *Microtus*. The mtDNA and Y-chromosomal variation suggest splitting of *Chionomys* into two monophyletic lineages: a group *nivalis* and a group *roberti/gud* (Yannic et al., 2012). Such phylogeny is also supported by data concerning dental morphology (Nadachowski, 1991) and differences in karyotypes (Zima and Král, 1984). As indicated Yannic et al. (2012), splitting occurred probably in the Early Pleistocene congruently with fossil data estimation (Nadachowski, 1991). It is generally acknowledged that *C. gud* and *C. roberti* which occur in the Middle East or the Caucasus diverged during the Middle Pleistocene (Bužan and Kryštufek, 2008). In contrast, *C. nivalis*, according to paleontological data from Holstein

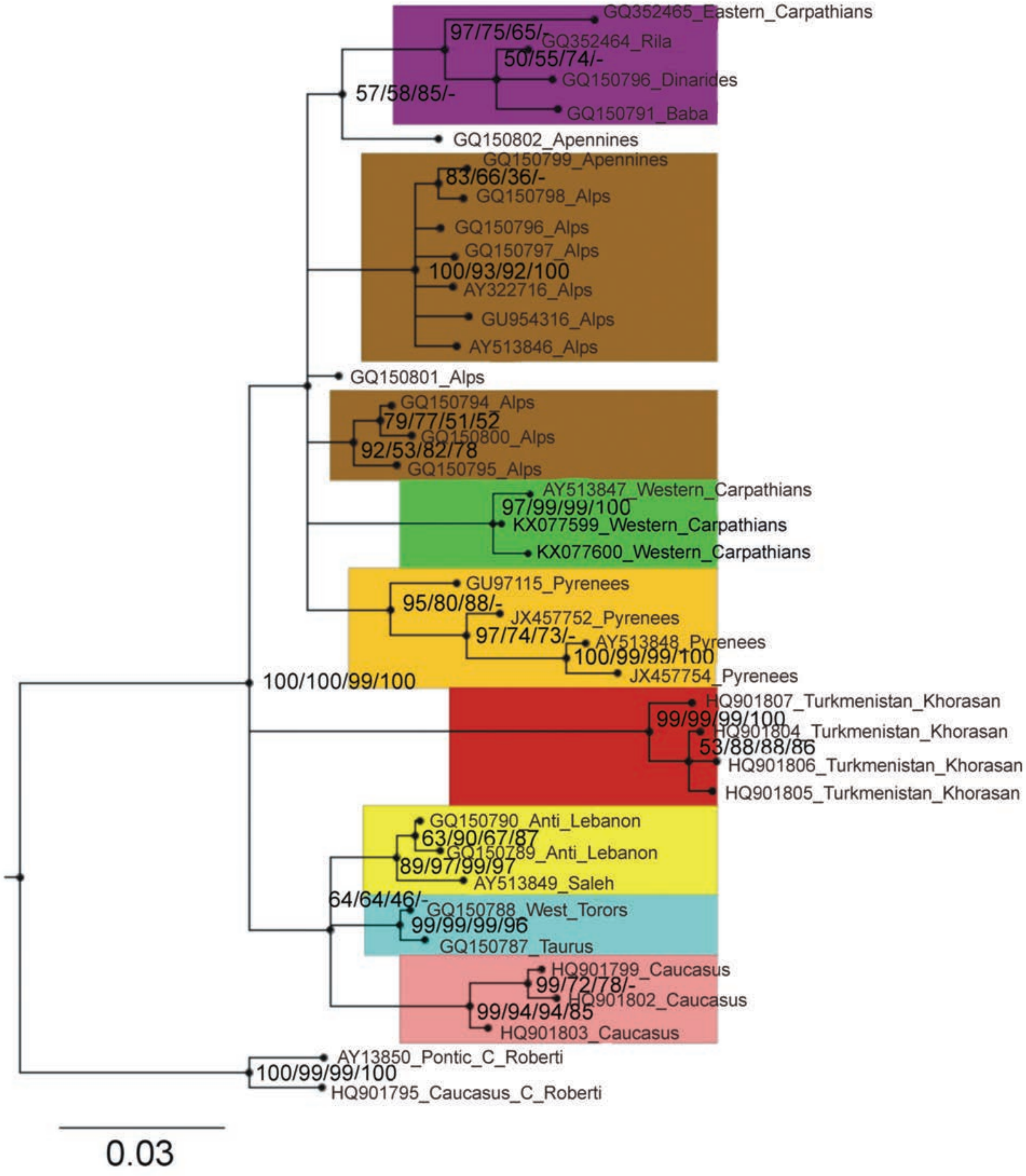

Fig. 3. Phylogenetic 50% majority rule consensus tree obtained with Bayesian inference (partitioned by haplotypes) with visualised main interior nodes of Bayesian posterior probabilities/ maximum-likelihood/ neighbour-joining/ maximum parsimony bootstrap support values. NJ, ML and MP trees reached the same topology Bayesian tree. The haplotypes are named according to their origin with GenBank Accession Numbers. Branch lengths are proportional to the number of substitutions per site (scale bar = 0.03 substitutions/ site). Subspecies information within visualised groups is presented in Table 1.

interglacial period had developed in the western mountain ranges in the Alps, the Carpathians, or the Pyrenees (Kowalski, 2001). While the eastern origin of *C. gud* and *C. roberti* was never questioned, western origin of *C. nivalis* remains still uncertain. The inclusion of the eastern subspecies *C. nivalis* was necessary to obtain a full picture of phylogeographic origin of *h. nivalis* (Yannic et al., 2012). Basic phylogenetic position of the eastern species *C. gud*, *C. roberti* and eastern subspecies of *C. nivalis* clearly establishes the Caucasus and the Middle East as the region of *Chionomys* origin (Yannic et al., 2012).

Table 3. Analysis of molecular variance of mtDNA haplotypes for the Western and the Eastern European group. The test of significance was assessed on 10,000 permutations.

Source of variation	d.f.	Sum of squares	Variance components	Percentage of variation	Statistics	*P*
Among groups	1	58.15	1.51 V_a	13.55	$F_{ct} = 0.14$	0.029
Among populations within groups	6	172.09	6.42 V_b	57.48	$F_{sc} = 0.66$	0.000
Within populations	27	87.33	3.23 V_c	28.97	$F_{st} = 0.71$	0.000
Total	34	317.57	11.17			

Based on our results, we suggest that *C. nivalis* evolved from ancestors *C. gud*, *C. n. dementievi* and *C. roberti*. Snow vole therefore would have broad and very fragmented distribution. Castiglia et al. (2009) indicate six different lineages, while four of them as allopatric, while the other two as sympatric in the Alps and the Apennines in contrast to previous scenario of two lineages based on allozymes only (Filippucci et al., 1991). Castiglia et al. (2009) also stressed the presence of one distinct haplotype in Tatra Mts which can provide proof of the existence of another glacial refugia in Central Europe, north of the main South European and the Middle East refugia. Phylogenetic reconstruction carried out by Bužan and Kryštufek (2008) suggests, that the easternmost subspecies *C. n. dementievi*, represents the oldest lineage of *C. nivalis* and this supports Eastern origin of the species. Level of nucleotide differentiation between *C. n. dementievi* and other subspecies of *C. nivalis* lies beneath the pragmatic limits of interspecies differentiation (>5%), as proposed Baker and Bradley (2006). Mitochondrial data thus provided no evidence to the recognition *C. n. dementievi* as a full species. Surprisingly low nucleotide diversity observed in *C. n. mirhareini* might indicate persistence of long term isolated population in the glacial refugia of the Western Carpathians. The Western Carpathians has been described as isolated glacial refugia for many species (Krascsenitsová et al., 2013; Zieliński et al., 2014; Klinga et al., 2015). Very low genetic differentiation between Alpine and the Western Carpathian populations indicate the origin of *C. n. mirhareini* in the Alps. Further work is needed to provide more detail information on dating of subspecies divergence.

Conclusions

Although the samples used in this study covered almost the whole species range of Snow vole in Europe, full reconstruction of its evolutionary history will need more complex species(-super) tree approach having more independent molecular markers. In this study we indicated impact of long term isolation due to climate change on genetic diversity of species.

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Influence of climatic factors on the population dynamics of small mammals (Rodentia, Soricomorpha) on the sites affected by windthrow in the High Tatra Mts

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Abstract

Hlôška, L., Chovancová, B., Chovancová, G., Fleischer, P., 2016. Influence of climatic factors on the population dynamics of small mammals (Rodentia, Soricomorpha) on the sites affected by windthrow in the High Tatra Mts. *Folia Oecologica*, 43: 12–20.

Climatic factors and related changes of the temperature, humidity and sunshine demonstrably affect the population dynamics of small mammals. This complex influence gets more intense in the case of natural and anthropic disturbances which occurred in the forest ecosystems of the High Tatra Mts in 2014 (wind calamity) and in 2015 (forest fire). During the period of research in 2005–2015, we were observing successive changes in the species composition, abundance and spatio-temporal distribution of small mammals on the seven permanent research areas by using the CMR method. Besides the changes of selected habitat variables, we were also continually measuring values of meteorological elements (such as air and soil temperature, relative air and soil humidity, thickness and duration of snow cover). Statistical testing of the thickness and duration of snow cover proved significant influence of these factors on the population dynamics of small rodents (Rodentia) and shrews (Soricomorpha). Winters with a thicker snow cover and longer snow periods had a positive effect on the reproduction and surviving of both taxonomic groups in the subsequent vegetation season. We have discovered the positive correlation between the temperature and the quantity dynamics of dominant small rodents while shrews responded to higher temperatures with less spatio-temporal activity. Gradient analysis of the complex influence of measured meteorological elements proved species-specific differences in the responses of small mammals to the current and conditions of weather indicated by ecological requirements of plant species within a specific habitat.

Keywords

population dynamics, small mammals, snow cover, temperature

Introduction

Small ground dwelling mammals (Rodentia, Soricomorpha) are highly adaptable animals which can be found in all habitats ranging from the tropics to the polar regions (Hayward and Phillipson, 1979). They are an important part of food webs and an interacting element between vegetation and soil subsystems (Golley et al., 1975). Detailed information are available at present for several species on small mammals biology, autecology, population and communities organisational levels and functions in various, e.g. forest and grassland

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ecosystems (Barrett and Peles, 1999). This makes small mammals a suitable object for testing ecological hypothesis based on a landscape scale.

Changes of weather evidently influence population density, survival and growth of small herbivore rodents. Chen et al. (2015) reported nonlinear responses to several meteorological parameters, e.g. precipitation or air temperature. Population dynamic of small mammals is influenced also by the weather in previous winter, especially snow cover depth and number of days with snow cover. Mostly Russian authors, e.g. Formozov (1946, 1961) and Semyenov et al. (1958) studied survival rate of small mammals according to the snow parameters in past. Fuller et al. (1969) presented winter mortality as an important determination factor for the size of small mammals spring population. Several authors, e.g. Vickery and Bider (1981), Hansson (1987), Hansen et al. (1999), Stokes et al. (2001), Lima et al. (2002), Kalcounis-Rueppell et al. (2002), Vieira et al. (2010) studied the influence of climatic factors (temperature, humidity, snow cover) on population dynamics, diurnal activity, fecundity, survival rate or food behaviour of small mammals. In Slovakia, Hlôška and Saniga (2005) studied the influence of precipitation on diurnal activity of small mammals in supra-montane vegetation zone in the Malá Fatra Mts. Jurčovičová and Kozubová (2007) studied the influence of temperature and precipitation on small mammals diversity and density in the Nature Reserve Šúr in south-western Slovakia.

In area of the High Tatra Mts (Slovakia) had occurred considerable natural and anthropic disturbances in 2014 (wind calamity) and in 2015 (forest fire) which changed significantly character of local forest ecosystems. The main symptoms were that matured trees were almost completely destroyed and canopy closure was eliminated. Thus the aim of our paper was to test the following hypotheses in such specific habitat conditions: 1) Snow cover height and duration of snow cover influence reproductive activity and abundance of small mammals in the next breeding (vegetation) season; 2) Air temperature modifies ground surface activity of small mammals; 3) Population dynamics of species are changing according to the values of observed meteorological parameters (air temperature, soil temperature and moisture, precipitation) and microhabitat properties featured by site conditions and successional stage of vegetation.

Materials and methods

Study plots

The research was carried out in the Tatra Mountains from 2005 to 2015 on five research plots representing different intensity of natural disturbances and one reference undisturbed plot in larch-spruce forest. These six plots were located in the range of 925 to 1,260 m asl: NEX – Jamy, 49°09′37″N, 20°15′21″E, 1,100 m asl, forest stands affected by the wind calamity in year 2004, no management intervention (no processing of wind-thrown and broken trees, no forestation); EXT – Danielov dom, 49°07′13″N, 20°09′50″E, 1,260 m asl, forest stands affected by the wind calamity in 2004, treated by applying common forestry measures (wood mass removed, plot forested partly); REF – Smrekovec, 49°07′15″N, 20°06′26″E, 1,210 m asl, intact stands, so-called reference (control) plot; FIR 1A and FIR 3A – Tatranské Zruby, 49°07′49″N, 20°11′53″E and 49°08′02″N, 20°11′32″E, 1,025 and 1,100 m asl, two plots in forest stands affected by the calamity and later by a fire; CVL (Čierny vodný les) – Nový Smokovec, 49°08′06″N, 20°12′30″E, 1,015 m asl, forest stands affected by the wind calamity, water-holding measures applied; OVL (Oliverov vodný les) – Tatranská Lomnica, 49°10′20″N, 20°16′59″E, 925 m asl, forest stands affected by the wind calamity, water measures applied. On each trapping point we estimated habitat variables (altitude, orientation, inclination) and vegetation cover using phytocenological records. To characterise successional stages of study habitats, phytocenological mapping was performed during 2–4 vegetation seasons in each plot and Ellenberg's eco-indices were calculated.

Trapping of small mammals

So called quadrat method was used for small mammals captures. Research sites were of uniform size 75 × 75 meters, covering an area of 0.56 ha. Each capture campaign organized twice per year (in spring and in autumn) lasted three days and three nights. Thirty six Chmela-type traps were installed on each site on a regular mesh, distance 15 m. The trapped animals were marked and released (CMR method). Mixture of fish, nuts, oat, extruded water larvae and sunflower oil served as bait. The traps were checked several times during day. Coded ear marks for Rodentia and marking colour for Soricomorpha were used for marking the catches. After marking, on each trapped small mammal we estimated sex, sexual status, and approximate age. Trap effort was standardized for each site for each trapping sessions by dividing the number of captures by the number of nights that sites were open (Lentic, 2003). Standardized trap data (captures/plot/night) of individual abundance were used in all analyses.

Climatic data and analyses

Meteorological parameters (snow cover height and length, air temperature and humidity, soil temperature in 2005–2015) and abundance of dominant and eudominant species, as well as spatio-temporal distribution of sexually active females in small mammal populations were used for the analysis of weather impact on population dynamics. Snow depth (in cm) was measured at the meteorological station Tatranska Lomnica, 830 m asl by a snow stake. Air temperature (°C) and humidity (%) was measured at 200 cm height by the Hygroclip 2 (Rotronic, Switzerland) sensor as 60 min instant values. Soil temperature was measured in 8 cm depth by a termocouple Campbell 107 as 60 min instatnt value. All meteorological data were recorded and stored by the Campbell CR10x dataloger (Campbell Scientific, UK). Data matrix contained 1,603 rows and 46 columns. Contingency tables were used for classification, transformation a visualisation of data. Correlations were tested in statistical environment R (R Core Team, 2015). Direct gradient methods in CANOCO for Windows 4.5 and CanoDraw for Windows 4.14 (Cajo and Šmilauer, 2002) were applied in multidimensional analysis of ecological data.

Results

Small mammals community

During our study we trapped and marked 1,288 individuals from 14 species of small mammals. Three species were eudominant, one species was dominant, one species was subdominant and the largest number of species (nine) had subrecendent proportion. An overview of species composition, abundance, diversity and equitability of small mammals are shown in Table 1. Five species had euconstant proportion; *Apodemus flavicollis*, *Clethrionomys glareolus*, *Microtus agrestis*, *Sorex araneus* and *Sorex minutus*. Also five species were classified as accessory species; *Apodemus sylvaticus*, *Arvicola amphibius*, *Micromys minutus*, *Microtus arvalis*, *Neomys fodiens*. Four species in the sample had accidental proportion; *Apodemus agrarius*, *Muscardinus avellanarius*, *Neomys anomalus* and *Sicista betulina*.

Table 1. Number of individuals, number of species, species diversity (H´), equitability ($E_{1/D}$), relative abundance (D) and frequency (K) of small mammals on six research plots during 2005–2015 (list of mammal species is arranged alphabetically)

Species / research plot	CVL	EXT	FIR1A	FIR3A	NEX	OVL	REF	n	D (%)	K (%)
Apodemus agrarius	–	–	–	–	5	–	–	5	0.39	14.29
Apodemus flavicollis	34	15	56	22	13	23	10	173	13.43	100.00
Apodemus sylvaticus	–	1	2	–	–	–	–	3	0.23	28.57
Arvicola amphibius	1	–	–	–	–	2	–	3	0.23	28.57
Clethrionomys glareolus	91	76	66	93	131	100	122	679	52.72	100.00
Micromys minutus	–	–	–	1	2	–	–	3	0.23	28.57
Microtus agrestis	14	22	18	14	5	19	1	93	7.22	100.00
Microtus arvalis	1	–	–	2	–	–	–	3	0.23	28.57
Muscardinus avellanarius	–	–	5	–	–	–	–	5	0.39	14.29
Neomys anomalus	–	–	–	–	–	1	–	1	0.08	14.29
Neomys fodiens	4	–	–	–	–	3	–	7	0.54	28.57
Sicista betulina	–	1	–	–	–	–	–	1	0.08	14.29
Sorex araneus	40	59	63	24	24	62	8	28	21.74	100.00
Sorex minutus	8	6	2	4	4	7	1	32	2.48	100.00
Number of individuals	193	180	212	160	184	217	142	1,288		
Number of species	8	7	7	7	7	8	5	14		
Diversity index (H´)	2.083	1.969	2.108	1.824	1.476	2.026	0.792	1.961		
Equitability ($E_{1/D}$)	0.412	0.463	0.543	0.368	0.269	0.398	0.268	0.205		

Variability of climatic factors

According to the meteorological observation in Tatranská Lomnica (830 m asl) the average snow cover height varied in the range of 1.0 cm (winter 2014/15) to 19.9 cm (winter 2005/06) in the study period 2005–2015. The trend of snow cover height was declining ($r^2 = 0.63$) with slight increase in the winters of 2012/13 and 2013/14. Duration of snow cover above 1 cm ranged from 54 days (winter 2014/15) to 134 days (winter

2005/06). The trend of snow cover days was less evident than snow height (r^2 = 0.29) but also declining. Snow cover lasting more than 100 days occurred five times during the study period (Fig. 1). Average snow cover above 8 cm was found during only four winter seasons (2005/06, 2006/07, 2012/13 and 2013/14; Fig.1). During the catches, air temperature ranged from 1.2 to 28.6 °C, relative air humidity varied from 45 to 100% and soil temperature varied in the range of 7.5 to 28.2 °C. The average values of meteorological parameters are shown in Table 2. Differences in the air and soil temperature, respectively, were significant among the sites (Kruskal-Wallis ANOVA, air: χ^2 = 54.5, df = 6, $P < 0.001$; soil: χ^2 = 187.2, df = 4, $P < 0.001$) as well among the years (air: χ^2 = 382.6, df = 7, $P < 0.001$; χ^2 = 180.9, df = 7, $P < 0.001$).

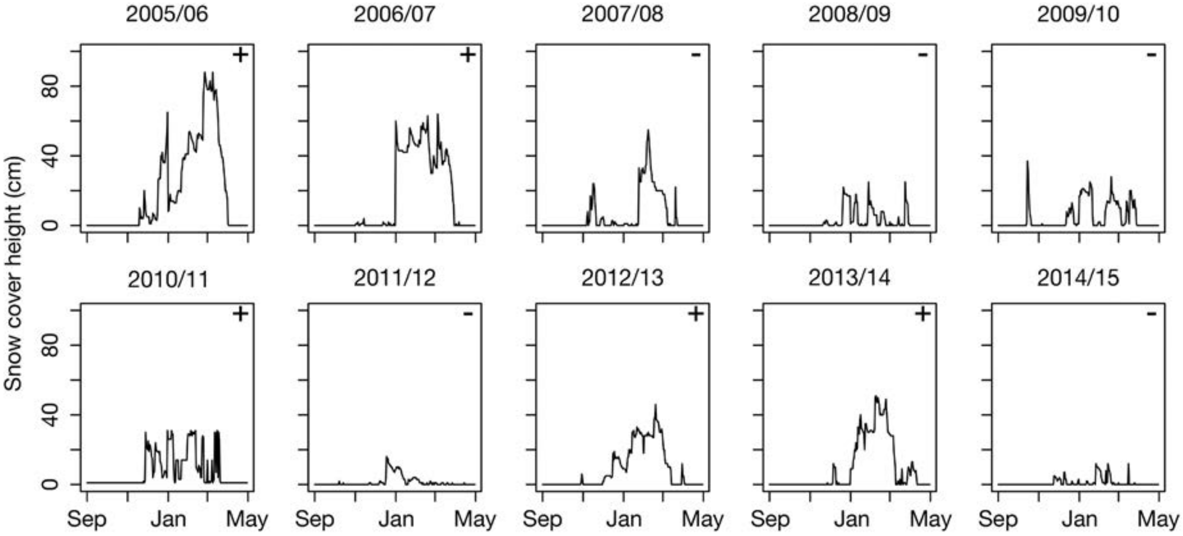

Fig. 1. The winters with snow cover above 100 days and average height above 8 cm (+) and winters with snow cover below 100 days and average height below 8 cm (–) as measured in Tatranská Lomnica (830 m asl).

Table 2. Average air temperature, humidity and soil temperature on research plots during 2005–2015

Variable / research plot	CVL	EXT	FIR1A	FIR3A	NEX	OVL	REF
Air temperature (°C)	13.34	12.72	10.97	9.84	12.30	13.67	10.88
Relative air huminidy (%)	80.26	72.76	69.28	73.36	82.96	82.24	75.23
Soil temperature in16 cm (°C)	15.86	14.25	14.47	13.99	10.42	–	–

Influence of snow cover on small mammals

Abundance of small rodents (Rodentia) increased significantly after long lasting and snow rich winters. Variable winter weather or winters with discontinued snow cover caused statistically significant population decline (one-sample t-test, $t = 3.9$, df = 10, $P = 0.002$; Fig. 2a). Number of individuals after the winters with sufficiently deep and long duration of snow cover ranged from 8.3 to 16.1 captures per sites and nights. Number of individuals during breeding seasons following poor snow winters ranged from 2.8 to 6.3 captures per sites and nights. We found significant fluctuation changes also in Soricomorpha population ($t = 4.513$, df = 8, $P = 0.001$, Fig. 2b). Population size increased during breeding seasons that followed winters rich on snow. The catches increased from 0.9 captures per sites and nights in 2006 up to 4.9 in 2007. Whereas average snow cover height was 18.9 cm and its duration was 134 days in winter 2005/06 and 16.0 cm and 108 days in winter 2006/07.

The snow cover height and duration determined also species richness of small mammals. While species number varied between three and seven after snow poor winters, after snow rich winters increased up to six and nine species. The difference was significant (one-sample t-test, $t = 10.6$, df = 10, $P < 0.001$).

Continuous snow cover significantly increased proportion of sexually active male and female individuals in local Rodentia populations. On the contrary, snow poor winter with warm and rainy weather negatively influenced reproduction capacity. In 2007 breeding season, proportion of sexually active individuals was

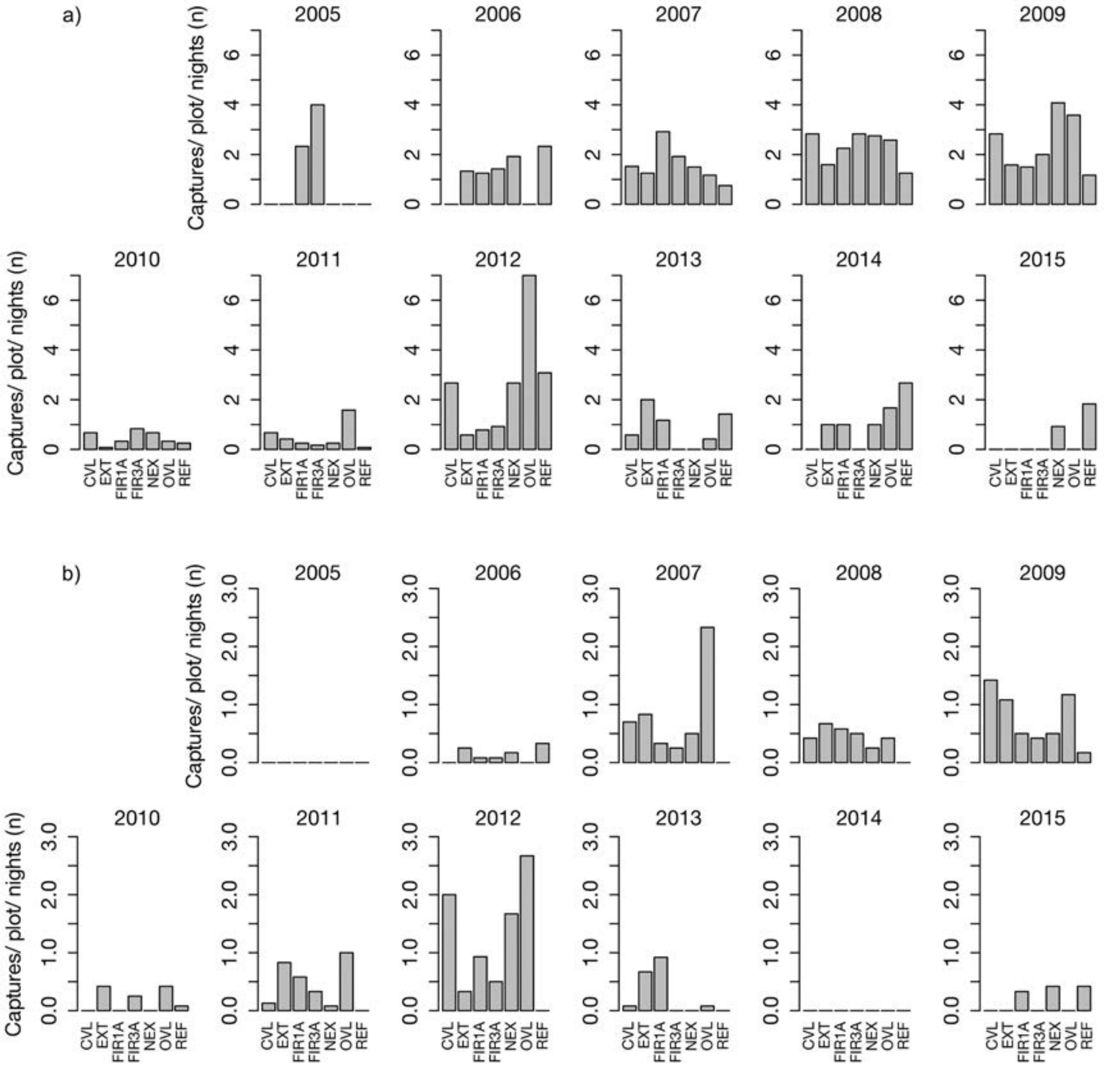

Fig. 2. Fluctuation in numbers of individuals of a) rodents and b) shrews trapped as six study plots during breeding seasons 2005–2015. Snow cover height and its duration in winters preceding breeding seasons see in Fig. 1.

significantly higher after winter with deeper and longer duration of snow cover ($\chi^2 = 25.9$, df = 2, $P < 0.001$), slight decline was observed in 2008 and 2009. High portion of the individuals in reproductive age was recorded again in summer 2011 after snow rich winter 2010/11 ($\chi^2 = 13.8$, df = 1, $P = 0.001$). Notable decline in numbers of sexually active individuals of both sexes of rodents were recorded after mild winters 2007/08 and 2011/12 (Fig. 3). The differences in ratio between sexually active and inactive individuals induced by previous winter characteristics are bigger in shrews than in rodents populations (Fig. 3).

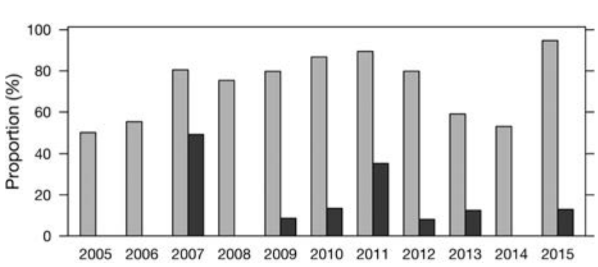

Fig. 3. Relative ratio of sexually active individuals in rodents (light grey, n = 457) and shrews (dark grey, n = 320) during breeding seasons 2005–2015. Snow cover height and its duration in winters preceding breeding seasons see in Fig. 1.

We did not find significant correlations neither between number of individuals and snow height (rodents, r = 0.34; shrews, r = –0.43; $P > 0.05$) nor between number of individuals and duration of snow cover (rodents, r = 0.13; shrews, r = –0.12; $P > 0.05$) in both groups of small mammals (Fig. 4).

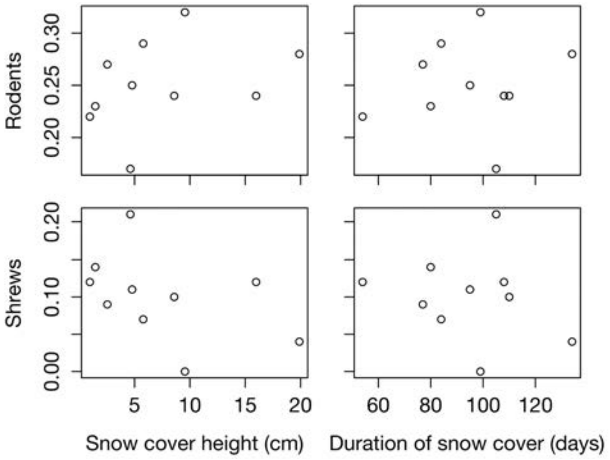

Fig. 4. Relations between snow cover height, snow cover duration and the numbers of rodents and shrews (captures/ plot/ night) in the next growing seasons.

Temperature and dominant species of small mammals

We tested the hypothesis on differences in surface activity of dominant small mammals induced by temperature. Significant differences in temperature tolerance were found in three species, for the air temperature (Kruskal-Wallis ANOVA, $\chi^2 = 8.8$, df = 2, $P = 0.013$), as well as for the soil temperature ($\chi^2 = 70.2$, df = 3, $P < 0.001$). During catches, the average air temperature with maximum surface activity of *A. flavicollis* was 13.0 °C and soil temperature was 14.8 °C. Species *C. glareolus* was the most active at the air temperature of 12.3 °C and soil temperature of 11.9 °C and activity of *S. araneus* culminated at 13.1 °C and 13.3 °C respectively.

Climatic gradients and distribution of small mammals

Effects of four climatic variables (soil moisture, soil temperature, air temperature and precipitation) were explained in RDA analysis. The first ordinary axis was identified by level of natural disturbance (wind in 2004) as well as anthropogenic disturbance (fire in 2005). Second ordinary axis explained the moisture gradient. Successional changes induced by windstorm took place on the five study plots (REF, NEX, EXT, OVL, CVL), whereas two similar plots (FIR1A and FIR3A) were affected by fire in early stage of succession. The order along the moisture gradient was as follows: REF, FIR1A, FIR3A, NEX, EXT, OVL, CVL. The numbers of *N. fodiens, S. minutus, C. glareolus* and *M. agrestis* species correlated well with soil moisture. The number of *S. araneus* individuals increased with increasing air temperature. Species *A. flavicollis* positively reacted to increasing amount of precipitation (Fig. 5).

Spatiotemporal changes in the distribution and number of individuals in small mammals populations we assessed by phytocenological bio-indication of plot conditions using the Ellenberger's indicator values. The indicator values calculated for the study plots and years are shown in Table 3. Soil moisture gradient positively correlated with the number of *A. agrarius, N. fodiens* and *S. araneus* individuals. An increase of population size we observed in *A. flavicollis* species along pH and soil nitrogen gradients. Species *C. glareolus* showed elevated affinity to increasing continentality of microhabitats (Fig. 6). The values of Ellenberg's indices have changed according to successional stage of vegetation and determined both spatial and temporal dynamic of small mammals communities.

Discussion

Presented results documented some influence of the snow height and duration of snow cover on abundance of small rodents, proportion of sexually active individuals, and population growth. These demographic and population parameters correlated well with long-lasting and snow reach winters. Contrary to that, these population variables were negatively influenced by preceding winters with low snow cover, short or

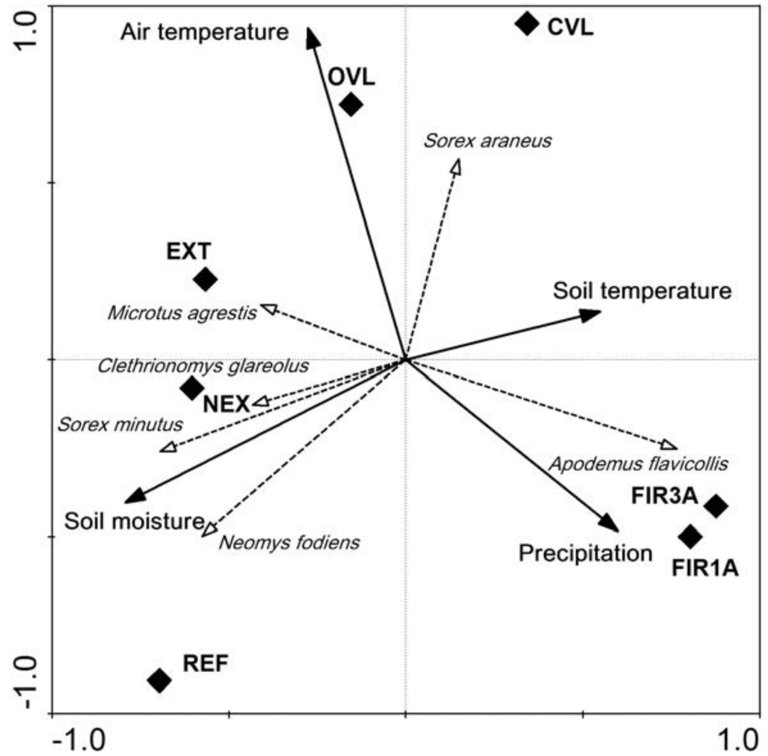

Fig. 5. Results of RDA analysis on species abundance and environmental data (meteorological characteristics) in study plots. First canonical axis explains 28.4% and second 16.7% from the whole data variability.

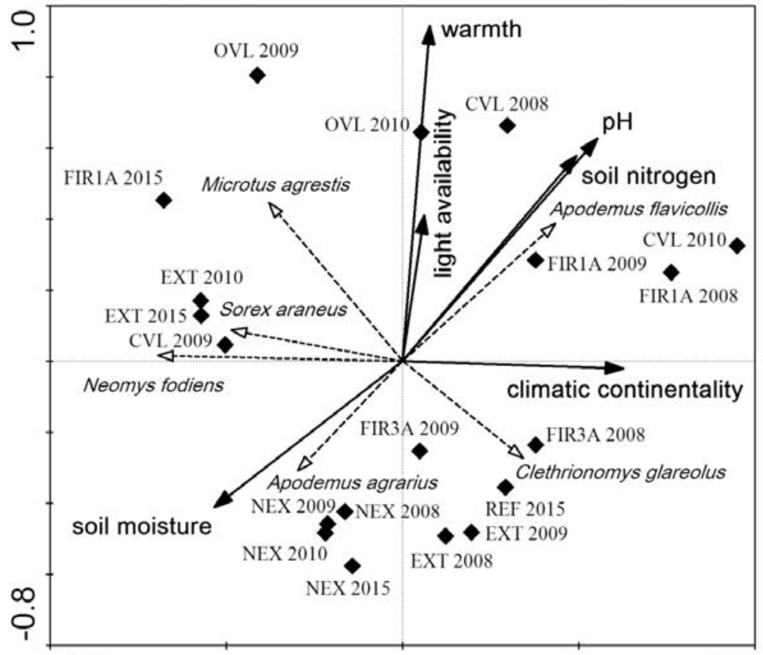

Fig. 6. Results of RDA analysis on species abundance and environmental data (Ellenberg's eco-indices) in study plots. First canonic axis explains 47.8% and second 11.1% from the whole data variability.

interrupted snow coverage periods. In shrews populations, the negative influence of high and long-lasting and positive effect of low and discontinuous snow-cover were observed.

Table 3. Ellenberg's eco-indices of six study plots counted on the basis of the phytocoenological indication of the plant species. Values are averaged from 2–4 vegetation seasons in each plot.

Plot	CVL	EXT	FIR1A	FIR3A	NEX	OVL	REF
Light	6.24	5.62	6.76	6.85	5.92	6.02	4.93
Warmth	4.57	4.16	4.36	4.07	4.02	4.63	4.05
Continentality	4.01	4.21	4.25	4.31	3.77	4.07	4.33
Humidity	5.77	5.83	5.39	5.45	6.21	5.72	5.54
pH	4.24	2.59	3.80	3.68	2.47	3.34	2.41
Nitrogen	5.08	3.67	5.56	5.46	3.44	4.51	3.41

Fuller et al. (1969) stated the influence of microclimate factors during winter (especially snow height and duration) on small mammals mortality and spring reproduction size in his several years long study. High mortality of small mammals during winters with limited snow cover reported several Russian authors (e.g. Formozov, 1946, 1961; Kirikov, 1946; Semyenov et al., 1958). Iľenko and Zubchaninova (1963) reported home range changes and sexual ratio changes in *C. glareolus* and *A. sylvaticus* species induced by height and duration in snow cover. Our study demonstrated that the winter periods with continuous snow cover significantly increased the ratio of sexually active individuals in rodents population. Mild winters with missing snow cover and warm weather had opposite influence on reproduction capacity. Similar changes were observed in the ratio between sexually active and inactive individuals in local population of Soricomorpha. Spottiswoode and Saino (2010) reported possible influence of environmental changes on sexual behaviour. The influence of climate changes on sexually specific mortality presented also Møller (2012).

Winter season weather in the Tatra Mts foothills is changing in the last decades as a response to global climate changes. In long term run, natural disturbances and perturbations caused by climate variability significantly modify species richness and abundance of small mammals. Blois et al. (2010) predicted changes in species diversity by increase of ubiquist species in local populations. In their comparative study has been suggested that increase of the air temperature above the value which small mammals had been exposed during their evolutionary traits might stimulate disintegration of native populations and invasion of alien species. According to our study, the influence of ambient temperature determined by the air and soil temperature plays significant role on the diurnal activity of small mammals. Vieira et al. (2010) studied the influence of ambient temperature and precipitation on the small mammals diurnal activity and reported positive correlation between activity with ambient temperature under elevated relative air humidity. However, under low air moisture the correlation between animal activity and ambient temperature was negative. Based on our results we conclude that besides body size, the biorhythm and spatial activity is mostly driven by ambient temperature and moisture (Lovegrove, 2003). Also Bronson (2009) found that mammals with smaller body were more sensitive to the environmental factors such as temperature and precipitation.

Multidimensional analysis of our data (abundance and ecological distribution of small mammals according to the selected climate parameters) confirmed significant influence of measurable climate gradients on the number and distribution of small mammal individuals. We found the site conditions (indicated by plant communities) as reliable indicator of favourable microhabitats for distinguished small mammal species. Thus such environmental gradients could be generally understood as important endogenous components of their ecological niches (Forman and Godron, 1986).

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Null model analysis of spatial species associations in spruce, tree line and dwarf-pine bird assemblages in the High Tatras, the Western Carpathians

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Abstract

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Jared Diamond proposed several assembly rules based on the assumption of competitive interactions among species. The first Diamond's rule proposes that communities are formed of certain permissible combinations of species that can co-exist. The fifth assembly rule states that some pairs of species never co-occur, forming so called "checkerboard" or complementary distributions. The objective of this study was to test these propositions on spruce, tree-line and dwarf-pine bird assemblages censused by the fixed radius point count method in the High Tatras, Slovakia. The null model simulations yielded no clear assembly patterns. The binary null models had tendency toward random associations, while quantitative null models suggested segregations. Presence/absence null models showed tendency toward random associations in post-breeding and breeding spruce bird assemblages, while quantitative null models yielded half random and half segregations in post-breeding season and all types of associations were detected during the breeding with slight prevalence of segregation. All binary tests indicated random associations in the post-breeding bird assemblages in the upper tree line and dwarf pine communities, whereas quantitative models showed prevalence of segregation. Binary models indicated slight prevalence of random associations in the breeding bird assemblages of the upper tree line and dwarf pine communities from territorial records and prevalence of segregation from all records. Quantitative models did not show consistent results in these habitat types detecting prevalence of segregations. In summary, the first Diamond's rule was not supported due to random patterns of unique species combinations and the fifth rule was supported partly by quantitative null model analyses.

Keywords
binary null models, bird communities, co-occurrence, quantitative null models, species associations

Introduction

Null model analyses of spatial and temporal species associations are commonly applied on testing hypothesis of compensatory dynamics and complementary distributions (e.g. Gotelli, 2000; Gotelli and McCabe, 2002; Ulrich and Gotelli, 2010; Korňan, 2013; Korňan and Kropil 2014). Compensatory dynamics and checkerboard distributions assume negative covariance of competing species in spatial and temporal patterns. These phenomena may be tested on the level of two or several species, guild/s, and assemblage or community.

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Compensatory dynamics and checkerboard distributions have played a crucial role in the development of competitive bird assemblage concepts (Lack, 1971; MacArthur, 1972; Cody, 1974; Diamond, 1975; see Wiens, 1989; Gonzalez and Loreau, 2009 for review). Initially, interspecific competitive interactions were viewed as the dominant force of nature driving spatiotemporal patterns and coexistence among species for decades. In the first half of 1980's, the competitionist view was heavily criticized (see Wiens, 1989 for review). At that time, bird community assemblage, began to be viewed as being much more complex, resulting from competition as well as many other processes, including food resource abundance, stochastic weather events, habitat change, winter mortality, predation, parasitism, other disturbances etc. later referred to "pluralistic concept" (Holmes et al., 1986; Wesołowski and Tomiałojć, 1997; Korňan, 2013; see Wiens, 1989; Brawn et al., 2001 for review). Thus, the pluralistic concept combines biotic and abiotic processes influencing survival of populations forming communities and operating on various temporal and spatial scales. Based on experimental evidence, however, some authors still consider interspecific competition as the primary factor (see Dhondt, 2012 for review). Moreover, competitionist view (complementary distribution) sensu Diamond's assembly rules was supported by community wide analyses of many taxonomical groups from compiled data matrices (Gotelli and McCabe 2002, Ulrich and Gotelli 2010). Furthermore, negative co-occurrence patterns revealed by null model analyses that support the competition theory were detected in wide range of assemblages, e.g. diatoms (Heino and Soininen, 2005), ants (Badano et al., 2005), fish (Bhat and Magurran, 2007), bird (Sarà et al., 2006), and small mammals (Abu Baker and Patterson, 2011). In contrast, other authors reported opposite results also from compiled data matrices of wide range of taxonomic groups (Schluter, 1984; Houlahan et al., 2007). In addition, a number of other studies analysing various taxonomic group assemblages, e.g. zooplankton (Jenkins, 2006), crustaceans (Sfenthourakis et al., 2006), fish (Perez-Neto, 2004), birds (Gotelli et al., 1997, Feeley, 2003, Wang et al., 2011), and carnivores (Šálek et al., 2014), detected prevalence of random or positive species associations in co-occurrence patterns tested out by various null models and indices.

The results to date are contradictory, and discussion on the relative importance of interspecific competition continues. Nevertheless, other community processes e.g., unique habitat associations, limited dispersal, historical and evolutionary processes that prevent species co-occurrence may generate negative species associations, as well as missing species combinations (Ulrich and Gotelli, 2007). The topic of general validity of competition processes in complementary distribution patterns remains unresolved and further studies and needed.

The primary objective of this study is to test Diamond's first and fifth assembly rules (Diamond, 1975, p. 344) on the data set of breeding and post-breeding bird assemblages in spruce, upper tree line and dwarf pine bird assemblages. The first and fifth Diamond's assembly rules states: "(1) If one considers all species combinations that can be formed from a group of related species, only certain ones of these combinations exist in nature. (5) Some pairs of species never coexist, either by themselves or as part of a larger combination." The working questions for our research were as follows: The first objective of our research was to determine whether the spatial and abundance patterns of birds in our study supported the role of interspecific competition, as proposed by Diamond. Are the studied bird assemblages formed by specific species combinations under interspecific competition assumptions that permit specific community structure? Do the spatial patterns observed in our study system support assumption of complementary (checkerboard) distribution? We applied binary and quantitative null models and co-occurrence indices to test these hypotheses on assemblage level.

The study was conducted in three main types of habitat during breeding and post-breeding seasons. The second objective is to test effect of habitat type and season on assembly patterns. Because habitat and seasonal effects can influence bird assemblage structure and assembly rules, we proposed two hypotheses: (1) More structured assembly patterns (negative associations) should occur in the breeding season because of the territorial patterns exhibited by birds at that time. Conversely, random species associations are more likely to occur in the post-breeding period when birds do not defend territories and move more opportunistically. (2) Bird assemblages of spruce forests should indicated stronger assembly coming from species competitive interactions than those in dwarf pine habitats. This is due to higher species richness and mean population and total assemblage densities in spruce communities. Consequently, we assume stronger tendency toward complementary distribution (segregation, negative species associations) in spruce communities than dwarf pine and upper tree line communities, in which we expect tendency toward disassembly (random species associations).

Material and methods

Study area

The research was performed in the High Tatras, the Western Carpathians, North-central Slovakia. The bird point count transects were conducted in the Furkotská, Mlynická and Mengusovská valleys in the wider area of Štrbské pleso ski resort. Air temperatures in July average about 10 and 12 °C. Mean annual precipitation varies between 1,200-1,600 mm. Snow cover lasts 140–200 days in a year (Miklós et al., 2002).

The study area is covered by spruce, upper tree line and dwarf pine communities. Spruce forest were dominated by Norway spruce (*Picea abies*), with an admixture of European larch (*Larix decidua*) and Rowan (*Sorbus aucuparia*). Upper tree line communities consisted of Dwarf pine (*Pinus mugo*), Swiss pine (*Pinus cembra*), European larch and Norway spruce with an admixture of Common aspen (*Populus tremula*) and Goat (Pussy) willow (*Salix caprea*). Dwarf pine communities were composed of dwarf pine with some Norway spruce, Swiss pine, Goat willow and Common aspen. The study area is covered by continuous forest cover and was in some places affected by damaging windstorm in 2004.

Bird counts

Birds were counted by the fixed-radius point count method in post-breeding season in 2008 and breeding season in 2009 (Bibby et al., 2000). Count point radius of 50 m was used in spruce communities, while radius of 100 m was applied for counting in tree-line and dwarf-pine communities. Radius of 50 m is generally recommended for closed habitats such as forests, whereas radius of 100 m is suitable for open habitats such as meadows, pastures, etc. Radius of points was estimated by eye. During bird counting, all visual and acoustic records of birds were positioned into standardized field sheets. Distances of calling birds were not included into the analyses of population abundances by detectability functions that could increase accuracy of estimates. For presence/absence data this procedure is not necessary. Count points were positioned by a GPS apparatus. Minimum distance between count points was at least 200–300 m estimated by walking. Population and total assemblage densities were computed from all samples (pooled data) for each habitat. Primary data sets are archived by the first author and are available upon request.

During post-breeding season, birds were counted along four point transects. The first transect (transect A, 7 points) was located along the ski chairlift cleared corridor beginning in Štrbské pleso and ending on Solisko. This transect intersected spruce (three points), upper tree line (two points) and dwarf pine communities (two points). The second transect (transect B, 6 points) was located in upper tree line (one point) and dwarf pine communities (five points) in broader area of Solisko. The third transect (transect C, 8 points) was set in spruce (four points) and upper tree line communities (four points) in the area of Solisko. The fourth transect (transect D, 9 points) was situated along the tourist trail Štrbské pleso – Popradské pleso (red line) crossing mainly spruce forest (seven points) less upper tree line (one point) and dwarf pine communities (one point). In total, two to five samples (counts of all points per transect per season) were carried out on these transects (Fig. 1). Two standardize sampling effort, we used only two samples per season around same dates, i.e. 12–13 July 2008 and 1–2 August 2008 between 4:03 and 10:00 Central European Time (CET). Bird counting was conducted by both authors, each two transects.

During breeding season, bird counts were carried out in the period from 20 May 2009 to 20 July 2009 on four point transects. Birds were sampled four times per breeding season on all transects. Three samples were conducted in the mornings between 4:52 and 10:29 CET and one bird count was in evening between 16:27 and 20:56 CET. The first transect (transect A) was located along the ski chairlift cleared corridor beginning in Štrbské pleso and ending on Solisko. This transect had seven points and crossed three habitat types: spruce forest (three points), upper tree line communities (two points), and dwarf-pine communities (two points). Bird sampling was carried out on this transect in the following dates 20 May, 17 June, 3 July and 20 July. The second transect (transect E) was located along the tourist trails beginning at the inn Chata pod Soliskom toward the Furkotská valley (blue line) and from the crossing point in the Furkotska valley toward Štrbské pleso (yellow line). The second transect had five count points, out of which two points were in upper tree-line community and three points in dwarf-pine community. The bird counting was carried out on 22 May, 17 June, 30 June and 6 July. The third transect (transect F) lay in Mlynická valley and consisted of five count points spread in spruce forest. The bird counting was conducted on 20 May, 1 July, 8 July and 18 July. The fourth transect (transect G) was set along the tourist trail Štrbské pleso – Popradské pleso (red line) consists of 13 count points, out of which eight were located in the spruce forest, three were in upper tree line communities and two points were in the dwarf-pine communities (Fig. 1). Bird counting was performed on 21 May, 19 June, 1 July and 19 July. Bird counting in the breeding season was performed only by MK.

Data matrix preparation

Data matrices were separately constructed for post-breeding season 2008 and breeding season 2009 in MS Excel 2007. Each type of bird assemblage was characterized by pooled data of all points of this habitat type from all transects. One type of data matrix was prepared for post-breeding data from all record. Two types of data matrices were prepared for breeding data. The first data matrix type was set up from all records (territorial song, non-territorial call, visual records), whereas the second

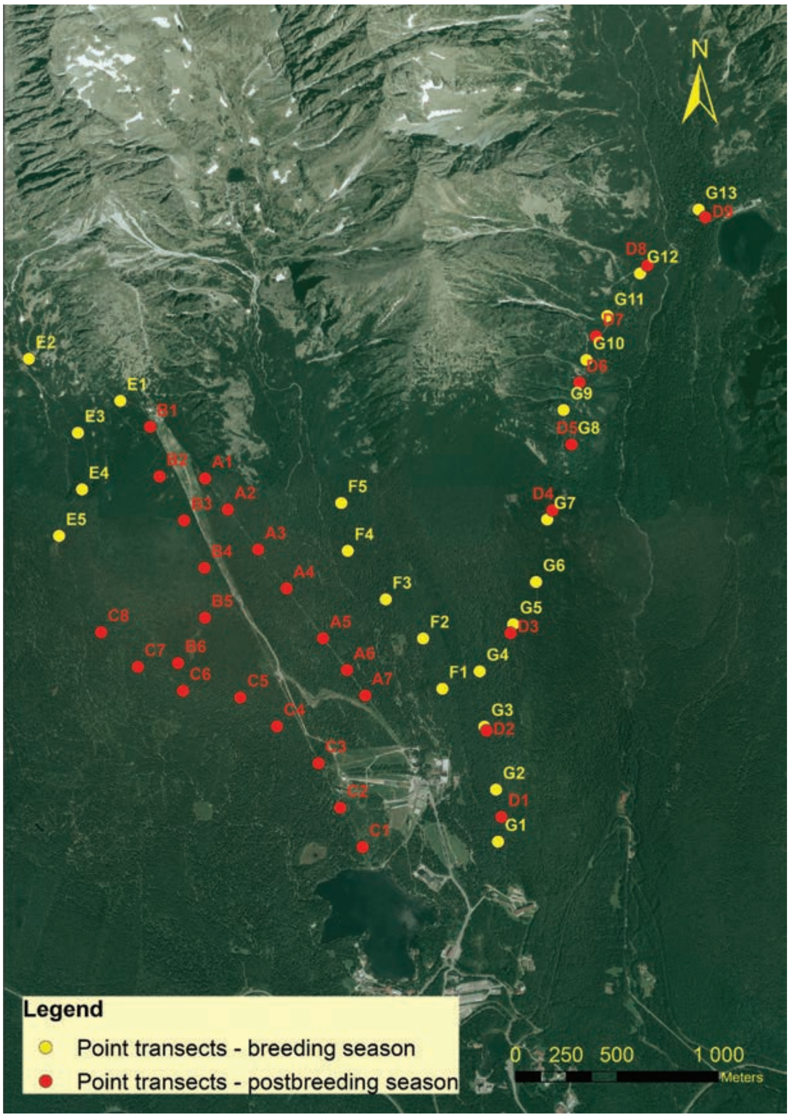

Fig. 1. Map of bird count point transect locations in the study area.

data matrix type was constructed only from territorial records. We expected clearer patterns of complementary distribution in territorial matrices because these data covered birds that presumably bred in the given points, whereas matrices with all records also contained non-breeding individuals (floaters, juveniles) that did not have to necessarily show spatial interactions due to spatial movement. Territorial records consisted only of counts of singing territorial (stationary) males. All matrices were composed of species abundance values (whole integers) per 50 m or 100 m radius point samples. The binary data matrices were constructed from the quantitative data matrices simply by transforming quantitative information into binary code (as either present or absent).

Two matrices were prepared for post-breeding season bird assemblages. One matrix described upper tree line (8 points) and dwarf pine (8 points) communities (24 species × 16 points) and one matrix for spruce communities (16 species × 14 points). Two breeding data matrices (15 species × 14 points, 19 species × 14 points) was prepared for dwarf-pine (7 points) and upper tree line samples (7 points) and two matrices (16 species × 16 points, 21 species × 16 points) was constructed for spruce communities.

Statistical analyses

In order to test species co-occurrence patterns in spatial data sets in the simplest form, four binary (presence/absence) indices were used – number of checkerboards (CHECKER), variance ratio (V-ratio), checkerboard score (C-score) and number of unique species combination (COMBO). The number of checkerboard index counts the number of species pairs in the data matrix forming perfect checkerboards (Diamond, 1975; Gotelli, 2000). The second applied index for testing species association is variance ratio (Schluter, 1984;

Gotelli, 2000). The index is based on computation of the ratio of the variance in total species number in point samples to the sum of the variances of the individual species (Schluter, 1984). Similar to CHECKER is the checkerboard score (Stone and Roberts, 1990; Gotelli, 2000). This index examines checkerboard patterns, or lack of them, over all pairs of sites (Stone and Roberts, 1990). The index number of species combinations was proposed by Pielou and Pielou (1968) in order to test for a number of specific species combinations in a community structure. Gotelli and McCabe (2002) argue that this index is directly designed to test Diamond's first and second assembly rules.

To test species covariation from quantitative data matrices, three quantitative covariance metrics – quantitative number of checkerboards (CA_{ST}), quantitative number of aggregations (AA_{ST}), and the Chao's index of similarity for n communities (MA) were used in null model analyses. The quantitative index number of checkerboards is the analog of the presence/absence checkerboard index with abundance or density data (Ulrich and Gotelli, 2010). The second applied metric for measuring quantitative species association was the number of quantitative aggregations. The index is a count of aggregated species by site 2 × 2 submatrices in the matrix (Ulrich and Gotelli, 2010). The third used matrix was the Chao's index (Chao et al., 2008; Ulrich and Gotelli, 2010). The index values in communities driven by competition processes should be significantly lower than in randomized data matrices by null models.

Binary null models are designed for analyses of binary (presence/absence) matrices. A total of nine null model solutions is possible to apply for analysis of presence/absence data matrices (Gotelli, 2000). We applied only null models with best statistical properties regarding low rates of statistical Type I and Type II errors. Low Type I error rate means that the algorithm does not have high rate of identification of random matrices as structured, whereas the low Type II error rate indicates that the algorithm does not have high rate of classification of structured matrices as random. Only two binary null models, SIM2 (row sums fixed and column equiprobable constrain) and SIM9 (sums of rows and columns fixed constrain), had acceptable statistical error rates (Gotelli, 2000). The algorithm SIM9 was not applicable for simulations by V-ratio index.

We used same statistical criteria as described above for selection of optimal quantitative null models algorithms with low rates of statistical errors. The optimal solution based on wide diagnostic testing of null model algorithms and indices by Ulrich and Gotelli (2010) for analyses of quantitative data matrices are algorithms IT (aa) and IA (rc). Algorithm IT assigns individuals randomly to matrix cells with probabilities proportional to observed row and column abundance totals until, for each row and column, total abundances are reached (Ulrich and Gotelli, 2010). Algorithm IA reassigns all individuals randomly to matrix cells with probabilities proportional to observed row and column abundance totals until the matrix-wide total number of individuals is reached (Ulrich and Gotelli, 2010). This algorithm can generate matrices with empty rows or columns.

Binary null model analyses were performed in the numerical package EcoSim 7.0 (Gotelli and Entsminger, 2001) and quantitative null model analyses were done in Turnover 1.1 (Ulrich, 2010). Sequential swap randomization algorithm was used for randomizations of the original data matrices by binary null models. Since we were interested in the variance of these indices to the both sides, i.e. we searched for segregation as well as for aggregation patterns in species distribution, two-tailed tests were used to test for significance of the observed index values. Two-tailed tests in binary analyses and one-tailed tests (package limitation) in quantitative analyses were applied with the aim to test all possible outcomes (negative, positive, and random associations) of null model analyses. We used 10,000 iterations in all simulations and statistical threshold level was set on $\alpha = 0.05$.

Results

Characteristics of bird assemblages

During the breeding season (all records), we detected a total of 21 bird species at 16 points in spruce communities. The bird assemblage was dominated ($x \geq 5\%$) by Common chaffinch *Fringilla coelebs* (22.6%), Coal tit *Periparus ater* (15.9%), Goldcrest *Regulus regulus* (13.5%), Eurasian robin *Erithacus rubecula* (11.5%), Eurasian treecreeper *Certhia familiaris* (7.5%), and Eurasian siskin *Carduelis spinus* (5.6%). The total breeding bird assemblage density was estimated on 200.5 ind./10 ha. Post-breeding season bird assemblages in spruce forests were species poor, with only 16 bird species were detected in 14 bird count points in 2008. In total, six species – Coal tit (28.6%), Goldcrest (19.1%), Crested tit *Lophophanes cristatus* (10.2%), Common crossbill *Loxia curvirostra* (8.8%), Spotted nutcracker *Nucifraga caryocatactes* (8.2%), and Common chaffinch (6.8%) were classified as dominants. The total post-breeding bird assemblage density was estimated on 133.7 ind./10 ha.

Species richness of the breeding bird assemblage of the dwarf pine and upper tree line communities was 19 species from pooled data from 14 points (all records). Dunnock *Prunella modularis* (31.1%), Common chiffchaff *Phylloscopus collybita* (13.0%), Common chaffinch (9.3%), Eurasian blackcap *Sylvia atricapilla* (8.5%), Eurasian robin (6.7%), Willow warbler *Phylloscopus trochilus* (6.7%) and Goldcrest (5.2%) were the dominant species in the assemblage. The total breeding bird assemblage density was estimated on 61.4 ind./10 ha. Post-breeding bird assemblage of this habitat had pooled species richness 24 species from 16 points. The post-breeding bird assemblage was dominated by five species: Common crossbill (32.9%), Spotted nutcracker (16.1%), Common chiffchaff (11.8%), Coal tit (9.1%) and Lesser redpoll *Acanthis cabaret* (6.5%). The total density of the post-breeding bird assemblage of dwarf pine and upper tree line communities was estimated on 37.0 ind./10 ha.

Null model analyses

Spruce bird assemblages

The results of binary null model simulation by SIM2 algorithm and four co-occurrence indices showed half random associations and half positive associations (Table 1) in post-breeding bird assemblage of spruce forest point samples. Only random associations were detected in the same assemblage when tested by SIM9 algorithm and three indices. Null model analysis by IT (aa) algorithm and three species association indices of spruce bird assemblage detected 67% of random patterns and 33% segregations (Table 2). IA (rc) algorithm in simulations by the same indices and the bird assemblage showed opposite patterns (67% segregations, 33% random associations). Null model simulations by SIM2 and SIM9 algorithms and all indices detected random associations in all cases when testing breeding bird assemblage of spruce forest from territorial or all records (Table 1). Simulations by IT (aa) algorithm and three indices of breeding bird assemblage of spruce forest from territorial records indicated dichotomous patterns (aggregation, segregation, and random associations). Each index yielded different association result (Table 2). Two segregations and one random association were detected from the same assemblage from all records. IA (rc) algorithm showed consistent pattern for territorial and all records regarding the species association output related to index type, however, again each index revealed different associations (aggregation, random, segregation).

Dwarf pine and upper tree line bird assemblages

Null model analysis by SIM2 and SIM9 algorithms and four indices of dwarf pine and upper tree line post-breeding bird assemblages indicated random associations in all cases (Table 1). Simulations by IT (aa) and IA (rc) algorithms and three indices of dwarf pine and upper three line bird assemblage yielded 67% of negative associations and 33 % random associations (Table 2). The simulations by both algorithms of dwarf pine and upper three line assemblages showed identical results for all combination of algorithm and index.

Co-occurrence pattern simulation results of dwarf pine and upper three line breeding bird assemblages differed when considering combination of individual algorithms and indices (Table 1). Testing of species associations by SIM2 algorithm and four indices showed consistent pattern for territorial and all records when considering combination of individual algorithms and indices (67% positive associations, 33% random associations). Yet, simulations by SIM9 algorithm and three indices detected 67% of random associations and 33% of segregation when analyzing territorial records. Simulations by the same algorithm and indices from all records showed opposite pattern (67% of segregations, 33% random associations). Results of null model simulations by IT (aa) and IA (rc) algorithms indicated the consistent results in testing dwarf pine and upper tree line breeding bird assemblages for territorial and all records for all combinations of algorithm and index (Table 2). Nevertheless, IT (aa) algorithms detected four segregations and two random associations, whereas IA (rc) algorithms revealed four segregations and two aggregations.

Discussion

Design of null models

We selected binary (presence/absence) and abundance null models with lowest rate of statistical Type I and Type II errors (Gotelli, 2000; Ulrich and Gotelli, 2010), thus results should have acceptable statistical power. Another problem is the size of data matrices. We used six data matrices (24 × 16, 16 × 14, 15 × 14, 19 × 14, 16 × 16, 21 × 16) that are relatively small enhancing only low statistical power of analysis (Gotelli and McCabe, 2002). This can be possibly one of the causes of high rate of nonsignificant results (community disassembly). Low sample size from upper tree line and dwarf pine communities caused that we have to combine these two habitats into one data matrix. This was the only way to include these two habitats in the null model analyses. The main reason of low sample sizes was the small size of the research area, in which it was impossible to obtain more bird counts samples. Combining dwarf pine and upper three line communities into one data matrix created a natural ecological gradient, since these two habitats are floristically and structurally more similar then spruce forests.

Null model outcomes and possible scenarios

Post-breeding bird assemblage of spruce, upper tree line and dwarf pine communities analyzed by binary null models showed no assembly because 71% of simulations of spruce forest and 100% of simulations of upper tree line and dwarf pine bird assemblage indicated random associations. The simulations of the index number of species combinations revealed random associations in all cases. Therefore, the results do not support

Table 1. Results of the binary null model analyses by the SIM2 (row sums fixed and column equiprobable constrain) and SIM9 (sums of rows and columns fixed constrain) algorithms with four indices (CHECKER – number of binary checkerboards, Combo – number of unique species combinations, C-score, V-ratio) of post-breeding and breeding bird assemblages of spruce, upper tree line and dwarf pine communities in the High Tatra Mts. Observed values of individual indices, their simulated values (10,000 iterations), statistical probability at α = 0.05 (two-tailed test), and the types of detected species associations are given. Explanations: Obs. – observed value of an index, Sim. – mean of the simulated values of an index, P1 – left tail probability (observed <= expected), P2 – right tail probability (observed >= expected).

Site/index	CHECKER				Combo				C-score				V-ratio			
	Obs.	Sim.	P1	P2	Obs.	Sim.	P1	P2	Obs.	Sim.	P1	P2	Obs.	Sim.	P1	P2
Post-breeding season																
SIM2 algorithm																
Spruce communities	38	45.32	0.0565	0.9615	14	13.94	1.0000	0.9387	4.53	5.54	**0.0122**	0.9881	2.22	1.00	0.9963	**0.0044**
Dwarf pine and upper tree line communities	171	176.05	0.2177	0.8208	16	15.95	1.0000	0.9519	3.79	4.04	0.1262	0.8766	1.57	1.00	0.9359	0.0763
SIM9 algorithm																
Spruce communities	38	38.53	0.5299	0.6120	14	13.89	1.0000	0.8902	4.53	4.31	0.9509	0.0537	–	–	–	–
Dwarf pine and upper tree line communities	171	167.00	0.8638	0.1863	16	15.91	1.0000	0.9081	3.79	3.75	0.6918	0.3219	–	–	–	–
Breeding season																
SIM2 algorithm																
Territorial records																
Spruce communities	50	50.17	0.5081	0.5984	15	15.19	0.5965	0.8150	3.25	3.60	0.1336	0.8710	1.40	1.00	0.8913	0.1414
Dwarf pine and upper tree line communities	41	39.70	0.6816	0.4329	13	13.84	0.1491	0.9923	3.05	4.55	**0.0006**	0.9994	2.78	1.00	0.9998	**0.0002**
All records																
Spruce communities	81	79.04	0.6876	0.3966	15	15.77	0.2142	0.9817	3.68	3.41	0.8791	0.1257	0.79	1.00	0.3298	0.7304
Dwarf pine and upper tree line communities	68	65.58	0.7335	0.3500	14	13.97	1.0000	0.9692	3.26	4.50	**0.0006**	0.9994	2.95	1.00	1.000	**0.0001**
SIM9 algorithm																
Territorial records																
Spruce communities	50	47.63	0.8928	0.1960	15	15.23	0.6029	0.8495	3.25	3.21	0.6799	0.3430	–	–	–	–
Dwarf pine and upper tree line communities	41	31.06	0.9968	**0.0058**	13	13.44	0.4799	0.9215	3.05	2.85	0.9694	0.0354	–	–	–	–
All records																
Spruce communities	81	81.22	0.5490	0.5889	15	15.80	0.1863	0.9879	3.68	3.52	0.9307	0.0741	–	–	–	–
Dwarf pine and upper tree line communities	68	52.94	0.9986	**0.0018**	14	13.89	1.0000	0.8868	3.26	3.03	0.9885	**0.0126**	–	–	–	–

Table 2. Results of quantitative null model analyses by the IT (aa) and IA (rc) algorithms with three indices (CA_{ST} – number of quantitative checkerboards, AA_{ST} – number of quantitative aggregations, MA – Chao's index of similarity of *n* communities) of post-breeding and breeding bird assemblages of spruce, upper tree line and dwarf pine communities in the High Tatra Mts. Observed values of individual indices, their simulated values (10,000 iterations), statistical one-sided probability at $\alpha = 0.05$ are given. The abbreviations of the algorithms and indices given in parenthesis follow Turnover 1.1 manual (Ulrich 2010).

Site/index	CA_{ST} (WCS)			AA_{ST} (Wtog)			MA (Chao)		
	Observed	Simulated	P	Observed	Simulated	P	Observed	Simulated	P
Post-breeding season									
IT (aa) algorithm									
Spruce communities	0.06	0.04	0.0800	0.11	0.13	0.2110	0.26	0.51	**0.0024**
Dwarf pine and upper tree line communities	0.03	0.02	**0.0274**	0.05	0.08	**0.0006**	0.20	0.52	**0.0002**
IA (rc) algorithm									
Spruce communities	0.06	0.05	0.4000	0.11	0.13	**0.0176**	0.26	0.48	**0.0016**
Dwarf pine and upper tree line communities	0.03	0.03	0.1812	0.05	0.08	**0.0002**	0.20	0.51	**0.0002**
Breeding season									
IT (aa) algorithm									
Territorial records									
Spruce communities	0.03	0.06	**0.0008**	0.05	0.12	**0.0002**	0.54	0.61	0.1768
Dwarf pine and upper tree line communities	0.04	0.06	0.0522	0.11	0.17	**0.0004**	0.49	0.69	**0.0070**
All records									
Spruce communities	0.04	0.06	0.0682	0.06	0.11	**0.0002**	0.66	0.63	0.3966
Dwarf pine and upper tree line communities	0.05	0.06	0.1598	0.12	0.15	**0.0144**	0.45	0.69	**0.0006**
IA (rc) algorithm									
Territorial records									
Spruce communities	0.03	0.07	**0.0002**	0.05	0.12	**0.0002**	0.54	0.60	0.1766
Dwarf pine and upper tree line communities	0.04	0.07	**0.0002**	0.11	0.17	**0.0002**	0.49	0.69	**0.0044**
All records									
Spruce communities	0.04	0.06	**0.0002**	0.06	0.10	**0.0002**	0.66	0.62	0.2262
Dwarf pine and upper tree line communities	0.05	0.07	**0.0002**	0.12	0.15	**0.0002**	0.45	0.68	**0.0022**

assumptions of Diamond 1 assembly rule. Quantitative null models applied for analysis of post-breeding bird assemblage of these two groups of habitats detected 50% segregations and 50% random associations for spruce bird assemblages and 67% segregations and 33% random associations. These patterns do not indicate clear assembly organization for these assemblages. However, there was a tendency toward segregations in dwarf pine and upper tree line communities, which supports the hypothesis of complementary distribution.

Binary null model analysis of the breeding bird assemblage of spruce forest from territorial and all records indicated random associations in all cases. The results for the dwarf pine and upper tree line bird assemblages were contradictory both for territorial and all records because all types of associations were observed. However, as before, random association prevailed in territorial records (57%) and all records (43%) showing tendency toward disassembly. Diamond 1 and 2 assembly rules were not supported due to random patterns of species combination index for all bird assemblages including territorial and all record samples in all cases. Quantitative null model analyses of spruce forest bird assemblage failed to support any clear assemblage organization pattern. Positive, negative and random associations occurred in even proportion except simulation by the IT (aa) algorithm of all records in which two random associations and one segregation occurred. Breeding bird assemblage of dwarf pine and upper tree line communities from territorial and all records revealed prevalence of segregation (67%) against random (17%) and positive associations (17%). This result supports complementary distribution hypothesis. Over all, the results of null model simulation did not yield any clear assembly patterns. In fact, binary null models had tendency toward random associations, while quantitative null models toward segregations.

Assembly rules are defined as the patterns mediated by interactions between species; these patterns if detected are evidence of competition, allelopathy, facilitation, mutualism and all other biotic interactions that affect real ecological communities (Wilson, 1999). Interspecific competition in communities can also be minimised by resource partitioning patterns along several axes: food, spatial, temporal, and thermal (e.g. Luiselli, 2006; Korňan and Adamík, 2007). In the next section, we primarily focus on spatial patterns of assemblages. Diamond (1975) proposed concept of assembly rules, e.g. checkerboard distribution, forbidden species combinations, incidence function, and established the notion that interspecific competition is the main natural mechanism driving these assembly rules. Coming from an example of a game board for draughts or checkers consisting of alternating squares of different colours, Diamond (1975) defined „checkerboard distribution“ in which a member of a pair of species occupies only one colour that means, translating to real nature, occupying different islands or spots in environment by only one species from the pair. The idea of checkerboard distribution was transferred to spatiotemporal patterns of communities that are known as complementary distribution and compensatory dynamics and has become one of the most widely tested concepts in ecology (Connor et al., 2013).

Studies of complementary distribution revealed contradictory results. Earlier, Schluter (1984) meta-analyzed 37 presence/absence spatial matrices from various taxonomical animal groups by simple variance ratio test and came to conclusion that positive associations are the rule in nature while negative ones are uncommon, suggesting that complementary distribution were rare. More recently, Gotelli and McCabe (2002) conducted a meta-analysis of 96 data sets from studies reporting spatial distribution of various plant and animal taxonomic groups with application of binary null model (SIM9, fixed row and column totals) and three indices (number of checkerboards, C-score, and number of species combinations). They detected fewer species combinations, more checkerboard species pairs, and less co-occurrence in the analyzed matrices than expected by chance, thus supporting the concept of Diamond's assembly rules and complementary distribution. An even more recent meta-analysis of 149 spatial empirical abundance matrices and 36 interaction matrices collected from published papers and posted data sets showed that more 80% of these matrices were significantly segregated when analyzed by abundance IT null model with Chao's similarity index and variance ratio (Ulrich and Gotelli, 2010). Negative species association were, in addition, reported in other studies analyzing e.g. diatom, ant, fish, bird, and mammal assemblages (Kobza et al., 2004; Badano et al., 2005; Heino and Soininen, 2005; Sarà et al., 2006; Abu Baker and Patterson, 2011). In contrast, there are numerous other studies from different taxonomic groups that detected prevalence of random or positive species associations carried out by various null models and metrics (e.g. Feeley, 2003; Perez-Neto, 2004; Sfenthourakis et al., 2006; Jenkins, 2006; Wang et al., 2011; Connor et al., 2013; Šálek et al., 2014). Ulrich and Gotelli (2010) argue that prevalence of positive associations by the variance ration index in the studies of Schluter (1984) and Houlahan et al. (2007) could be a result of improper statistical design. In fact, their analyses assumed equivalence of sites or times in the matrices in probability of occurrence of individuals of different species. Ulrich and Gotelli (2010) point out that correct approach is to use the IT algorithm that preserves the columns totals for abundance incorporating differences in suitability or conditions among sites or times.

The meta-analyses results seem convincing, nonetheless they are not. After all, segregation results of null model analyses should be taken only as a signal of competition due to the fact that other community processes e.g., unique habitat associations, limited dispersal, historical and evolutionary processes that prevent species co-occurrence may generate negative species associations and missing species combinations as well (Ulrich and Gotelli, 2007). Our study is purely based on species covariance and does not have experimental nature. To distinguish among these community processes, we would have to perform a well-designed field surveys and experiments that would enable us prove the mechanism of assembly processes.

Scale effects

Interspecific competition can operate on several spatial levels in different way and different assumptions can be drawn from microhabitat to landscape scale in relation to null model analysis design. Interference and exploitation competition can operate on the level of a single tree. An excellent example of the interference competition and predation risk effects is the guild of foliage gleaners of boreal forest, in which feeding position on a tree (leaves, twigs, branch, trunk) is influenced by dominance status of tit species (see review in Dhondt, 2012, p. 108–113). This model of species packing and resource partitioning enables co-existence of tits on microhabitat scale. Bird point counts on 50 or 100 m radius circular plots and consequent binary null models are not able to detect such interaction due too large scale at which they are conducted. In this case, species packing causes presences on a point sample, thus causing aggregation. Nevertheless, quantitative null models should be able to detect competitive interaction even in this case because exploitation and interference competition should effect population growth parameters that should be reflected in abundance changes among tit species on count point level (Dhondt, 2012).

Segregation at larger spatial scales such as bird count area scale or landscape scale might be divided into two not necessarily exclusive patterns. The first is spatial turnover, where species replace each other across a spatial gradient (Leibold and Mikkelson, 2002). The second is a checkerboard pattern, the mutual exclusion of species without clearly defined spatial gradients. This pattern is predicted by the principle of competitive exclusion (Diamond, 1975). Spatial turnover may be reflected in spatial patterns of density gradient turnover among competing species not necessarily by presence/absence turnover. The first model would be hardly detected by binary null models, while the second model as well as the presence/absence checkerboard pattern meets the assumptions of binary null model analysis. Quantitative null models are sensitive to changes in abundance, and thus are suitable for detection of segregation in all described cases. Based on above, we consider spatial scale of 50 and 100 m radius bird count plots fully appropriate for estimating bird abundance and conducting null model analyses on local and regional scale.

We are fully aware that our results can be only interpreted in the given temporal and spatial scale and generalizing the conclusions on macroecological scale (continental or range scale) could be misleading because other mechanisms and processes may operate on such scales (Fisher et al., 2010). One year snap shot data of climax forest breeding bird assemblages can give a general picture of species and quantitative structure of the assemblage based on long term monitoring data from Slovakia and Poland (Korňan, 2013; Wesołowski et al., 2015).

Patterns of diversity can be properly interpreted only within the broad context of regional and historical influences (Ricklefs, 2004). Based on Ricklefs' notion (2004), past concept of communities should be understand as a point of overlapping regional species distributions. Patterns and processes of these local distributions can be properly understood only by considering interaction within the region as a whole. Coming from this notion, Ricklefs (2008) "disintegrated" previous ecological community concepts based heavily on point studies and asserted that distribution of species within a region is more fundamental biologically than the coexistence of many species at a point. Furthermore, he called for urgent need of macroecological studies on several spatial scales to properly understand processes operating at these scales and forming community patterns.

Habitat and season heterogeneity

The hypothesis that random associations of post-breeding bird assemblages should prevail due to opportunism and movement patterns was strongly supported by binary null models. This pattern was even more straight forward in the matrix of dwarf pine and upper tree line communities that showed pure random association in all analyses. Quantitative null models showed more contradictory results. Simulations of spruce forest bird assemblage by two algorithms and three indices indicated half random associations and half segregations. It is impossible to compare the results with similar studies worldwide since we did not find in the scientific databases such as Web of Science and SCOPUS any studies of bird species associations focused on post-breeding season and analysed with similar methods. The segregation pattern could have been caused by a random segregation pattern of the data matrix that could have resulted from randomly assembled bird assemblages randomly forming segregation pattern as a result of opportunistic movement of birds. If we have more data matrices from this habitat type then it would be possible to draw more general conclusions.

The prediction that species more diverse spruce forest bird assemblage during the breeding season should show the structured assembly pattern then species poorer assemblages of dwarf pine and upper tree line communities was not supported by the null model analyses outcomes. Simulations by both algorithms and indices showed very dichotomous results indicating all types of associations (aggregation, segregation, random association). Surprisingly, null model analysis of upper tree line and dwarf pine bird assemblages yielded strong prevalence of negative species associations, even though random and positive association were also detected. This finding might have been partly caused by the natural habitat gradient between dwarf pine and upper tree line communities causing increased microhabitat heterogeneity that could effect spatial distribution of species. For instance, Chiffchaffs and Willow Warblers were associated with the presence of deciduous trees, Coal Tits and Crested Tit with the presence of spruce, Chaffinch with presence of trees, etc., while other species were more evenly distributed in dwarf pine communities e.g., Water Pipit *Anthus spinoletta* and Dunnock, this could possibly form a checkerboard pattern due to habitat heterogeneity. Of course, to prove this explanation, we would need to sample habitat structure in detail and map breeding territories of birds and analyse territory associations in relation to habitat structure.

Our study of bird species associations of dwarf pine and upper tree line bird assemblage is the first attempt to describe such patterns in communities above upper tree line in mountains. As in many other major topics in ecology, the issue of complementary distribution will not be solved in near future and the continuing controversy will probably persist for many future years. Overall, role of interspecific competition as a primary factor driving spatiotemporal dynamics of communities remains open. From current empirical evidence we can conclude that communities occupying arid and tropical zones exhibited tendency toward segregation (Ulrich et al., 2012). Patterns in arctic environment are still poorly studied.

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Breeding bird assemblage of a fir-oak natural forest in Ponická dúbrava – the oldest Slovak nature reserve

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Abstract

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The bird assemblage of the Ponická dúbrava National Nature Reserve (13.3 ha), preserving a mixed nature forest composed mainly of fir, oak, spruce and beech was studied using a modified mapping method during the breeding period in 2015. The site is rather unique, containing elements of both lowland and mountain forests. The aims of the study were to determine the structure of the bird assemblage, compare it with other bird assemblages from oak-beech and mixed natural forests, and define the most important habitat indicator species. Altogether, 37 breeding bird species were recorded and the estimated rarefaction species number per 10 ha was 30.9. Total bird density reached 63.0 pairs/10 ha. Five species were found to be dominant (>5% of the total density): *Fringilla coelebs*, *Erithacus rubecula*, *Periparus ater*, *Regulus regulus* and *Ficedula albicollis*, representing 42.6% of the total density. Comparing with other eight bird assemblages from natural forests using a cluster analysis, the assemblage from the Ponická dúbrava clearly fits into those from mixed beech-fir-spruce forests. Factor analysis revealed six species separating the assemblage from oak-beech stands: *Regulus regulus*, *Poecile montanus*, *Periparus ater*, *Pyrrhula pyrrhula*, *Prunella modularis* and *Turdus viscivorus*. Based on our data, the reserve represents a valuable rare natural habitat of very high bird species diversity.

Key words

diversity, indicators, mixed forest, Western Carpathians

Introduction

In Europe, forest biodiversity conservation is high priority because woodland habitats used to dominate the continent before massive human effect on the landscape took place. At the continental scale, only about one-third of the original post-glacial forest cover is still present (Mikusiński et al., 2001). Primeval forest is the forest community that emerged in a natural way, under the effect of spontaneous factors and developed without any significant human effect (Korpeľ, 1995). The terms “primeval forest”, “primary forest” or “pristine forest” are often used as a synonymous with “virgin forest” (Schuck et al., 1994), or the “forest undisturbed by man” (Parviainen, 2005). The forests undisturbed by man are rare in the European temperate zone due to the historical continuous use of forests. Thus, the term “natural forest” (the less strict category) is more relevant in practice, as some levels of human impact can nearly always be found in European forests (Parviainen, 2005). Within Europe, Slovakia is a country with the highest forest cover and the highest proportion of strictly protected forest areas with no active intervention in relation to its overall forest area (MCPFE,

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1993). Bird assemblages of several natural forests have been studied in the Slovak territory. Bird assemblages of natural or semi-natural broad-leaved forests were studied by Turček (1955), Feriancová-Masárová et al. (1987, 1991), Krištín (1991, 1996, 1999), Kropil (1993), Bohuš (1993), Bohuš et al. (1999), Lešo (2001, 2003a, 2003b), Lešo and Kropil (2007, 2014), Korňan (2009). Bird assemblages of natural mixed and coniferous forests were studied by Topercer (1989, 1997), Kropil (1992a, 1996a, 1996b), Saniga (1994, 1995, 2011), Krištín (1991, 1999), Pochopová and Kropil (2002), Cečuch and Kropil (2004), Saniga and Saniga (2004), Korňan (2004), Baláž and Kocian (2006), Baláž (2008), Baláž and Balážová (2012), Korňan and Adamík (2014). In central and eastern Europe, the Białowieża Forest protected in the Białowieża National Park is considered to be the best preserved large area of natural forests, where bird assemblages were studied by Tomiałojć et al. (1984), Tomiałojć and Wesołowski (1990, 1996), and Wesołowski et al. (2002, 2006). Forest reserves represent important refugia for biodiversity conservation, and their study can contribute to better understanding of anthropogenic changes undergoing in managed forests. The Ponická dúbrava belongs to the first two natural reserves established in the territory of Slovakia. It was established in 1895 to protect natural beech-oak forest stand on acid bedrock composed of quartzite. No forest management has been performed there up to the present. From that aspect, the forest occurring there can be considered as a natural one and its tree structure is rather unique. Despite the fact, that the reserve was declared 120 years ago, no faunistic survey has been performed there. The aims of this study were to: 1) determine the structure of the bird assemblage; 2) evaluate the relationship with other bird assemblages from selected oak-beech and mixed natural forests; 3) define the most important habitat indicator species; and 4) evaluate the importance of the reserve for biodiversity conservation.

Material and methods

Study plot

The reserve (13.3 ha) is situated in central Slovakia (centre of the reserve 48°41′38″N; 19°18′36″E; Fig. 1), geomorphologically belonging to the Zvolenská kotlina Basin (Western Carpathians). The lower parts of the reserve belong to the intramontane basin climate, upper parts to the montane climate (Špánik et al., 2006). The mean annual temperature is 7.2–7.7 °C, mean annual precipitation is 770–820 mm (Škvarenina et al., 2004). The altitude ranges from 500 to 650 m asl, orientation is south-east, slope inclination is 50–100%. The mean age of trees is over 150 years; mean height of the tree layer, depending of tree species, 12–30 m; mean breast-height diameter of trees 30–67 cm. The forest stand has very diverse tree composition. Fir (*Abies alba*), spruce (*Picea abies*) and beech (*Fagus sylvatica*) compose the stand in periphery and in the western part of the reserve. The Sessile oak (*Quercus petraea*; with an admixture of *Q. polycarpa* and *Q. dalechampii*) dominates the central part of the reserve where it is being intermixed with fir, Scots pine (*Pinus sylvestris*), hornbeam (*Carpinus betulus*) and some other rare tree species. The shrub layer, composed mainly of fir natural regeneration, is moderately developed. Multi-storeyed stand structure prevails (Fig. 2). Quartzite rocks stick out of the ground surface and create various rock structures.

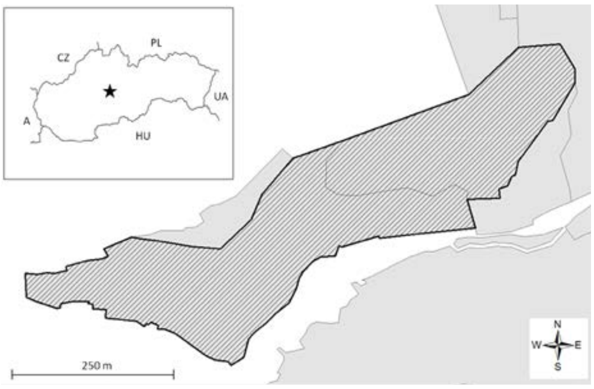

Fig. 1. The Ponická dúbrava NNR (13.3 ha) and its localization within Slovakia; area of the reserve is hatched; white colour – open and semi-open habitats (fields, orchards, meadows, urban area); grey colour – forests.

Bird census

A modified mapping method was used to census breeding birds (breeding pairs). Nine census visits were performed between 12 April and 1 June 2015. During each visit around 15 minutes per ha were spent for observations (approximately 3–4 hours per whole study plot). Most controls started from sunrise. To map bird species active during dusk and after sunset, two census visits started 1–2 hours before sunset. Censuses were carried out during favourable meteorological conditions, not during periods of heavy rain and wind. During each visit, all visual and acoustic registrations with emphasis on simultaneous records, nest findings and other data related to bird occurrence were plotted onto a map (scale 1:1,500) and the total numbers of pairs belonging to all registered species were estimated. At the end of the season the number of breeding pairs of each species was estimated as the maximum value of species abundance during nine census visits considering also spatial distribution of records obtained during the nine census visits. That manner brings some risk of overestimating of migratory species during waves of

Fig. 2. The forest stand structure in the centre of the reserve.

their migration, but I preferred this modification over the combined mapping procedure (Tomiałojć, 1980) due to difficult passability over the whole reserve arising from the steep slope and occurrence of crags. Bad passability complicated tracing of territorial birds, what is one of the principles of the mapping method. Only birds with at least two records of territorial behaviour (during two different controls) or those verified by finding nests were counted as breeding pairs. In other cases they were considered as accidental 'visitors'.

Data analysis

For estimating the total abundance, only territories with at least one half of their area situated within the study plot were included. In cases where part of the territory within the study plot represented less than an estimated 0.5 of the territory area (edge territories or large territories), a '+' sign was attributed and it was excluded from total breeding pairs amount (not from the breeding species list). Diversity (*H´*) and equitability (*J´*) were calculated according to the Shannon formula (Krebs, 1989) using the binary logarithm. Rarefaction following Krebs (1989) was calculated to standardize sample size for comparison of species richness. Cluster analysis using unweighted pair-group average clustering of Euclidian distances was used to compare the bird assemblage with other bird communities from selected oak, oak-beech and fir-beech-spruce natural forests in Slovakia. Selection of certain bird assemblages for the analysis was subjective, based on the representativeness of forest stand structure. Factor analysis was used to reveal bird species which contributed mostly to the separation of ornithocenoses in the dendrogram. Species with loadings higher than 0.7 to unrotated first two factors (principal components) were considered as important indicator species. Statistical analyses were performed in the package Statistica for Windows 10.0 (StatSoft, 2001). Rarefaction was calculated using online Rarefaction Calculator (http://www.biology.ualberta.ca/jbrzusto/rarefact.php).

Results and discussion

Basic cenological characteristics

In total, 37 breeding species were detected within the reserve during one breeding season (Table 1). Besides several visitors, also another two potential breeders were recorded within the reserve (*Bonasa bonasia, Phoenicurus ochruros*), but their registrations did not fulfil criteria for considering them as breeding species. Standardised species number after rarefaction procedure reached 30.09 species per 10 ha (Fig. 3). Shannon index of species diversity reached 4.64 bits and equitability 0.89. Comparing with results from some other natural mixed forests of the Central Europe, ascertained by similar census methodology (Pavelka and Pevelka, 1990; Glowaciński and Profus, 1992; Kropil, 1996a, 1996b; Krištín, 1999; Korňan, 2009; Korňan and Adamík, 2014) and natural oak-beech forests (Kropil, 1993; Lešo and Kropil, 2014), the number of bird species per 10 ha and bird species diversity reached the highest values in the Ponická dúbrava. These cenological parameters even exceed values from the Białowieza National Park (Tomiałojc et al., 1984; Tomiałojć and Wesołowski, 1996; Wesołowski et al., 2006), as well as mean species richness and diversity of 14 mixed forests and 35 deciduous forests from the Czech Republic (Storch and Kotecký, 1999). Apart from the high heterogeneity of the habitat and tree composition, the edge effect undoubtedly plays some role, since the reserve is surrounded by open or semi-open habitats from three sides. Although no ecotonal specialists, perhaps except for *Sturnus vulgaris*, enriched the bird assemblage. The overall diversity of forest birds may depend on microclimatic stability, tree replacement and demography (Segura et al., 2014). Tits can be used as appropriate and easy-interpretable indicators of general character of habitats, since they are adapted to different forest types. High structural heterogeneity of the habitat and diverse tree composition conditioned presence of all six tit species occurring within central Europe. This finding is rather rare, above all, regarding small area of the reserve. Considering other results taken in the natural forests of the Central Europe, only Kropil (1996a) and Krištín (1999) recorded all tit species within one study plot, namely in the Dobročský prales and the Mláčik. That is to say, the area of their study plots was considerably higher (24 ha study plot in the Dobročský prales; transects across 147 ha of the Mláčik).

Table 1. Structure of breeding bird assemblage of the Ponická dúbrava National Nature Reserve (13.3 ha)

Species	Pairs	Density (pairs/ 10 ha)	Dominance %
Fringilla coelebs	12	9.0	14.2
Erithacus rubecula	9	6.7	10.7
Periparus ater	5	3.7	5.9
Regulus regulus	5	3.7	5.9
Ficedula albicollis	5	3.7	5.9
Sylvia atricapilla	4	3.0	4.7
Certhia familiaris	3	2.2	3.6
Turdus merula	3	2.2	3.6
Parus major	3	2.2	3.6
Sitta europaea	3	2.2	3.6
Cyanistes caeruleus	3	2.2	3.6
Phyloscopus collybitta	3	2.2	3.6
Sturnus vulgaris	2	1.5	2.4
Turdus philomelos	2	1.5	2.4
T. troglodytes	2	1.5	2.4
Phylloscopus sibilatrix	2	1.5	2.4
Dendrocopos major	2	1.5	2.4
Columba palumbus	2	1.5	2.4
Prunella modularis	1.5	1.1	1.8
Muscicapa striata	1	0.7	1.2
Poecile palustris	1	0.7	1.2
Poecile montanus	1	0.7	1.2
Lophophanes cristatus	1	0.7	1.2
Regulus ignicapillus	1	0.7	1.2
Turdus viscivorus	1	0.7	1.2
Garrulus glandarius	1	0.7	1.2
Phylloscopus trochilus	1	0.7	1.2
Cuculus canorus	1	0.7	1.2
Streptopelia turtur	1	0.7	1.2
Columba oenas	1	0.7	1.2
Pyrrhula pyrrhula	1	0.7	1.2
Dendrocopos leucotos	0.5	0.4	0.6
Dryocopus martius	+	+	0.0
Strix aluco	+	+	0.0
Picus canus	+	+	0.0
Accipiter nisus	+	+	0.0
Buteo buteo	+	+	0.0
Total	83.5	63.0	100

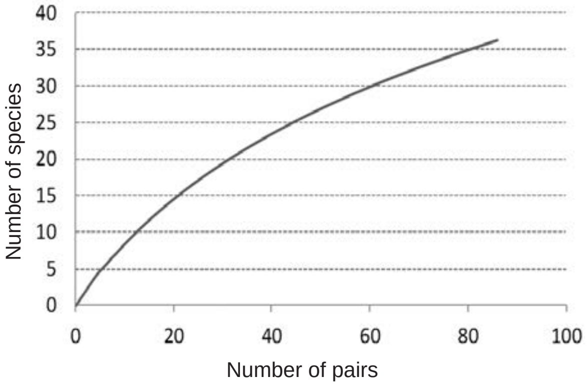

Fig. 3. Estimated number of bird species depending on their abundance in the Ponická dúbrava NNR (13.3 ha) calculated by rarefaction.

Overall density estimated in the Ponická dúbrava reached 63.0 breeding pairs per 10 ha. Five species were found to be dominant (>5% of the total density): *Fringilla coelebs, Erithacus rubecula, Periparus ater, Regulus regulus* and *Ficedula albicollis,* representing 42.6% of the total density. Relatively small portion of dominant species reflects a high diversity of the ornithocenosis (Magurran, 2004), confirming the conclusions mentioned above. High diversity and equitability is apparent also from the species rank (Fig. 4). Habitat generalists (*Fringilla coelebs* and *Erithacus rubecula*) and specialists related to coniferous forests (*Periparus ater* and *Regulus regulus*) prevailed among dominant species, being supplemented by an oak forest specialist *Ficedula albicollis*. This combination of dominant species is rather unique, and has no parallel in published results at least from Slovakia. Overall density does not differ markedly from other mixed forests of the Central Europe (54–76 pairs/ 10 ha; Pavelka and Pavelka 1990; Saniga, 1994, 1995; Kropil, 1996a, 1996b; Krištín, 1999; Korňan, 2009, 2013; Korňan and Adamík, 2014), but is substantially lower when comparing with oak-beech forests (70–100 pairs/10 ha; Lešo and Kropil, 2014), or oak-dominated natural forest stands in the Białowieza National Park in eastern part of Europe (82–118 pairs/ 10 ha; Wesołowski et al., 2002, 2006).

Hole-nesters represented 38.9% of the overall density. Comparing with the studies conducted in oak-beech natural forests (Lešo and Kropil, 2014), the relative portion of the hole-nesters is lower in the Ponická dúbrava by ca. 10%. The higher difference is apparent in absolute density of the hole-nesters reaching 24.3 pairs/10 ha in the Ponická dúbrava NNR vs. ca. 35–45 pairs/10 ha in oak-beech natural forests. Higher absolute density of this nesting guild differentiates mixed and coniferous forests from deciduous forests in general (Tomiałojc et al., 1984, Wesołowski et al., 2006). High tree holes supply was a characteristics feature of the site, especially in the central part of the reserve with dominant portion of oak. Virkkala et al. (1994) considered hole-nesting bird species as good indicators of conservation value of nature reserves in southern Finland. They confirmed a positive effect of nature reserves on hole-nesting birds if the area of old-growth forests was larger than 5 km^2. However, the abundance of hole-nesters might be used as a rough indicator of the general conservation value of forests in nature reserves.

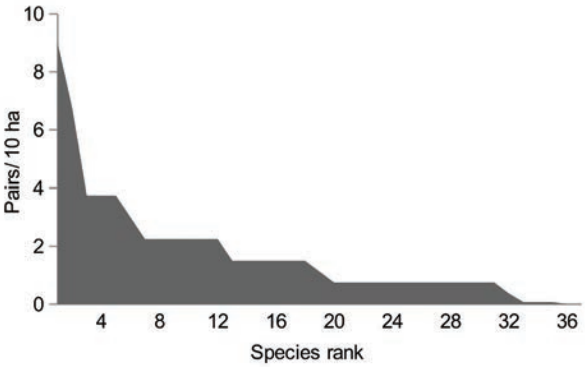

Fig. 4. Descending curve of bird species' density (N = 37) in the Ponická dúbrava NNR.

Classification of bird assemblage and determining of indicator species

Comparing with other eight bird assemblages from natural forests using a cluster analysis, the bird assemblage from the Ponická dúbrava NNR ranks among those from mixed beech-fir-spruce forests (Fig. 5).

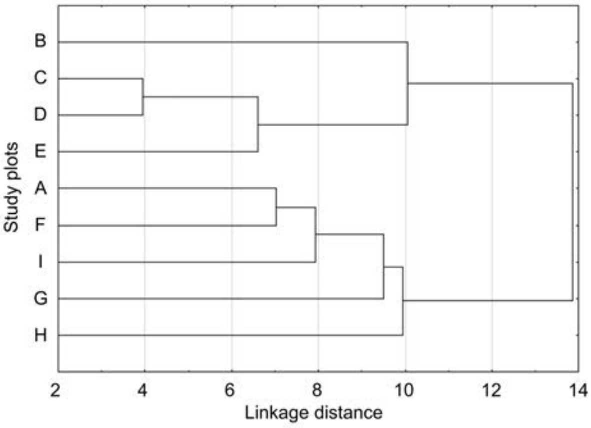

Fig. 5. Classification of bird assemblages from selected natural forests of Slovakia. A – Ponická dúbrava, B – Kováčovské kopce (Lešo, 2001), C – Kokošovská dubina (Lešo and Kropil, 2014), D – Malé brdo (Lešo and Kropil, 2014), E – Bujanov (Lešo and Kropil, 2014), F – Dobročský prales (Kropil, 1996a), G – Badínsky prales (Kropil, 1996b), H – Šútovská dolina (Korňan and Adamík, 2014), I – Mláčik (Krištín, 1999).

Classification separated bird assemblages from deciduous forests (oak and oak-beech forests B–E) and the second cluster represents bird assemblages from mixed forests (A, F–I). Despite the name of the reserve emphasizing occurrence of oak, the classification procedure clearly assigned the bird assemblage from the Ponická dúbrava to mixed forests' bird assemblages.

Two first axes generated in factor analysis explained 39.9% of the total variance. The first axis can be clearly interpreted, drawing the line between broad-leaved and coniferous (or mixed) forests. Interpretation of the second axis is impossible. Totally, 22 bird species reached loadings to the first two factors higher than 0.7 and were considered to be important for separating bird assemblages from broad-leaved versus coniferous (or mixed) forests. These bird species were ordinated on the first two PC axes, creating two distinct clusters representing indicators of lowland (deciduous) and mountain (coniferous) forests (Fig. 6). Of them, six species occurring in our study plot separated the bird assemblage from oak-beech stands: *Regulus regulus*, *Poecile montanus*, *Periparus ater*, *Pyrrhula pyrrhula*, *Prunella modularis* and *Turdus viscivorus*.

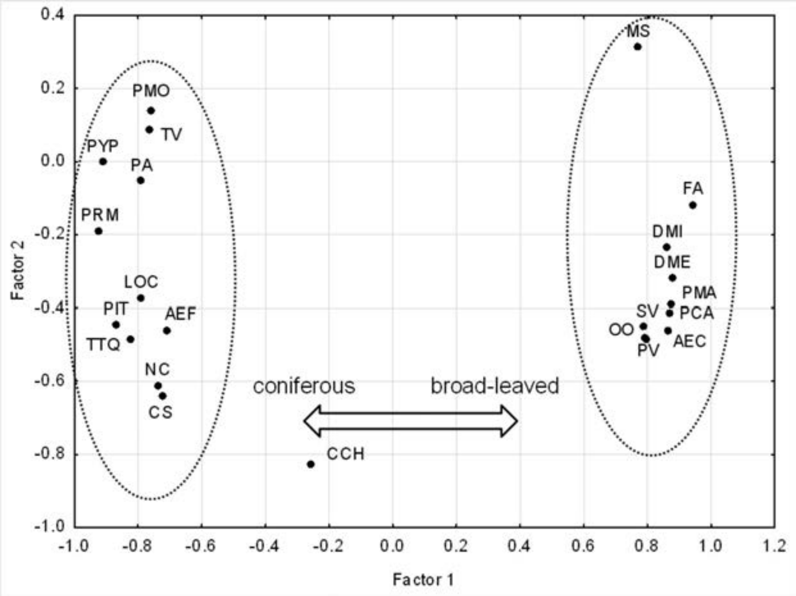

Fig. 6. Ordination diagram – projection of indicator species on the first two PCA-axes. Bird species abbreviations (according to Kropil 1992b): AEC – *Aegithalos caudatus*, AEF – *Aegolius funereus*, CCH – *Carduelis chloris*, CS – *Carduelis spinus*, DME – *Dendrocopos medius*, DMI – *Dendrocopos minor*, FA – *Ficedula albicollis*, LOC – *Loxia curvirostra*, MS – *Muscicapa striata*, NC – *Nucifraga caryocatactes*, OO – *Oriolus oriolus*, PA – *Periparus ater*, PCA – *Parus caeruleus*, PIT – *Picoides tridactylus*, PMA – *Parus major*, PMO – *Poecile montanus*, PRM – *Prunella modularis*, PV – *Picus viridis*, PYP – *Pyrrhula pyrrhula*, SV – *Sturnus vulgaris*, TTQ – *Turdus torquatus*, TV – *Turdus viscivorus*.

Importance of the natural reserve for diversity conservation

Natural forests of a sufficient area preserve bird diversity at local and regional scale, what can reduce effect of biotic homogenization occurring over large areas of Europe (Reif et al., 2012). It is crucial to describe and analyze structure of natural forests for the management of other managed forest ecosystems and nature conservation aims (Korňan, 2004). Within central Europe, several tens of natural forests were the subject of ecological studies, most of them within the territory of Slovakia. The natural forest occurring in the Ponická dúbrava is specific by its rare tree-species structure. Due to hard-passable terrain, the site has remained almost unspoiled for more than a century with well preserved native structure of the forest stand despite very small area of the reserve. Stable tree composition conditioned by successful natural regeneration of tree species, including oak, indicates native character of the forest stand. Contrariwise, several reserves in Slovakia with dominant share of oak, where natural regeneration of oak is difficult, indicate modification of tree composition by forest management in the past (Korpeľ, 1995). Apart from questionable natural character of some reserves, also small area of reserves located in lowlands causes lower stability of their tree composition. The minimal recommended area for establishing natural reserves in oak-beech forests is about 50 ha, while only 10 ha in mixed forests (Bücking, 2003). The Ponická dúbrava belongs to the network of the special areas of conservation (SAC) meeting the criteria of NATURA 2000 sites. Despite the fact that its small area does not allow us to consider it as important bio centre for bird diversity conservation on the large scale, its importance lies in preserving rare, valuable and stable forest site containing elements of both lowland and mountain forests, providing refuge for specific bird assemblage of remarkable high diversity.

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Bird community structure and population trends in the Little Carpathians Mts vineyard area

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Abstract

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The birds of the vineyards on the eastern slopes of the Little Carpathians Mountains (south-western Slovakia) were studied during breeding seasons between the years 2010 and 2015. A point census method was used to count birds once or twice in May on two study sites (a transect in the vicinity of Modra town and a transect between Bratislava-Rača and Svätý Jur). The whole study area was designated as an Important Bird Area and established as a Special Protected Area according to the Bird Directive. Individual counting points were situated in different habitats including suburban areas, green lines with scrubs, the edges of small forest patches, forest edges, small gardens, cultivated vineyards, etc. 62 and 53 bird species were found in the first and the second transect, respectively (64 birds in total). The total number of all individuals was 2,383 at the Modra site and 972 at the Rača-Svätý Jur site. The most abundant species on both transects was *Sturnus vulgaris* (21 and 36%, respectively). Another abundant species at the Modra site (dominance between 5 and 7%) were *Turdus merula*, *Passer montanus*, *Passer domesticus* and *Delichon urbicum*, while at the Rača-Svätý Jur site *Fringilla coelebs* and *Apus apus* were abundant. Several species with higher conservation importance were found: *Upupa epops*, *Lullula arborea*, *Pernis apivorus*, *Jynx torquila*, *Lanius collurio* and *Sylvia nisoria*. A decline of some species like *Chloris chloris*, *Delichon urbicum*, *Emberiza citrinella*, *Fringilla coelebs*, *Saxicola torquata*, *Sylvia atricapilla* and *Upupa epops* was recorded since the beginning of the study. Continuous and long-term monitoring may bring important data about the population status of birds in human-affected landscape.

Keywords

birds, Malé Karpaty Mts, monitoring, vineyards

Introduction

European farmlands have been changed a lot in recent decades. These historical changes in agricultural practices have been linked to a farmland biodiversity including bird species and their population trends (Siriwardena et al., 2000; Vretenberg et al., 2006). Generally, avian abundance and biomass are both declining with the most of the decline being attributed to more common species (Inger et al., 2014). Analysis of an extensive European dataset confirms the large decline of widespread farmland birds in Europe. Common farmland birds have on average fallen in number by nearly half (Voříšek et al., 2010). Population declines and range contractions were significantly greater in countries with more intensive agriculture, and significantly higher in the former European Union countries (Donald et al., 2001). Local and regional differences in biodiversity patterns and in land use history within European farmlands can provide differences in species dynamics and

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species-habitat interactions (Tryjanowski et al., 2011). One of the biggest causes of the farmland biodiversity decline is the loss of ecological heterogeneity at multiple spatial and temporal scales (Benton et al., 2003).

Vineyards and viticulture are regarded as a minor part of the agricultural landscape. In Slovakia, vineyards are part of the historical structures of the cultural landscape. Usually they create a mosaic of dominant vineyards, often combined with orchards, grasslands and seldomly ploughed fields (Špulerová et al., 2011). Studies on the specific role of viticulture in the maintenance of farmland biodiversity are relatively rare and have been focused on different groups of animals (Bruggisser et al., 2010; Tanadini et al., 2012) and some of them on the role of biodiversity in the biological protection of viticultures (Ponti et al., 2005). Several studies have provided data about biodiversity of vineyard habitats in Little Carpathians area as well (Majzlan 2011; Mihál et al., 2014).

Extensive farmlands contain patches of rich biodiversity, including birds that are known as indicators of high nature value farmlands (Morelli et al., 2014). Some of the very valuable farmland areas for birds have been included in important bird areas in Slovakia (Rybanič et al., 2004). One of these areas is also the Little Carpathians Mts area, especially its south-eastern slopes, which are historically managed as the vineyards for a long period. There has been not so much attention given to ornithological studies in farmlands and especially not in vineyard areas in Slovakia. The present study is a result of continuous survey within this area and gives results of this monitoring since 2010.

Material and methods

The study area is situated on the south-eastern slopes of Little Carpathians Mts in south-western Slovakia at an altitude from 150 to 270 m asl. The area represents a vineyard landscape characterized with intensive or abandoned vineyard fields combined with green lines, small forest patches, forest edges and gardens. Birds were studied at two different sites (transects), the first one in the vicinity of Modra town and the second between the towns of Bratislava-Rača and Svätý Jur (Fig. 1). The study area and both sites are parts of important areas for the conservation of birds in Slovakia. The Little Carpathians were designated as an Important Bird Area (Rybanič et al., 2004) and later established as a Special Protected Area according to the Directive on the conservation of wild birds (Directive 2009/147/EC).

Birds were studied during breeding seasons between the years 2010 and 2015 – the site Modra was studied during this period, while the site Rača-Svätý Jur was studied during the period 2010–2013. A point census method, with 20 point counts per transect, was used. At each point all birds heard or seen were counted during a 5-min period in a distance 100 meters from the counting point and additionally in a distance more than 100 m. Both transects were censused once or twice during May or the beginning of June at both sites in morning hours between 6 and 10 AM. The survey was a part of PECBM (Pan-European Common Birds Monitoring) (Voříšek et al., 2010). Counting points were distributed at least in 300 m distances in different habitats including the edges of vineyard plots, green lines, small

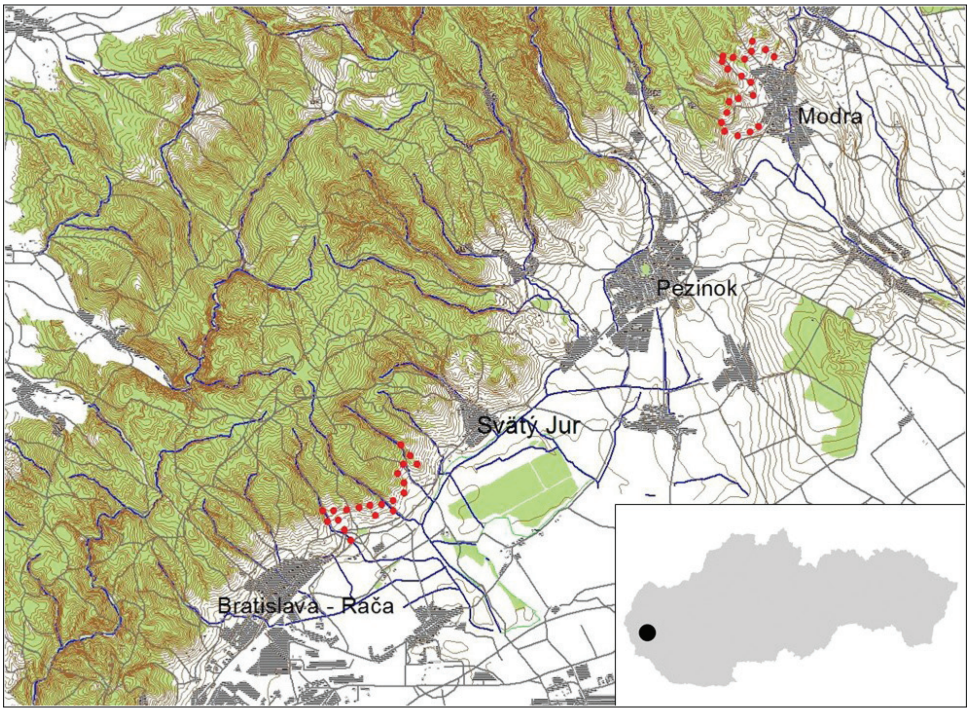

Fig. 1. Locations of individual census points within both transects in the study area.

forests, the edges of forested areas, suburban areas, and gardens, in order to cover a variety of specific environments. Each counting point consists of two or more of the above mentioned habitats with different proportions of them in 100 meter distances.

In order to analyse count data from both sides and produce estimates of yearly indices and trends, the program TRIM was used (van Strien et al., 2004). The program can be used to estimate indices trends and analyse time series of counts with missing observations (Pannekoek and van Strien, 2001). For the analysis of trends and indices, 32 species were selected. Species with a higher dominance and frequency, as well as several other common birds and species occurring in farmland habitats, were included into this analysis. The data of species composition at both study sites were analysed using non-metric multidimensional scaling (NMDS) and Bray-Curtis index in order to analyse similarities between the two studied sites and individual counting points according bird community composition. The Bray-Curtis index is suitable for quantification of the compositional dissimilarity of communities of species on different sites based on counts at each site. Each counting point of studied transects in each particular studied year was used as an individual sample. Statistical analysis was done using the statistical software, PAST (Hammer 2015).

Results and discussion

Totally, 64 bird species were found on both study sites. A higher number of species (62) was found at the Modra site while at the sites Bratislava-Rača and Svätý Jur only 53 species were found. A checklist of species and their dominance and frequency is in Table 1.

The total number of species is not so high compared to other studies conducted in vineyard areas within Europe. During the study in a wine-growing area in Loire valley (France), a total number of 93 species was found (Pithon et al., 2015). This difference in results is caused by a different methodology of data sampling with higher frequency of sampling visits in that study. There is a significant difference between extensive, intensive and abandoned vineyards. Extensively used vineyards have significantly more bird species than abandoned and extensively used ones. Abandoned vineyards were rich in species and individuals, mainly woodland species, whereas intensively used vineyards had both fewer species and individuals (Verhulst et al., 2004). Both study sites in the Little Carpathians area consist of intensively used vineyards and abandoned ones. Several woodland species were found. The reason for that is the composition of habitats surrounding some census points including forest edges, gardens and small forest patches.

The most abundant species at both sites was the starling (*Sturnus vulgaris*). The dominance of the species was 21% at the Modra site and at Rača-Svätý Jur even higher at 36%. The total number of individuals at the Modra site was 498 and at Rača-Svätý Jur 348. Other dominant species at the Modra site were: *Turdus merula* (7%), *Passer montanus* (6%), *Passer domesticus* and *Delichon urbicum* (each 5%). The situation was a bit different at Rača-Svätý Jur. Other dominant species were *Fringilla coelebs* (6%) and *Apus apus* (5%). The swift (*Apus apus*) was recorded also at the Modra site but was not so abundant. Vineyard countryside is not a breeding habitat for this species but is very suitable feeding habitat. Higher dominance at Rača-Svätý Jur site was caused by the vicinity of Bratislava city with higher breeding possibilities for the species than in the Modra site. Similarly for *Delichon urbicum* and *Hirundo rustica,* both sites are feeding habitats only. The house sparrow (*Passer domesticus*) was found to be a dominant species at the Modra site but was absent at the Rača-Svätý Jur site. Another species that was found only in Rača-Svätý Jur site was *Pica pica*. Higher occurrence of *Corvus cornix* was found in this site, while at the Modra site only one observation of this species was made. The differences in bird composition between both studied sites in individual years are shown with the results of NMDS analysis and based on Bray-Curtis similarity measures (Fig. 2). The stress value (0.4349) is rather high, which indicates a low quality of the model. Some of counting points within both sites are overlapping indicating a similarity of bird composition. However several counting points at the Rača-Svätý Jur site have different bird compositions caused by a higher abundance of species related to urban environment. The configuration of local habitat within the landscape may be as critical for bird community composition as the composition of the local habitat itself (Melles et al., 2003).

The most frequent species that were found within all visits and both sites (100% frequency) were 14 species (*Phasianus colchicus*, *Streptopelia turtur*, *Cuculus canorus*, *Lanius collurio*, *Parus major*, *Sylvia atricapilla*, *Sturnus vulgaris*, *Turdus merula*, *Turdus philomelos*, *Luscinia megarhynchos*, *Fringilla coelebs*, *Serinus serinus*, *Carduelis carduelis*, *Emberiza citrinella*; Table 1). The highest frequency (100%) at the Modra site had 9 species (*Streptopelia decaocto*, *Jynx torquila*, *Oriolus oriolus*, *Hirundo rustica*, *Delichon urbicum*, *Hippolais icterina*, *Passer montanus*, *Carduelis cannabina*, *Miliaria calandra*). The highest frequency at the Rača-Svätý Jur site had 6 species (*Apus apus*, *Corvus cornix*, *Lullula arborea*, *Sylvia communis*, *Chloris chloris*, *Coccothraustes coccothraustes*). Several species had very occasional occurrence and vineyards are not typical habitats for them. Those species were: *Anas platyrhynchos*, *Phalacrocorax carbo* and *Merops apiaster*. The bee-eater (*Merops apiaster*) was found only once in the Modra site. There are not any known breeding sites of this species in the vicinity. However, vineyards could be a breeding habitat for this species. There has

Table 1. Checklist of species within both sites with their dominance and frequency

Site	Modra		Rača-Svätý Jur	
Species	Dominance (%)	Frequency (%)	Dominance (%)	Frequency (%)
Phasianus colchicus	2.5	100	2.0	100
Anas platyrhynchos	0.1	12.5	0.2	25
Ciconia nigra	0.1	25	0.2	50
Phalocrocorax carbo	0.1	12.5	–	–
Accipiter nisus	0.0	12.5	–	–
Buteo buteo	0.5	62.5	1.7	75
Pernis apivorus	0.0	12.5	0.1	25
Falco tinnunculus	0.2	37.5	0.1	25
Crex crex	0.0	12.5	–	–
Columba palumbus	0.7	75	0.1	25
Streptopelia decaocto	1.3	100	0.1	25
Streptopelia turtur	3.1	100	2.4	100
Cuculus canorus	0.9	100	0.8	100
Apus apus	1.0	37.5	4.9	100
Merops apiaster	0.4	12.5	–	–
Upupa epops	0.1	12.5	0.1	25
Dendrocopos major	0.3	62.5	0.6	75
Dendrocopos medius	0.0	12.5	0.3	50
Dendrocopos minor	–	–	0.6	50
Dryocopus martius	0.1	12.5	–	–
Picus viridis	0.0	12.5	0.2	50
Jynx torquila	1.4	100	0.6	50
Lanius collurio	1.8	100	1.2	100
Oriolus oriolus	2.1	100	1.1	75
Corvus corax	0.1	12.5	–	–
Corvus cornix	0.0	12.5	1.0	100
Garrulus glandarius	0.0	12.5	–	–
Pica pica	–	–	0.7	75
Aegithalos caudatus	0.1	12.5	–	–
Cyanistes caeruleus	0.5	87.5	0.7	75
Parus major	4.1	100	4.2	100
Poecile palustris	0.1	25	0.1	25
Lullula arborea	0.4	75	0.9	100
Hirundo rustica	0.8	100	0.7	25
Delichon urbicum	4.7	100	0.6	25
Phylloscopus colybita	0.2	50	0.3	50
Phylloscopus sibilatrix	0.3	75	–	–
Hippolais icterina	0.9	100	0.1	25
Sylvia atricapilla	2.9	100	4.4	100
Sylvia borin	0.5	87.5	0.4	75
Sylvia communis	0.8	87.5	0.9	100
Sylvia curruca	0.3	62.5	0.3	75
Sylvia nisoria	0.2	62.5	0.4	50
Sitta europea	0.5	75	0.4	25
Sturnus vulgaris	20.9	100	35.8	100
Turdus merula	7.3	100	3.3	100
Turdus philomelos	3.4	100	1.6	100
Erithacus rubecula	0.1	37.5	0.2	50
Luscinia megarhynchos	2.6	100	2.9	100
Phoenicurus ochruros	0.3	50	0.1	25
Saxicola torquata	0.4	75	1.1	75
Ficedula albicollis	0.0	12.5	0.1	25
Muscicapa striata	0.1	25	–	–
Passer domesticus	5.4	100	–	–
Passer montanus	6.3	100	1.1	75
Motacilla alba	0.2	37.5	–	–
Motacilla cinerea	–	–	0.1	25
Fringilla coelebs	3.6	100	6.3	100
Serinus serinus	2.5	100	0.9	100
Chloris chloris	3.4	87.5	2.8	100
Carduelis cannabina	1.4	100	0.7	U5
Carduelis carduelis	3.2	100	2.5	100
Coccothraustes coccothraustes	0.3	75	2.0	100
Miliaria calandra	1.1	100	0.8	50
Emberiza citrinella	3.2	100	3.8	100

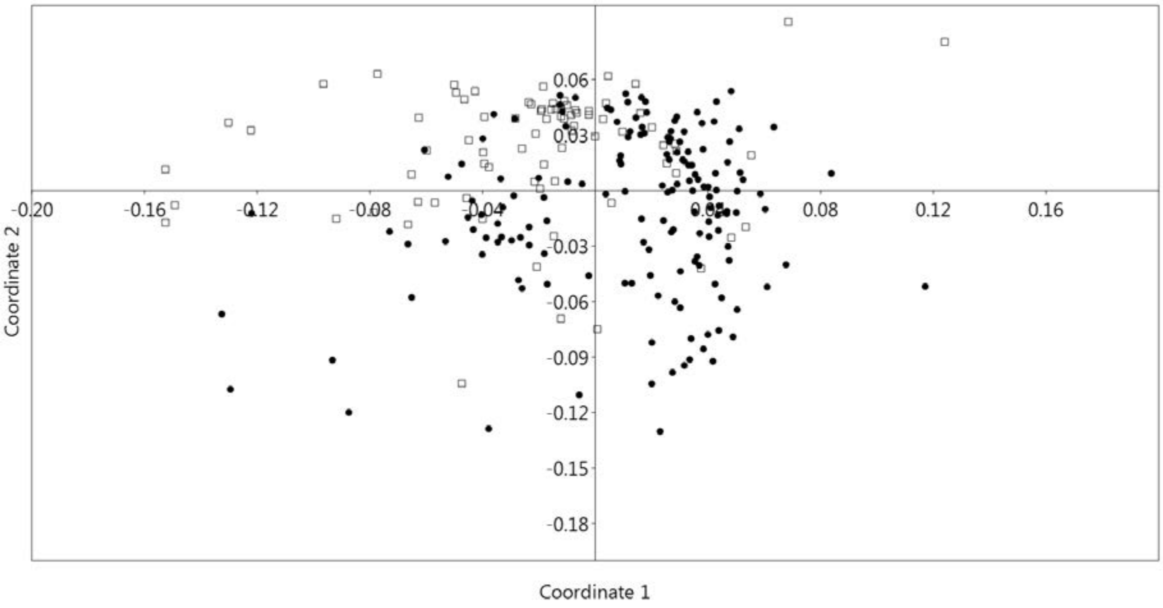

Fig. 2

Fig. 2. Non-metric multidimensional scaling ordination of sites based on Bray-Curtis similarity measures representing the variation in bird communities in two transects. Modra (dots) and Rača-Svätý Jur (open squares). Stress=0.4349.

been evidence for the breeding of the species in vineyard area in the vicinity of Dolné Orešany village (Králiková and Králik, 2005).

Regarding conservation status vineyards on Little Carpathians, the foothills sheltered quite a high number of different species with higher conservation priority. Some of those species (5 species) are listed in a current national red list of birds (Demko et al., 2013). One species *Hirundo rustic*a is listed as vulnerable (VU) and 4 in the category of near threatened (NT): *Apus apus*, *Upupa epops*, *Lullula arborea* and *Delichon urbicum*. From the total number of 64 bird species, 11 (17%) of them are regarded as objectives of established SPA Little Carpathians and 8 (*Pernis apivorus*, *Dendrocopos medius*, *Dryocopus martius*, *Ciconia nigra*, *Ficedula albicollis*, *Jynx torquila*, *Lanius collurio*, *Sylvia nisoria*) are included in Annex I. of the Directive on the conservation of wild birds (Directive 2009/147/EC).

The results of the analysis of trends and indices using the TRIM program showed that the majority of species demonstrate uncertain population trends (Table 2). Five species showed a significantly moderate decline during the studied period (*Chloris chloris*, *Delichon urbica*, *Emberiza citrinella*, *Fringilla coelebs*, *Sylvia atricapilla*). Two of these species *Chloris chloris* and *Emberiza citrinella* have shown decline also on European level (Voříšek et al., 2008) but in long-term trends *Chloris chloris* has showed a moderate increase (Voříšek et al., 2010). *Parus major* has shown in the study area a moderate increase that is similar to short-term trends on the European level (Voříšek et al., 2010). The Great Tit is not a typical farmland species but was found quite abundant at both study sites. It is a result of a heterogeneous mosaic of habitats at the study sites with small forests and forest edges. Two species (*Lullula arborea*, *Passer montanus*) showed a strong increase. The Woodlark (*Lullula arborea*) responds positively to increasing vineyard cover in the landscape and inhabits intensive vineyard fields. The species positively selects vineyards as opposed to semi-natural habitats but there are no consistent selection criteria between different vineyard habitat variables (Pithon et al., 2015). The Tree Sparrow (*Passer montanus*) has shown on the European level a moderate and continuous decline (Voříšek et al., 2008; Voříšek et al., 2010). The population of Tree Sparrow has increased significantly in Finnish farmland. The species colonized places where the House Sparrow was present but species did not compete with each other (Vepsäläinen et al., 2005). Only two species, *Upupa epops* and *Saxicola torquata,* showed a significantly steep decline at study sites. The Hoopoe was registered only in the first studying years. A similar situation was found also in another transect close to the Modra site situated in oak forests (unpubl. data). Trends of both steep declining species on the European level are uncertain (Voříšek et al., 2010).

Thus according to the presented results, vineyards in the Little Carpathians area, which is characterized by its heterogeneous mosaic habitats, and connections to suburban areas and forested areas, represents an important area for bird diversity. In comparison, other types of farmlands like abandoned arable fields

Table 2. Results of analysis of trends and indices of selected bird species

Species	Trend (±SE)	Trend classification
Apus apus	1.3063 (0.2244)	Uncertain
Carduelis cannabina	1.0342 (0.1670)	Uncertain
Carduelis carduelis	1.1482 (0.1083)	Uncertain
Cucullus canorus	0.9407 (0.1227)	Uncertain
Chloris chloris	0.8424 (0.0716)	Moderate decline (P < 0.05)
Delichon urbica	0.835 (0.0612)	Moderate decline (P < 0.01)
Miliaria calandra	1.1825 (0.1598)	Uncertain
Emberiza citrinella	0.9271 (0.0251)	Moderate decline (P < 0.01)
Fringilla coelebs	0.9467 (0.0211)	Moderate decline (P < 0.05)
Hippolais icterina	1.2973 (0.1526)	Uncertain
Hirundo rustica	1.1423 (0.3102)	Uncertain
Jynx torquila	0.9721 (0.1177)	Uncertain
Lanius collurio	0.9878 (0.0982)	Uncertain
Lullula arborea	1.2315 (0.0812)	Strong increase (P < 0.05)
Luscinia megarhynchos	0.9250 (0.04)	Uncertain
Oriolus oriolus	1.0439 (0.1262)	Uncertain
Parus major	1.0594 (0.0212)	Moderate increase (P < 0.01)
Passer domesticus	1.0968 (0.0653)	Uncertain
Passer montanus	1.4096 (0.1045)	Strong increase (P < 0.01)
Phasianus colchicus	1.0506 (0.0653)	Uncertain
Serinus serinus	1.0516 (0.0644)	Uncertain
Streptopelia decaocto	1.0464 (0.0896)	Uncertain
Streptopelia turtur	0.9878 (0.0672)	Uncertain
Sturnus vulgaris	1.0005 (0.1243)	Uncertain
Sylvia atricapilla	0.8753 (0.0474)	Moderate decline (P < 0.01)
Turdus merula	0.9663 (0.0442)	Uncertain
Turdus philomelos	1.0607 (0.0635)	Uncertain
Upupa epops	0.1879 (0.2408)	Steep decline (P < 0.01)

are characterized by relatively uniform communities of birds with distinctive groups of dominant species (Orlowski 2005). Farmland patches with abundant tree and shrub cover score the highest on abundance and species richness especially during breeding season (Telleria et al., 2008). The bird community patterns are usually related to vegetation succession and land productivity (Nikolov et al., 2011). Bird composition and diversity is closely related to management practices and landscape use. There are several threats which affect the area including loss of historical structures of vineyard areas, strong pressure for urbanization, and abandonment of farming practices. Further continuous and long-term monitoring of these areas is necessary and brings important data about the population status of birds in human-affected landscape.

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Assessment of ornithochory in the north-western part of the Podunajská nížina Lowland (SW Slovakia)

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Abstract

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Plant seeds and fruits can be dispersed in several ways; diaspore dispersal by ornithochory is common to many plant species. The aim of the study was to assess the birds' potential in dispersal of woody species which are present in the riparian vegetation of two streams with tributaries in the lowland of SW Slovakia. We examined three hypotheses related to riparian woody vegetation: (1) ornithochory plays an important role in the formation of riparian vegetation, (2) riparian vegetation serves as a food source for bird species in highly deforested lowland landscape, (3) there are differences among selected indication groups of woody plant species by types of diaspore dispersal. Four indication groups represent natural alluvial woody vegetation, adjacent forests, other autochtonous woody species and non-native species. Characteristics, such as diaspore type, weight, maturity, and dispersal patterns within four indication groups of woody species were analysed. The occurrence of bird species, feeding strategy and weight categories of birds were assessed. In addition to field research, the data were obtained from the work of Turček "Ecological relationships of birds and woody plants" and from the D^3 Dispersal and Diaspore Database. The results show a high proportion (53%) of plants with fleshy fruits, consequently endozoochory (including ornithochory) appears to be the dominant pattern of diaspore dispersal of riparian woody species of the study area, and the second is anemochory. Evident differences in diaspore dispersal patterns were found within the indication groups. Five bird species participate in dispersal of more than 50% of the assessed woody plants. The analyses showed that a significant share of small-size birds (50–100 g) and large-size birds (500–1,000 g) spread riparian vegetation woody species.

Keywords

birds, diaspore, maturity, riparian vegetation, woody species

Introduction

Plants are usually not able to move from place to place and their seed dispersal depends on external factors (wind, water, animals). Therefore, the course of seed movement after release from the parent plant is so important. Regarding animals, most seeds are dispersed by three classes of vertebrates: birds, mammals (including humans) and reptiles (Traveset et al., 2014). Birds play a significant role in this process, as they are able in their digestive tract or at body surface (e.g. feathers, legs) to carry plant diaspores, even over long distances (Cain et al., 2000; Vittoz and Engler 2007; Nathan et al., 2008). The transfer of fruits and seeds by birds,

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so-called ornithochory, is indeed known, however, this phenomenon should still be examined (Pijl, 1972; Snow and Snow, 1988; Cousens et al., 2008; Pejchar et al., 2008; Traveset and Rodriguez-Perez, 2008; Garcia et al., 2010). As already mentioned by Morellato and Leitão-Filho (1996), numerous ecological factors may contribute to dispersal phenology. Ideally, seed maturation and dispersal would be timed to match the seasonal availability of good dispersal agents (where required) and the availability of good germination conditions. According to Kollmann (2000), the processes associated with the dispersal of fleshy-fruit species include fruit removal, seed rain, seed predation, seed bank dynamics, germination and establishment. In several studies, ornithochory was studied in the context of dispersal phenology (Snow and Snow, 1988; Debussche and Isenmann, 1992; Fuentes, 1992; Guitián, 1998; Hanya, 2005), wintering resources for European frugivores (Jordano and Herrera 1981; Tellería et al., 2005), nature conservation and natural restoration of disturbed areas (e.g. Bengtsson et al., 2003; Howe and Miriti, 2004; Tellería et al., 2005; Hilje et al., 2015). Riparian vegetation along rivers and streams represents an important natural or semi-natural element in the agricultural and urbanised areas of lowlands, but it is also accompanied by non-native species. In the context of riparian vegetation, several studies are aimed at hydrochory but stressed the importance of anemochory and ornithochory (e.g. Merrit and Wohl, 2002; Leyer, 2006; Nilsson et al., 1991, 2010, Parolin et al., 2013).

The aim of the study was to assess the potential of bird species as dispersal agents of woody plants, growing in study sites, representing the riparian vegetation of Stoličný potok and Gidra streams (regional bio-corridors) within the scope of indication woody species groups. As indication groups, native species of riparian vegetation, species of adjacent forests, other native woody species and non-native species were chosen. The mentioned theme has become important due to the disappearance of a large number of trees from the landscape, particularly on agricultural land after the elimination of small hedges and streamside vegetation (Kopecká, 2011; Tóth and Supuka, 2014) and the spread of built-up areas in Slovakia (Šveda and Vigašová, 2010; Ružičková et al., 2011, 2015; Kopecká et al., 2015). According to Supuka et al. (2013), agricultural land covers in Slovakia 50% of the overall territory. In this type of landscape, there is an ongoing intensive anthropogenic activity. One of the partial problems with a significant negative biotic and ecological impact is the rapid decrease in scattered non-forest woody vegetation. Landscape change along the studied streams, monitored over the period 2006–2014 expressed, in particular, at the expense of arable land in favour of built-up areas, indicating a dominant urbanization process (Ružičková et al., 2015). The analyses at the base of the target and other selected indication groups should be used for land-use management and nature protection. As stated by Kontrišová (2006), indication groups of plant species were often used in bio-monitoring for obtaining information on the state of soil and vegetation. According to Burley and Gauld (1995), it is necessary to determine which groups are sensitive to environmental and managerial change. The indication groups of species seem to be a suitable methodological approach for the assessment of forest fragments biodiversity (Reháčková and Ružičková, 2003; Ružičková, 2004); the groups of endangered, protected and forest species as the most sensitive to fragmentation, and on the other hand, synanthropic, invasive and non-native species as indicators of biotope disturbance. Turček (1961a) presented an ecological comparison of riparian vegetation of selected Slovak rivers on the basis of birds and woody species relations. Research of bird communities in riparian stand habitats of two rivers and four streams from the viewpoint of bioindication elaborated Kaňuch (2000). Bird assemblages of linear wood stands in the agricultural landscape of the Podunajská nížina Lowland was studied by Bohuš (2011). Bird diversity of two streams of the Trnavská pahorkatina Upland was elaborated by Kalivodová et al. (2010). In the assessment of ornithochory we applied i.e. the synthetic work of Turček (1961b) "Ecological relationships of birds and woody plants", where the author, a significant Slovak zoologist and ecologist (1915–1977), listed woody plants consumed and transmitted by bird species, and also a list of bird species that feed on various seeds and fruits of plants, and thus contribute to the dissemination and reproduction of various woody species. Turček's work is still cited by several authors who deal with the importance of birds for dissemination of the fruits and seeds of plants in different levels (e.g. Jordano and Herrera, 1981; Snow and Snow, 1988; Barnea et al., 1991; Cramp et al., 1994; Matthysen, 1998; Saniga, 2003; Schaefer and Ruxton, 2011).

In the study area, we examined three hypotheses related to riparian woody vegetation: (1) ornithochory plays an important role in the formation of riparian vegetation, (2) riparian vegetation serves as a food source for bird species in highly deforested lowland landscapes, (3) there are differences among selected indication groups of woody plant species by types of diaspore dispersal. Four indication groups represented natural alluvial woody vegetation, adjacent forests, other autochtonous woody species and non-native species.

Material and methods

Study area

The study area is located in SW Slovakia, in the Trnavská pahorkatina Upland, the north-western part of the Podunajská nížina Lowland (Fig. 1). It represents riparian vegetation of Stoličný potok stream with its tributaries (the streams Trniansky potok and Vištucký potok) and Gidra stream (with the tributaries of Štefanovský potok and Ronava streams), stemming in the Malé Karpaty Mts, flowing through the Trnavská pahorkatina Upland to the Podunajská nížina Lowland where the Stoličný potok stream flows into the Čierna voda river and Gidra to Dudváh river. The Stoličný potok (38.9 km) and Gidra (38.5 km) streams represent hydric bio-corridors at a regional level (Ružičková et al., 2015). Riparian vegetation of the studied streams (width about 7–15 m) is dominated by Black alder (*Alnus glutinosa*) and Common ash (*Fraxinus excelsior*). Upstream stands were classified as association *Stellario-Alnetum glutinosae* Lohmeyer 1957. Association *Carici remotae-Fraxinetum* Koch in 1926 occurs in bank growths almost at the entire length of the flows at the Trnavská pahorkatina Upland. Locally, stands of non-native tree species of *Robinia pseudoacacia,* added to the association *Chelidonio-Robinietum pseudoacacie* Jurko 1963, were recorded.

Data collection and analysis

An assessment of potential ornithochory was made according to the synthetic floristic and ornithological field research along the streams of the study area. The floristic research of riparian flora and vegetation along the studied streams was realized in 2008–2015. Data collection from the alluvial communities was done by Zürrich-Montpellier phytosociological method (Braun-Blanquet, 1964; Westhoff and Maarel, 1978). Recorded woody plants were analysed within the following four indication groups of woody species: (1) alluvial forests natural woody species; (2) forest species of adjacent forest communities, including characteristic species of oak-hornbeam forests and thermophilous Turkey oak – Sessile oak forests with Lady's mantle (Stanová and Valachovič, 2002; Jarolímek and Šibík, 2008); (3) other autochthonous woody species; (4) alien introduced and invasive species (Benčať, 1982; Medvecká et al., 2012). The periods of fruit maturity and remaining at mother plants were assessed according to field survey and published data (Pagan and Randuška, 1987, 1988; Snow and Snow, 1988; Úradníček et al., 2009). The scientific names of plants were listed by Marhold and Hindák (1998).

The mapping of birds along the studied streams took place from 2008–2015. The occurrence of bird species was assessed according to field research and our own published data (e.g. Kalivodová et al., 2010; Ružičková et al., 2015). During the breeding and migratory seasons, we investigated birds along the Stoličný potok and Gidra streams on selected line transects with a length of 500 or 1,000 m. Transects were determined by the landform, especially near water bodies and in stream parts with riparian vegetation. In total, we established nine transects with a length of 500 m and six transects with a length of 1,000 m (Fig. 1). From 2008–2010, we made these observations on the mentioned transects regularly in the spring (at the time 05:00–09:30 and 16:00–20:00 CET) and autumn migration period (07:00–11:00 and 14:00–18:00 CET). In the other months of the year, we conducted a stationary observation (at least once a month) between water bodies. For bird species, characteristics such as occurrence, weight and prevailing diet were added (Ferianc, 1977, 1979; Kalivodová and Feriancová-Masárová, 1993, 1999; Zuna-Kratky et al., 2000; Danko et al., 2002). The scientific names of birds were listed in accordance with Kovalik et al. (2010).

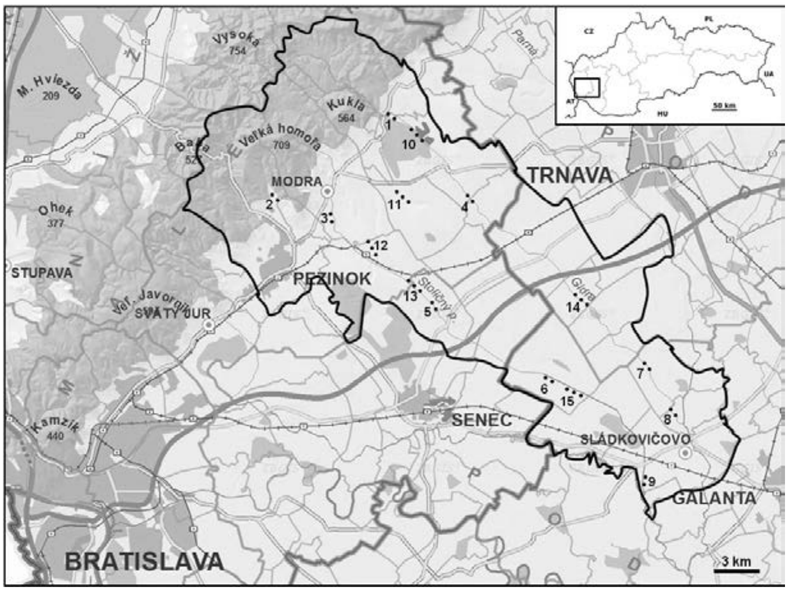

Fig. 1. Study area.

Data from Turček (1961b) were used for identification of bird species spreading the seeds and fruits of recorded woody plant species. Analyses focused on bird species, which potentially transport a minimum of 10% of recorded plant species. The ways of plants' diaspore dispersal were assigned according to Jurko (1990). The author introduced nine types of diaspore dispersal: anemochory, autochory, boleochory, endozoochory, epizoochory, hemerochory, hydrochory, myrmecochory and ombrochory and their combinations for about 2,500 plant species. For each plant species, one or a combination of two or four types of diaspore dispersal and vegetative reproduction is listed. In quantification, all types of diaspore dispersal were counted. Diaspores of the selected plant species were divided into the criteria as diaspore type (fleshy fruit, dry fruit and seed), the amount of nutrients, weight categories and number of seeds per diaspore. Data about diaspore characteristics such as weight and types of fruits were obtained from the D^3 Dispersal and Diaspore Database (Hintze et al., 2013) and from Bojňanský and Fargašová (2007).

Results

Diaspores maturing, availability and dispersal

Riparian vegetation of the study area plays an important function as a habitat and also as a food source for birds. As shown in Fig. 2, woody plants of stream-side vegetation in the studied streams provide seeds, dry and fleshy fruits, which are available as food for birds throughout the year. Fleshy fruits of *Hedera helix* are available year-round. In spring, seeds of *Salix* spp. and dry fruits of *Ulmus* spp. predominate. From June, the maturity of fleshy fruits begins; the most important among them are species with high coverage, abundance and production of fruits such as *Cerasus avium* and *Padus avium*. From August, fleshy fruits of the most abundant shrubs *Sambucus nigra* and *Swida sanguinea* are available. In September, the mature fruits of *Crataegus monogyna*, *Viburnum opulus*, *Rhamnus catharticus*, *Rosa canina* agg. and others predominate. Dry fruits of *Acer* spp., *Corylus avellana* and more are also available. In autumn, seeds of *A. glutinosa* and *R. pseudoacacia* are also accessible. At the edge of riparian vegetation, *C. monogyna*, *Ligustrum vulgare* and *Prunus spinosa* dominate. In winter, the fleshy fruits of *Viscum album*, found in tree-tops are available.

Endozoochory (including ornithochory) was the dominant pattern of diaspore dispersal of riparian woody species of the study area (Fig. 3). The second most important was anemochory. The other significant type of dispersal was hemerochory which is probably due to anthropogenic influence. Myrmecochory, ombrochory and epizoochory (including ornithochory) appeared to accompany them. In riparian vegetation, a significant presence of hydrochory could be expected for *A. glutinosa*.

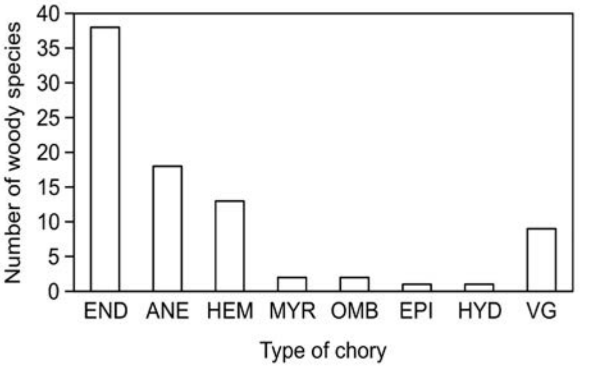

Fig. 3. Presence of diaspore dispersal types (END – endozoochory, including ornithochory, ANE – anemochory, HEM – hemerochory, MYR – myrmecochory, OMB – ombrochory, EPI – epizoochory, including ornithochory, HYD – hydrochory and VG – vegetative reproduction).

Characteristics of the diaspores of the studied woody species

The analyses of diaspore types showed a high proportion (53%) of plants with fleshy fruits (27 of 51). Most of the fleshy fruits had weight over 100 mg (Table 1). Each fleshy fruit and half of the dry fruits are rich of nutrients. Most of the dried fruits had weight less than 100 mg. Diaspores of *Salix* spp. form seeds had weigh less than 0.1 mg. For fleshy fruits, it is common that a higher number of seeds (55%) are present in the fruit. Dry fruits and seeds are mostly monospermous.

Birds' community and species feeding strategies

In the riparian vegetation, we registered 61 woody species, from that 44 tree species, 15 shrub species and two species of lianas, from which seven species were not listed in Turček (1961b). During mapping of the birds, we recorded 64 species of birds in the study area. Analyses were focused on 34 bird species (53%) which potentially transport a minimum of five plant species each of them (Table 3). In terms of the occurrence of bird species in the study area, 17 (50%) bird species were sedentary, of these 12 were breeding in riparian vegetation in the study area and five bird species reach riparian vegetation from the surrounding area. The other 17 bird species (from 34 above-mentioned) belong to migratory species; of these 13 were breeding in riparian vegetation in the study area.

The most preferred types of food of the analysed bird species were categorised like so: 18 species (53%) belonged to insectivorous, 11 species (32%) to omnivorous and five species (15%) to granivorous (Table 3).

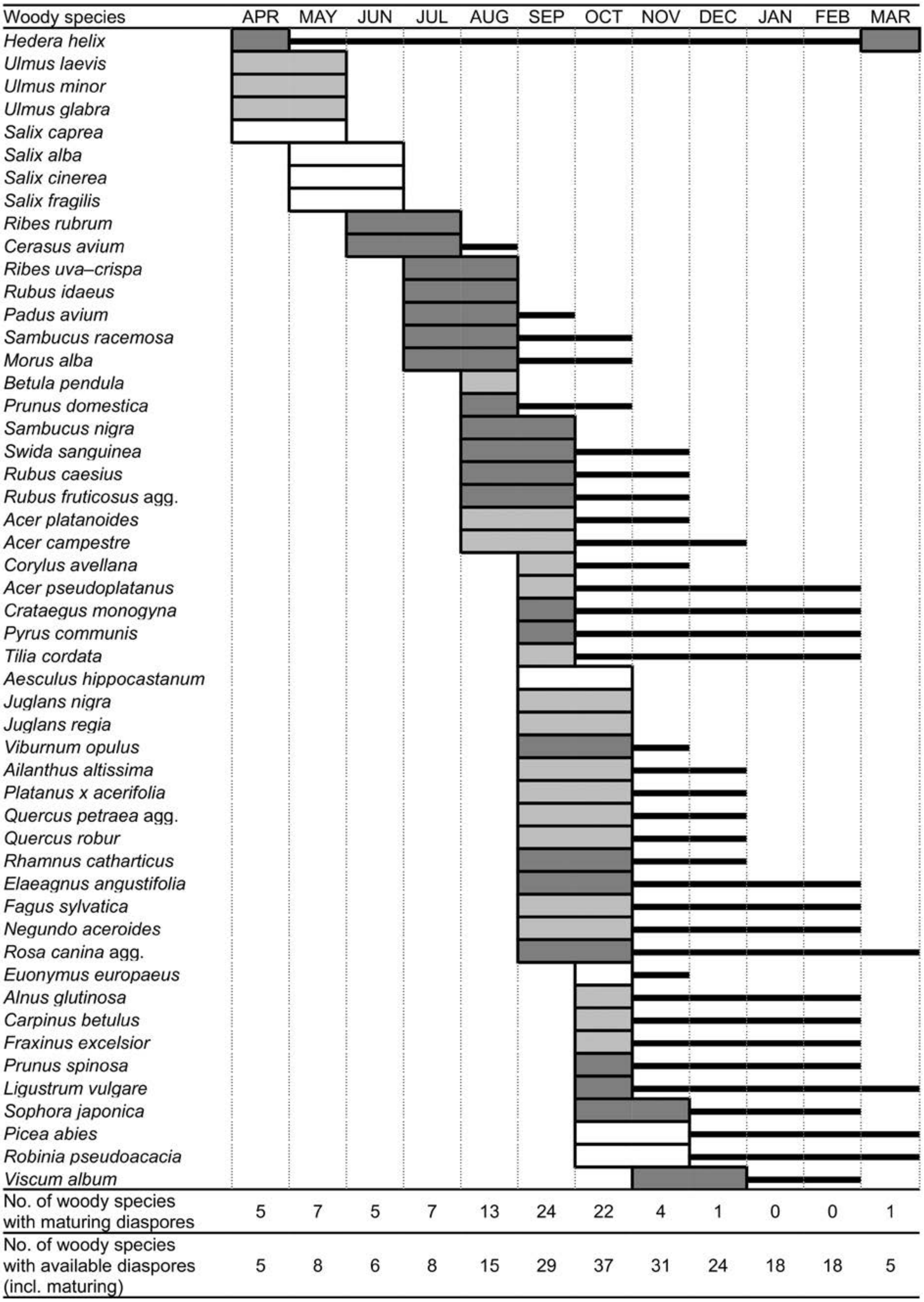

Fig. 2. Schedule of maturing and accessibility of woody species diaspores during the year (white – seeds, light grey – dry fruits, dark grey – fleshy fruits).

Table 1. Characteristics of the diaspores of evaluated woody species.

Diaspore type	Fleshy fruits	Dry fruits	Seeds	Sum
Total number of woody species	27	19	5	51
Number of woody species with significant amount of nutrients	27	11	0	38
Number of woody species without significant amount of nutrients	0	8	5	13
Number of woody species in weight categories of diaspores				
≤0.1 mg	0	0	4	4
0.1–1 mg	0	2	0	2
1–10 mg	0	4	1	5
10–100 mg	2	7	0	9
100–1,000 mg	19	3	0	22
>1,000 mg	6	3	0	9
Number of woody species according to the seeds amount				
1 seed per diaspore	12	18	5	35
2–10 seeds per diaspore	9	1	0	10
11–100 seeds per diaspore	6	0	0	6

Within the categories of most preferred foods, we noticed slight differences between sedentary and migratory species. Among sedentary insectivorous species were species which in the breeding season feed mainly on insects (on various development stages). This group included species such as *Parus major*, *Cyanistes caeruleus*, *Poecile palustris*, *Dendrocopos major*, *Dendrocopos medius*, *Dendrocopos syriacus* and *Sitta europaea*. Omnivorous species living in the study area feed on plant and animal food during the year. In spring, animal food (insects, molluscs, spiders etc.) are predominant, later, the green parts of plants; in winter, fruits and seeds.

The majority of migratory species in the study area (11 of 17) were insectivorous (e.g. *Erithacus rubecula*, *Oriolus oriolus*, *Sylvia* sp.). Most of them arrive when they can already find different stages of insects and depart when the insects are less abundant. Omnivorous migrants comprised four species of thrushes (*Turdus merula*, *Turdus philomelos*, *Turdus pilaris*, *Turdus viscivorus*), which consume a diversity of animal foods (earthworms, insects, larvae, pupae, molluscs, spiders etc.) and a variety of fruits, especially berries. Granivorous species comprised two of the identified migratory birds *Columba palumbus* and *Carduelis spinus*. Although they consume insects, they also prefer vegetable ingredients of food, mostly different seeds mainly in winter period.

Birds' size and diaspore dispersal

More than half of the studied 34 bird species (68%) were small-sized, weigh up to 100 grams (50% weigh up to 50 grams and 18% 50–100 g). Medium-sized birds (100–500 g) represented 20%. Bigger birds made up only 12% (6% weighing 500–1,000 g and 6% more than 1,000 g). In the study area, small-sized birds up to 50 g (17.5%) contributed to the transfer of 45 woody species (88%). In this category, there was a high difference between the minimal (5) and maximal (33) number of plants, dispersed by one bird, while the average number was 17 (Fig. 4). Birds in the weight categories of 50–100 g and 500–1,000 g made up a significant share of diaspore dispersal.

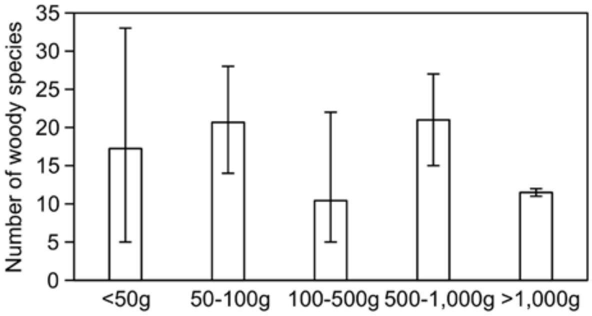

Fig. 4. Average number of woody plants dispersed by one bird species (with marked minimum and maximum values) in the selected bird's weight categories.

Indication groups of woody plant species

Woody species composition follows the character of landscape through which the streams flow. In the riparian vegetation, typical alluvial species occurred in addition to forest species, typical of oak-hornbeam forests, especially in the Malé Karpaty Mts, where the streams begin. The Gidra and Vištuk streams overflow near the turkey oak-sessile oak forest fragment Lindava. The Stoličný potok stream flows near the forest fragments Šenkvický háj and Martinský les, representing Euro-Siberian steppe oak woods. Streams in the long section run down the intensively used agricultural landscape with the current trend of settlement growth, which is reflected in the appearance of introduced non-native and invasive woody plants. The analyses showed well-marked differences in diaspore dispersal type and strategy among four selected indication groups (IG1–IG4) of woody species (Table 2) as follows.

Table 2. The selected indication groups of woody plants

Indicator groups of woody species	Characteristics	Woody plant species	No. of species
IG1 – alluvial forests woody species	Ash-alder alluvial forests natural plant species	*Alnus glutinosa*, *Fraxinus excelsior*, *Padus avium*, *Salix alba*, *S. caprea*, *S. cinerea*, *S. fragilis*, *Ulmus laevis*, *Viburnum opulus*	9
IG2 – characteristic species of adjacent forest communities	Oak-hornbeam forests species	*Acer platanoides*, *A. pseudoplatanus*, *Carpinus betulus*, *Cerasus avium*, *Corylus avellana*, *Euonymus europaeus*, *Fagus sylvatica*, *Swida sanguinea*, *Tilia cordata*	16
	Thermophilous turkey oak-sessile oak forests and forest mantle species	*Acer campestre*, *Crataegus monogyna*, *Prunus spinosa*, *Quercus petraea* agg., *Q. robur*, *Rhamnus catharticus*, *Ulmus minor*	
IG3 – other autochthonous woody species	Other native woody species	*Betula pendula*, *Hedera helix*, *Ligustrum vulgare*, *Picea abies*, *Prunus domestica*, *Pyrus communis*, *Ribes rubrum*, *R. uva–crispa*, *Rosa canina* agg., *Rubus caesius*, *R. fruticosus* agg., *R. idaeus*, *Sambucus nigra*, *S. racemosa*, *Ulmus glabra*, *Viscum album*	16
IG4 – non-native introduced and invasive species	Introduced species	*Aesculus hippocastanum*, *Elaeagnus angustifolia*, *Juglans nigra*, *J. regia*, *Morus alba*, *Platanus x acerifolia*, *Sophora japonica*	10
	Non-native invasive species	*Ailanthus altissima*, *Negundo aceroides*, *Robinia pseudoacacia*	

IG1) alluvial forests woody species (18%) – The group IG1 included nine tree and shrub species, typical for ash-alder alluvial forests. The riparian vegetation of the studied streams is dominated by *A. glutinosa*, in which dry diaspores are distributed by anemochory, combined with endozoochory, hydrochory and myrmecochory. Species with dry fruits are also present, such as *F. excelsior* and *Ulmus laevis* and several species of *Salix* spp. (Table 2) with lightweight seeds, well-adapted to anemochory. Fleshy fruits are typical for two species – *P. avium,* in which stone fruits mature in July, and *V. opulus* with fruits mature in September. In comparison with the other indication groups, seeds and dry fruits (Fig. 5) dominated among diaspores of IG1, resulting in the highest presence of anemochory (78%). The share of endozoochory (including a combination with anemochory) is about 50% (Fig. 6). In relation to ornithochory (including endozoochory and epizoochory), 28 bird species foraged and dispersed diaspores of nine woody species of riparian vegetation. Amongst the birds, 82% were breeding species, 71% represented small species in weight categories < 100 g. In spite of this, a very important distributor in the group IG1 was the large-sized bird *Anas platyrhynchos*, which spreads five of nine plant species (*A. glutinosa* and *Salix* spp.). The other considerable diaspore distributors were four bird species (Table 3): *Phasianus colchicus* (weight category > 1,000 g), *T. merula*, *Pica pica* (100–500 g) and small-size *Carduelis chloris* (<50 g).

IG2) forest species of adjacent forest communities (31%) – The group IG2 consisted of 16 species, typical for adjacent oak-hornbeam and Turkey oak – Sessile oak forests. Dry fruits such as acorns, nuts, nutlets and samaras are characteristic for forest species.

As is shown in Fig. 5, stream banks mainly reach species with dry fruits such as *Acer platanoides*, *A. pseudoplatanus*, *C. betulus*, *Fagus sylvatica*, *Quercus petraea* agg., *Q. robur* and *C. avellana* (Table 2). Species with fleshy fruits were also recorded, among them the shrubs *Euonymus europaeus*, *S. sanguinea* and *R. catharticus* prevailed. *E. rubecula*, *Turdus* spp. and *Sylvia borin* prefer fleshy fruits. A high share of endozoochory (87.5%), in combination with anemochory (Fig. 6), was characteristic for species in IG2. In the distribution of 16 woody plants of IG2, 32 bird species were involved, of which 75% bred there. In the distribution of trees and shrubs, small-sized birds (66%) potentially participated, but also large and medium-sized bird species (34%). The five most important distributors in the group IG2, which distributed 10–13 plant species from 16, were represented by different weight categories; the large-sized bird *Phasianus colchicus* (weight category > 1,000 g), the medium-sized bird species *G. glandarius* (100–500 g) and the small-sized species *D. major*, *P. major* and *S. europaea* (<100 g). All of them were sedentary species (Table 3). All five of the above mentioned bird species were involved in distribution of the following eight plant species: *C. avellana*, *Tilia cordata*, *Q. petraea* agg., *Q. robur*, *A. pseudoplatanus*, *C. betulus*, *C. avium* and *F. sylvatica*. From migratory birds significant are *Ficedula coelebs*, *Sylvia atricapilla*, *T. pilaris*, *T. philomelos*, *T. viscivorus* and *C. palumbus*, participating in the distribution of six–nine plant species from 32.

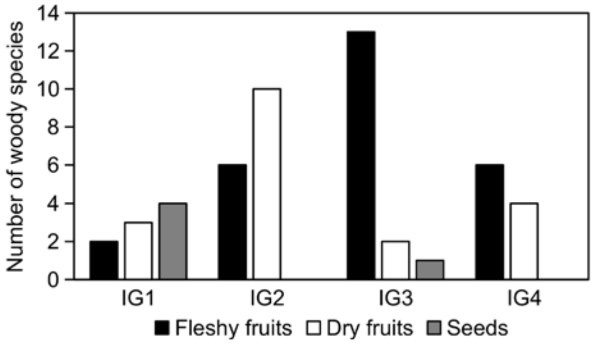

Fig. 5. Types of fruits within the indication groups of plants (IG1 – alluvial forests woody species, IG2 – forest species of adjacent forest communities, IG3 – other autochthonous woody species, IG4 – non-native introduced and invasive species).

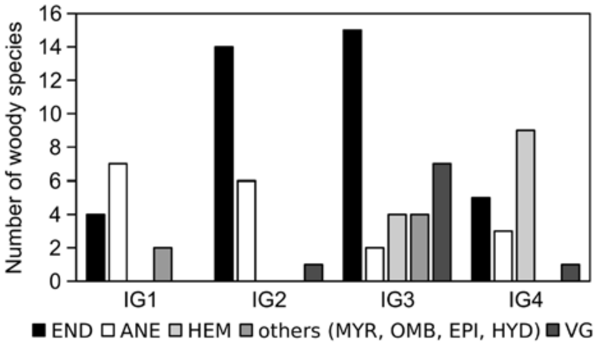

Fig. 6. Diaspore dispersal types within the indication groups (IG1–IG4, see Fig. 5) of plants (END – endozoochory, including ornithochory, ANE – anemochory, HEM – hemerochory, MYR – myrmecochory, OMB – ombrochory, EPI – epizoochory, including ornithochory, HYD – hydrochory and VG – vegetative reproduction).

IG3) other autochthonous woody species (31%) – The group IG3 consisted of 16 widespread native woody species, of which all the 34 bird species participated in the distribution (Table 2, 3). Fleshy fruits such as drupes and berries are typical for the majority of the plant species (81%). In lower proportions, dry fruits and seeds (Fig. 5) are present. In terms of diaspore dispersion in IG3, endozoochory dominated in combination with a wider range of diaspore dispersal patterns, including epizoochory and anemochory (Fig. 6). Compared with the other indication groups in IG3, there is a high proportion of vegetative reproduction which is typical especially for shrubs as *L. vulgare*, *Rubus* spp. and *S. nigra*. In the group IG3, the most important distributors (10) which contributed to the spread of 9–12 plant species from 16, were medium-sized birds (weight category 100–500 g) such as *G. glandarius*, *P. pica*, *T. merula*, *T. pilaris* and *C. palumbus*. Among small-sized species (<100 g), *E. rubecula*, *P. major*, *S. atricapilla* and *T. philomelos* contributed significantly (Table 3). All 10 bird species participated in the distribution of the following five plant species: *L. vulgare*, *Rubus caesius*, *R. idaeus*, *S. nigra* and *S. racemosa*.

IG4) non-native introduced and invasive species (20%) – The group IG4 included 10 non-native tree species, introduced as ornamental and fruit trees, three of them are also invasive (Table 2). Diaspore dispersal patterns respond to outlandish origins and types of fruits (Fig. 5). Plant species were primarily introduced by people; therefore hemerochory dominated. Fleshy fruits slightly prevail over dry fruits; consequently, endozoochory is more frequent in the group than anemochory (Fig. 6). 30 bird species from IG4 foraged and dispersed diaspores of ten non-native woody species. Altogether, six woody species (from 10) were potentially transported by two medium-sized bird species, *G. glandarius* and *T. merula*. Significant dispersal agents were also birds which transport three woody species such as *P. pica* and *C. palumbus* and small-sized birds such as *D. major*, *F. coelebs*, *P. major*, *S. atricapilla* and *Sturnus vulgaris* (Table 3).

Discussion

In the context of riparian vegetation, several studies are aimed at hydrochory but stressed the importance of anemochory and ornithochory (e.g. Nilsson et al., 1991, 2010; Merrit and Wohl 2002; Leyer, 2006). Our results showed that woody species in the studied

Table 3. Characteristics of analysed bird species and their potential of diaspores dispersal within the indication groups of plants

Bird species	Occurrence	Breeding	Prevailed food type	Weight (g)	No. of woody species spread by birds				
					IG1	IG2	IG3	IG4	Sum
Garrulus glandarius	S	N	O	100–500	1	13	12	6	33
Phasianus colchicus	S	B	O	>1,000	3	13	12	2	31
Parus major	S	B	I	<50	1	13	11	3	29
Turdus merula	M	B	O	100–500	3	8	12	4	28
Pica pica	S	B	O	100–500	3	8	12	3	27
Fringilla coelebs	M	B	I	<50	2	9	8	3	23
Sitta europaea	S	B	I	<50	2	13	6	2	23
Sylvia atricapilla	M	B	I	<50	2	6	10	3	23
Turdus philomelos	M	B	O	50–100	1	6	12	3	22
Turdus pilaris	M	N	O	100–500	2	6	11	1	22
Columba palumbus	M	B	G	100–500	1	6	9	3	21
Dendrocopos major	S	B	I	50–100	1	10	7	3	21
Cyanistes caeruleus	S	B	I	<50	1	9	8	1	20
Erithacus rubecula	M	B	I	<50	2	6	9	2	20
Poecile palustris	S	B	I	<50	2	8	6	1	17
Sturnus vulgaris	M	B	I	50–100	–	6	7	3	17
Turdus viscivorus	M	N	O	100–500	1	5	8	1	17
Carduelis chloris	S	B	G	<50	3	7	4	2	16
Corvus frugilegus	S	N	O	500–1,000	–	7	5	3	15
Sylvia borin	M	B	I	<50	1	4	8	1	14
Corvus cornix	S	N	O	500–1,000	–	4	6	2	12
Oriolus oriolus	M	B	I	50–100	1	1	8	2	12
Coloeus monedula	S	N	O	100–500	–	5	5	1	11
Dendrocopos medius	S	B	I	50–100	–	7	3	–	10
Sylvia curruca	M	B	I	<50	1	2	5	2	10
Sylvia communis	M	B	I	<50	1	2	6	–	9
Anas platyrhynchos	S	B	O	>1,000	5	2	1	–	8
Hippolais icterina	M	B	I	<50	1	2	4	1	8
Passer montanus	S	B	G	<50	1	2	2	2	8
Muscicapa striata	M	B	I	<50	1	1	3	2	7
Carduelis spinus	M	N	G	<50	1	1	3	1	6
Carduelis carduelis	S	B	G	<50	2	–	2	1	5
Dendrocopos syriacus	S	N	I	50–100	–	2	1	2	5
Phoenicurus phoenicurus	M	N	I	<50	1	–	4	–	5

S, sedentary (year-long) species; M, migratory species; B, species breeding in the study area; N, species non-breeding in the study area; I, insectivorous species; G, granivorous species; O, omnivorous species; IG1–4, indication groups of woody species 1–4.

riparian vegetation benefit from different types of diaspore dispersal, dominated by endozoochory (including ornithochory). The second most important is anemochory, especially in the indication group of alluvial plant species. For the five assessed woody species in which diaspore are dispersed primarily by anemochory and endozochory (Jurko, 1990), anemochory's and hydrochory's ranking index is listed in D^3 Database

(Hintze et al., 2013). Diaspores of *Betula pendula*, *Salix fragilis* and *Acer pseudoplatanus* are well-adapted for anemochory and hydrochory, lower ranking index values for anemochory and especially for hydrochory were given for *Carpinus betulus* and *F. excelsior*. As stated by Drezner et al. (2001), wind-dispersed species are proportionally more abundant in the pioneer *Populus-Salix* community. According to Fér (2013), seeds dispersal patterns (by water or wind) and their ability to float play an important role in the migration of aquatic and coastal plants in rivers and strongly influence the genetic variability on the landscape level. Plant species diaspores which are distributed by water float mainly in a one-way direction along a flow. On other hand, plant diaspores, which are dispersed by wind, are transfered along river corridors, but more common is dispersion among streams or river basins. After Hampe (2004), the influence of water dispersal decreases upstream, and birds remain the most reliable dispersal agents in the uppermost reaches. They are also indispensable for any seed dispersal upstream or between different streams.

In the study area, more than half of the bird species were small-sized, weighing up to 100 grams. Similarly, Herrera (1984) noted that the bird assemblage of southern Spain shows a higher proportion of small-sized species. He suggested that the dense vegetation structure, the mild climate and the abundance of energy-rich fruits are favourable to these small-sized species. Regarding the major diaspores distributors, Debussche and Isenmann (1992) reported from their study site in Montpellier (France), dominated by *Quercus ilex* and *Viburnum tinus*, more or less the same species we recorded in the riparian vegetation of the Podunajská nížina Lowland. In the suburb of Montpellier, small-sized passerines *S. atricapilla* and *E. rubecula* were by far the major dispersers. Thrushes *T. merula* and *T. philomelos* were the two most frequent medium-sized dispersers. The small-sized (<30 g) *P. major, C. caeruleus*, *F. coelebs*, *C. carduelis* and *C. chloris* were the major fruit-consumers. In the oak-turkey oak forest fragment Lindava in the Podunajská nížina Lowland, the most frequent diaspore distributors were *C. coccothraustes, G. glandarius, P. major, P. colchicus, S. europaea, P. pica, T. merula, D. major, F. coelebs, C. palumbus*, *C. caeruleus, T. philomelos* and *T. pilaris* (Gulyášová and Ružičková, 2013).

Jordano et al. (2007) found that although small-sized birds (<110 g) were by far the major seed dispersers of fleshy fruits seeds which were moved up to 250 m, larger frugivores (110–500 g) were the major dispersers of seeds that were moved between 250–990 m. Medium-sized birds (*T. viscivorus* and *Corvus corone*) contributed to short-distance dispersal (to 100 m), but they dispersed most seeds beyond 100 m. In contrast, small birds rarely dispersed seeds more than 100 m. By applying the conclusions of Jordano et al. (2007) in the study area, large and medium-size bird species (Table 3) belong to important distributors, which are able to spread plants' diaspores to longer distances. Vittoz and Engler (2007) elaborated typology of dispersal distances for seven dispersal types. Dispersal distance for endozoochory (seeds eaten by birds and large vertebrate) 400–1,500 m was estimated as the upper limit of the distances within which 50% and 99% of the seeds of a plant population are dispersed.

Snow and Snow (1988) presented in detail 43 plant species connected to 19 bird species in Southern England; 17 plant species were common and were found in our study area as well. Fleshy-fruited plants in the northern temperate zone commonly produce mature fruit crops in late summer and autumn when avian frugivores are usually abundant, however, a little further south, more fruit maturation occurs in winter when flocks of wintering migrant birds are foraging. According to Turček (1961b) in the dissemination of fleshy fruits of lianas *H. helix* and *V. album,* participated *T. merula, T. philomelos, T. viscivorus, S. vulgaris* and *S. atricapilla*. The mentioned species were observed by Snow and Snow (1988) in the period from December to May when fruits of *H. helix* were consumed. From granivorous species, the wood pigeon (*C. palumbus*) was observed to have eaten ripe and unripened fruits. According to Snow and Snow (1998), feeding on *V. opulus* fruits was observed in winter (December, January), in which *T. philomelos* was involved and *Pyrrhula pyrrhula*, from granivorous birds, made up a significant percentage.

The feeding strategy of birds depends on the seasons (Hume, 2002). In the period of breeding, they focus on insects which are often preferred by explicitly granivorous or omnivorous bird species. In the non-breeding season, they adapt to the available nutrition options. In the non-breeding season, tits feed also on the seeds of trees and plants as well as berries, fruits etc. (Glutz von Blotzheim and Bauer, 1993). In autumn and winter, woodpeckers feed on the seeds of coniferous and deciduous trees and nuthatches feed on insects and plants seeds (Glutz von Blotzheim and Bauer, 1994). Granivorous species (*Carduelis chloris, Passer montanus, Carduelis carduelis*) prefer different seeds throughout the year, even when feeding their offspring, and later feed on grain softened in crops (Snow and Snow, 1988).

Seed dispersal events take place within complex natural landscapes. As those landscapes are fragmented over time, the ability of seeds to move long distances may be reduced (Cain et al. 2000). Riparian zones might act as a refuge for bird populations in times of disturbance and as a stock of genetic biodiversity that can potentially be redistributed throughout fragmented landscapes by means of ornithochory (Bell et al., 2009). According to Garcia et al. (2010), temperate frugivorous birds should be classified as effective suppliers of the seed-dispersal ecosystem service on the landscape scale. The authors encourage conservationists and land managers to explicitly consider such a classification if they aim to develop integrative plans focused on specific species or target habitats and on the ecological interactions driving ecosystem fluxes.

Conclusions

The obtained results confirmed the specified hypotheses. Ornithochory plays important role in the formation of riparian vegetation of the study area. The 34 assessed bird species are the significant distributors of trees' and shrubs' diaspores within riparian vegetation, as well as among the streams, adjacent forest fragments and non-forest woody vegetation. On the other hand, woody plants of riparian vegetation in the study area provide seeds, dry and fleshy fruits which are available as food for birds throughout the year. In April and May, the maturity of dry fruits and seeds prevail, in summer, fleshy fruits dominate and in autumn, dry and fleshy fruits are available. More than half of the evaluated bird species (34) are small-sized birds (68%), weighing up to 100 grams. The average number of woody species, transferred by one bird species in the given size category, shows a significant share of small-sized birds in the weight category 50–100 g and large-sized birds (500–1,000 g). From the viewpoint of biodiversity protection and management evident differences among the four indication groups in seed dispersal appear to be significant. Among diaspores of alluvial forests woody species (indication group IG1), seeds and dry fruits were dominant which resulted in the highest presence of anemochory (78%). The share of endozoochory (including ornithochory) is about 50%. In the stream banks, we also recorded species of adjacent forest communities (IG2), for which dry fruits are typical. For forest species in IG2, a high share of endozoochory (87.5%) is characteristic in combination with anemochory. In terms of diaspore dispersion of autochthonous woody species (IG3), endozoochory dominates in combination with different diaspore dispersal patterns, including epizoochory and anemochory. In comparison with the other indication groups, endozoochory is the most widely used (93.8%) in IG3. In the distribution of non-native tree species (IG4), hemerochory prevails as was expected. Fleshy fruits slightly prevail over dry fruits; consequently, endozoochory is more frequent in the group as anemochory. All methods of plants' diaspore dispersal are important for maintaining diversity in deforested agricultural landscape. The results were obtained through joint interdisciplinary research; our synthetic study is a contribution to this issue and methodical approach to tackling the topic. Tree and shrub stands along the studied streams are ecologically significant linear elements in the agricultural and urbanised landscape of the Podunajská nížina Lowland. During the constant changes of the surrounding landscape, such spaces become refuges for many plants and bird species that not only find shelter and food there, but are also stopping points for migratory birds. The results confirm the importance of the studied streams for nature conservation as hydric biocorridors, which serve as essential habitats for birds.

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Expansion of the Striped field mouse (*Apodemus agrarius*) in the south-western Slovakia during 2010–2015

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Abstract

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Population of the Striped field mouse spread out into unoccupied territories leading to the rapid enlargement of their range of distribution is defined as an expansion. In 2010, the presence of the species in south-western Slovakia was recorded for the first time. During monitoring of this expansion (from 2010 to 2015) 59 new localities in south-western Slovakia were recorded, representing confirmation of the presence of *A. agrarius* in 18 new quadrates of Databank of Slovak fauna. Thus in 2015, marginal points of the distribution area were the Danube River in south-western Slovakia, the Šur National Nature Reserve in the west, the wetland near Tešmak in the east and the Jasová water reservoir in the north. The impact of this expansion on the quantitative composition of the small mammal's community has been evaluated for three sites (Čiližská mokraď wetland, Okoličianska mokraď wetland, Martovská mokraď wetland) and one larger area (south-western corner of Danubian lowland). In all the observed sites the expansion of *A. agrarius* was related to rapid increase of its abundance. However its representation in the small mammal's community was significantly growing only in the site Čiližská mokraď wetland and Martovská mokraď wetland. In general, the rapid increase of the abundance of *Apodemus agrarius* in the small mammal's community in the observed sites led to the significant decrease of the abundance of several species of small mammals, mainly *Apodemus sylvaticus, Clethrionomys glareolus* and *Sorex araneus*.

Keywords

small mammals' community, species expansion, Rodentia

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Introduction

Populations of the Stripe field mouse, *Apodemus agrarius*, are characteristic for their changes in the range of distribution. Its expansion from the centre of origin (eastern Russia; Suzuki et al., 2008) westward represents the most dramatic expansion of small mammals species unassisted by man (Hildebrand et al., 2013). Skeletal findings confirm the presence of this species in some parts of Europe already in the Pleistocene epoch, and in other parts during the Holocene epoch (Kowalski, 2001; Toškan and Kryštufek, 2006). However, paleontological findings (Horáček and Ložek, 1993), as well as the analysis of owl subrecent diet (Obuch, 1992; Obuch and Dorica, 2011) also indicate that some of the colonized territories were later retreated by this species to recolonize them subsequently.

Recent spread of the species in other areas is documented in several parts within the range of its distribution such as Northern Hungary (Bihari, 2007; Gubányi, 2010), Moravia and north of the Czech Republic (Polechová and Graciasová, 2000; Bryja and Řehák, 2002; Flousek et al., 2004), western Austria (Spitzenberger, 2001; Spitzenberger and Engelberger, 2014), the European part of Russia and northern Kazakhstan (Karaseva et al., 1992), or southeast of Russia (Bazhenov et al., 2015). During the period of 1980's to 1990's, changes in the species distribution were reported also in central Slovakia and the distribution rate was estimated at 3 km per year (Dudich, 1997). Factors affecting the current expansion of the species are climate change with increasing average temperature, continuing fragmentation of forests, expanding urbanization (Spitzenberger and Engelberger, 2014), building of water units in the country (Dudich, 1997) or conversion of the steppes to agricultural land (Karaseva et al., 1992). Large migration ability (Babinska and Werka, 1981; Liro and Szaki, 1987) or large reproductive potential (Stein, 1955; Pelican, 1965) are also supportive in spreading of the species. Expansion of *A. agrarius* in the area of soutwestern Slovakia, location where this species wasn't reported in the past research (e.g. Balát, 1956; Folk, 1956; Pachinger et al., 1996, 1997; Veselovský et al., 1997; Krištofík, 1999), was first documented in 2010 (Ambros et al., 2010).

An important feature of the species is the gradual increase in dominance (Stanko, 2014) and its competitive pressure on the certain syntopic occurring species such as Yellow-necked mouse *Apodemus flavicollis* (Gliwicz, 1981; Simeonovski-Nikolova, 2007) or Bank vole *Clethrionomys glareolus* (Gliwicz, 1981; Kozakiewicz and Boniecki, 1994). Dissemination of the *A. agrarius* on a new territory brings competitor of other species of the genus *Apodemus* or the family Muridae (Dudich, 1997) to the original community of small mammals. This competitive pressure of *A. agrarius* together with its epidemiological signification as a reservoir for spreading hantavirus (Lee et al., 1981; Klempa et al., 2005; Jakab et al., 2007), mastadenovirus (Klempa, 2009), *Borrelia burgdorferi* s.s. (Štefaníčková et al., 2004) or tick-borne encephalitis (Achazi et al., 2011) highlight the need to monitor the expansion of this species. Its expansion could be liable to pose a potential threat to the native biota (Johnson et al., 2001; Arriaga et al., 2004).

The aim of this paper is: (*i*) to describe the sequence of *A. agrarius* expansion within the area of south-western Slovakia during the years 2010 to 2015 and (*ii*) to analyse its expansion impact on the quantitative composition of the small mammals' community in the observed area.

Material and methods

The research was conducted on small mammals in different types of habitats from waterlogged areas overgrown by *Carex* sp. to the edges of channels, dead branches and remnants of old arms intersecting large areas of agrocoenosis. These water features belong to the system of Carpathian rivers in south-western Slovakia: Danube (Dunaj), Váh, Nitra, Žitava, Hron and Ipeľ.

Small mammals were captured during the years 2010 to 2015 by using two methods. First quadrat method using 25, 36 and 50 live traps exposed within the range of 1 to 4 nights. Captured species were marked with ear tags. Second one was the line method using 50 snap traps and 36 live traps exposed during 2 to 3 nights. Live traps were checked twice a day, morning and evening. Snap traps were checked once a day. The captured species of small mammals were examined for gender and age. Due to the use of two capture methods, different type and number of traps and various range of their exposition in the sites, we evaluated the abundance of the captured species through corrections for 100 traps per nights per session – C100TN (Gillies, 2013) using the following formula: number of captured individuals of given species × 100/ number of traps used per session. Research design allowed us to observe the annual changes in the abundance of *A. agrarius* and other small mammal species only within three sites (Čiližská mokraď wetland, Okoličianska mokraď wetland, Martovská mokraď wetland) and one larger area (south-western corner of the Danubian Lowland (Fig. 1).

One way ANOVA was used to compare to year changes in the abundance of *A. agrarius* and other small mammal species within observed sites. Statistical analyzes were run in STATISTICA 8.0 software (StatSoft Inc., 2007). Acquired knowledge about expansion of the species were visualized by Databank of Slovak fauna (DSF) with quadrant size 12 km × 11 km in ArcMap 10.1 (Esri, 2011).

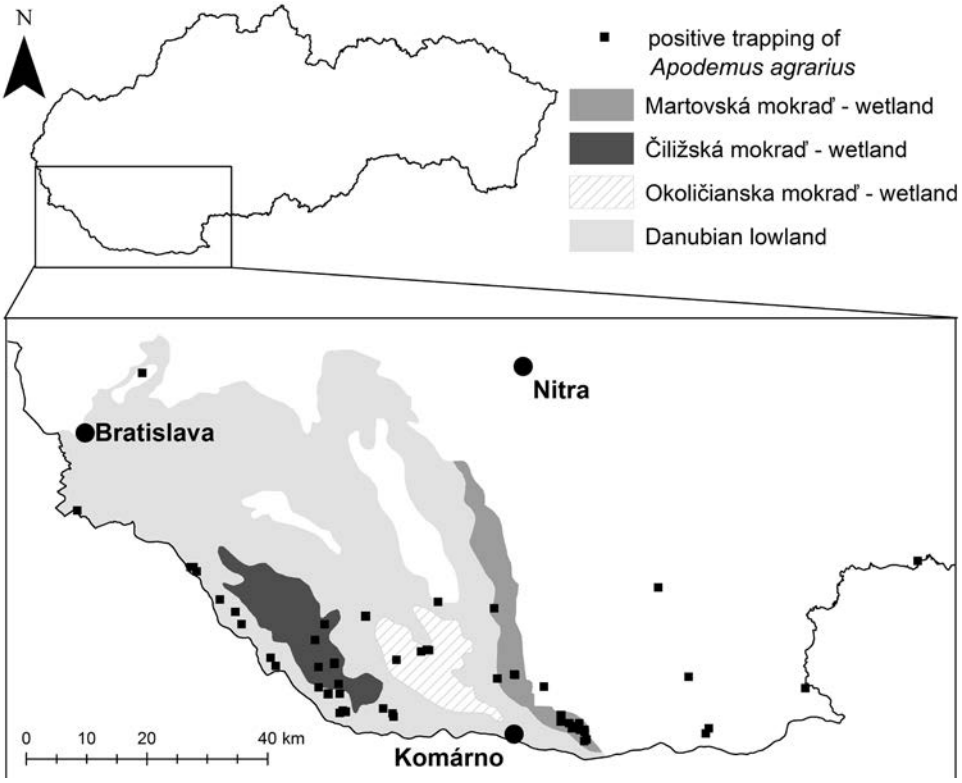
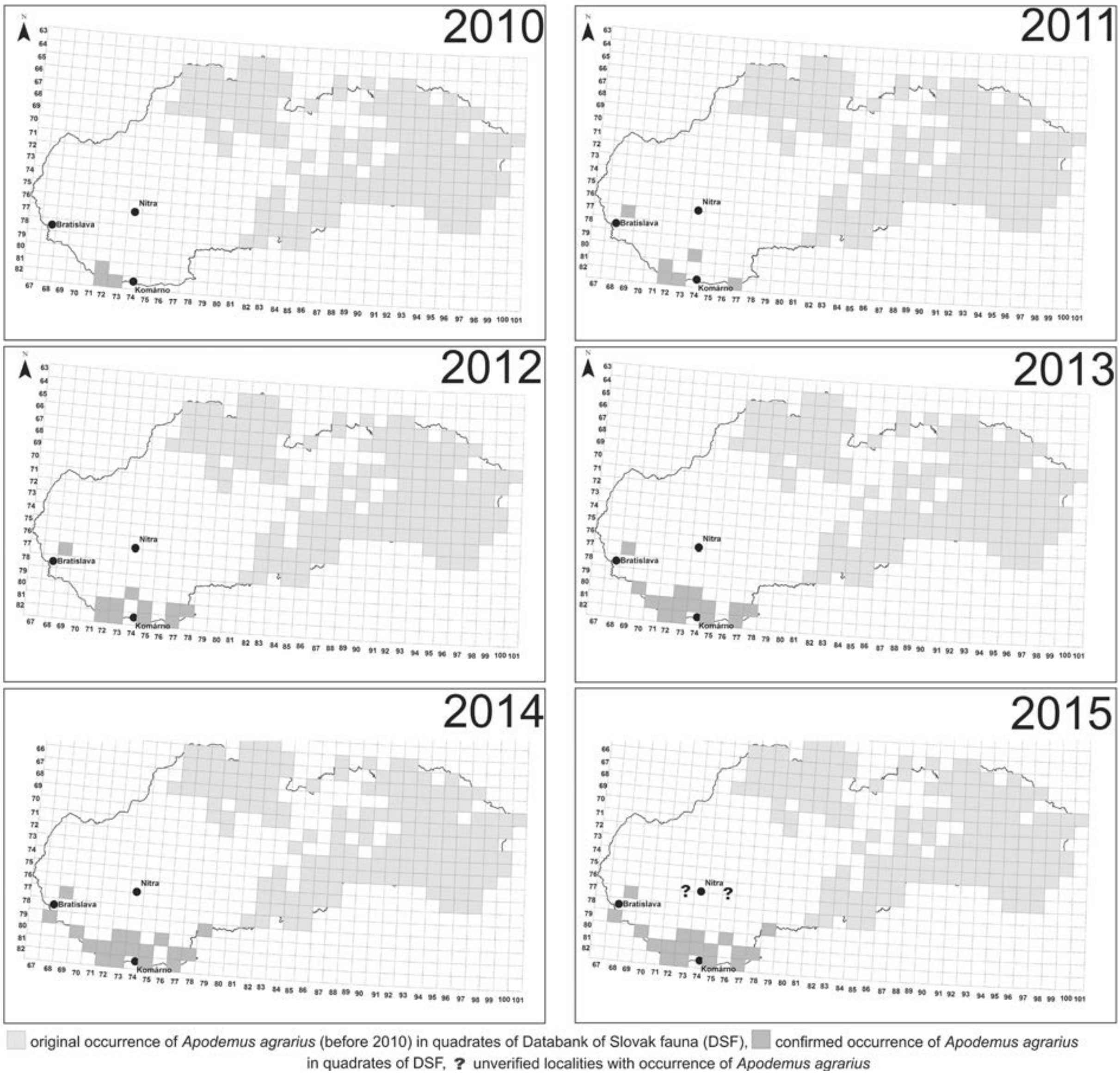


Fig. 1. Localization of *Apodemus agrarius* trapping plots in sites of southern Slovakia.

Results and discussion

During the years 2010 to 2015, we confirmed the presence of *A. agrarius* in 59 new localities of the south-western Slovakia that represents 18 quadrates of DSF (Fig. 2). Totally, 1,114 individuals of the species have been captured. In 2015, the marginal points of the distribution area of *A. agrarius* in the south-western Slovakia are: the Danube river in south-western Slovakia, the Šúr National Nature Reserve in the west, the wetland near Tešmak in the east and the Jasová water reservoir in the north. A complete list of the localities with confirmed presence in the particular years is in the Appendix 1.

Increasing of new quadrates to the northwest and to the northeast suggest that the expansion in the area of Slovakia arrived from the south – Hungary. It is just in Hungary where the spreading of the species to the northwest was recorded in the last years (Bihari, 2007) and the nearest confirmed locality with the species presence in the surroundings of the Lipót village (Gubányi, 2010) is only 4 km far from the locality of Bodíky. Even here, the species were recorded in the stationary trapping plot for the first time in 2010 after a long-term research. With this assumption it is necessary to take into consideration a natural barrier to spreading of the species which is the Danube river-basin, in large measure divided to the Gabčíkovo river barrage system and the river-basin of the Old Danube. Miklós et al. (2015) suppose that species spread just through the river-basin of the Old Danube where the stream with low water level is easier to overcome than the wide canal of the Gabčíkovo river barrage system with the massive and regularly mowed barrage. Nevertheless, Ambros et al. (2010) suggested also the possible human mediated dispersal origin of the population founding species in the south-western Slovakia which is connected with the cross-border transport of waste. Human mediated introduction of the species by industrial products in the south-eastern Russia is anticipated also by Bazhenov et al. (2015). In the years 2012 and 2014, broadest surroundings of Bratislava revealed localities with presence of *A. agrarius* (DSF 7769, 7968) (Fig. 2) that may be an after-effect of the recent species spreading in the east Austria (Herzig-Straschil et al., 2003; Spitzenberger and Engelberger, 2014). Spitzenberger and Engelberger (2014) state that the current expansion of *A. agrarius* in the south-western Slovakia is a part of the major range expansions in the western border of the range of distribution of its spreading in the Central Europe (the east of Russia, the north of Hungary, the southwest of Slovakia, the west and the centre of the Czech Republic). A possibility of existence of an isolated, long-overlooked population of *A. agrarius* in the southwest of Slovakia was excluded in the context of fossil and sub-fossil knowledge and intensive research carried out in the south-western Slovakia in the recent past (Balát, 1956; Folk, 1956; Pachinger et al., 1996, 1997; Krištofík, 1999; Ambros, 2010).



▨ original occurrence of *Apodemus agrarius* (before 2010) in quadrates of Databank of Slovak fauna (DSF), ■ confirmed occurrence of *Apodemus agrarius* in quadrates of DSF, **?** unverified localities with occurrence of *Apodemus agrarius*

Fig. 2. Progress of *Apodemus agrarius* expansion in south-western Slovakia during the years 2010–2015.

Building of hydraulic engineering units like channels (Dudich, 1997) or the change of steppe into agrocenosis (Karaseva et al., 1992) is described as a factor contributing to the species spreading. Spitzenberger and Engelberger (2014) consider the climate change with growing average temperature and the continuing fragmentation of forests together with the increasing urbanization to be the main factors of the current species expansion. Paleontological findings and analyses of the subrecent owl food indicate that in some cases deal only recolonizes the same territory which was colonized by it in the past (Obuch, 1992; Horáček and Ložek, 1993; Obuch and Dorica, 2011). This fact indicates also the comparison of the west range of distribution of *A. agrarius* with its preferred ectoparasite flea *Hystrichopsylla orientalis*. While the host species from the occupied territory withdrawn in the past, the parasite in this territory persists till today in another guild of host species (Dudich, 1997).

During the expansion the abundance of *A. agrarius* in small mammals' community changed annually in all sites (Fig. 3). Significant differences has been found only in Čiližská mokraď wetland (F = 2.98, n = 21, P = 0.046) and Martovská mokraď wetland (F = 2.82, n = 61, P = 0.033). Growing abundance of *A. agrarius* manifests itself naturally in the quantitative composition of the original community species (Fig. 3). In the three observed sites, we have recorded changes in the abundance of the species such as Wood mouse *Apodemus sylvaticus*, Yellow-necked mouse *Apodemus flavicollis*, Herb field mouse *Micromys minutus*, Bank vole *Clethrionomys glareolus* and surprisingly also Common shrew *Sorex araneus* (Tab. 1). In any case, the species penetration to new areas has to be shown also in the structure of the original community or ecosystem (Townsend and Crowl, 1991; McIntosh and Townsend, 1996). Similarly with our results, Stanko (2014) has recorded progressive increasing of the dominance of *A. agrarius* in the small mammals' community.

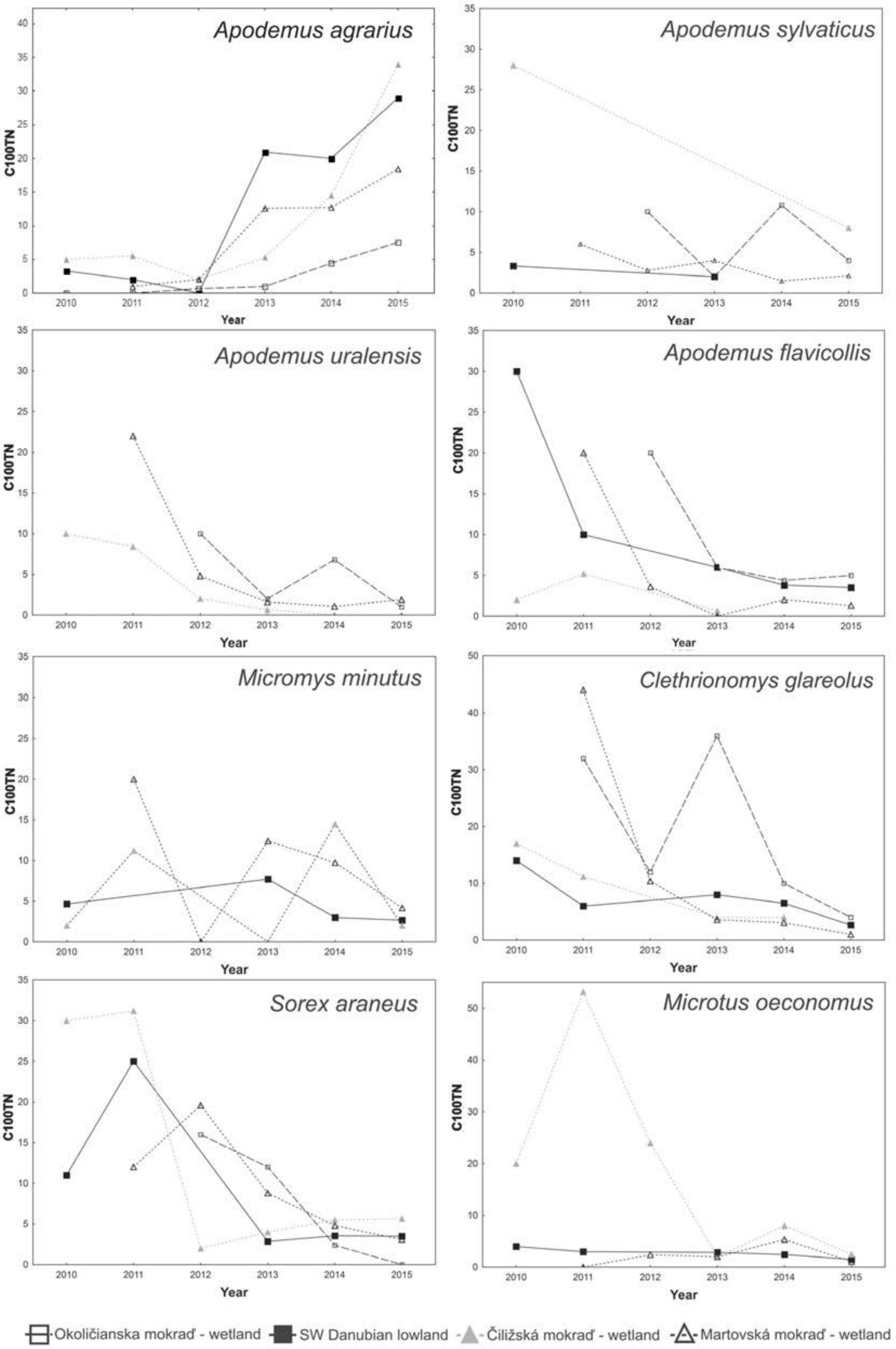


Fig. 3. Annual changes in abundance (mean) of *Apodemus agrarius* and other species of small mammals' community expressed by the proportion of the corrected number of trap-nights (C100TN) in studied sites.

Table. 1. ANOVA results for species with significant decrease of abundance in study sites

Sites	Species	F	n	*P*
South-west of Danubian lowland	*A. sylvaticus*	4.40	27	<0.01
	S. araneus	11.71	27	<0.001
Čiližská mokraď wetland	*A. sylvaticus*	18.40	21	<0.001
Martovská mokraď wetland	*A. flavicollis*	13.20	61	<0.001
	A. uralensis	3.87	61	<0.01
	C. glareolus	34.17	61	<0.001
	S. araneus	5.05	61	<0.01

n – number of sites.

Avoidance of *A. agrarius* to Yellow-necked mouse is a response to its aggressive behaviour during a breeding period (Simeonovska-Nikolova, 2007). However, Gliwicz (1981) suggested that in the time of lower accessibility to food, Yellow-necked mouse is becoming more dominant. Aggressive interactions have been also described between *A. agrarius* and Wood mouse. In sympatry populations, these two species may occur even in the same communities (Frynta et al., 1995). In places of absence of the *A. agrarius*, the space is occupied by Wood mouse (Dickman and Doncaster, 1986; Frynta, 1992). Aggressiveness as a consequence of competition for available burrows has been observed also between *A. agrarius* and Bank vole (Gliwicz, 1981). Kozakiewicz and Boniecki (1994) termed their mutual relation as a non-tolerant mutual interaction. However, the competitive pressure between the *A. agrarius* and Bank vole is lower in comparison with *A. agrarius* and Yellow-necked mouse (Gliwicz, 1981).

Zub et al. (2012) indicated a possible competitive relation between *A. agrarius* and Common shrew *Sorex araneus.* Their competition is also a consequence of overlapping of their diet niche, where up to 40% of the food of *A. agrarius* can be formed by an animal diet (Holišová, 1974). According to Zub et al. (2012), the increasing abundance of voles and mice causes increased consumption of vegetable food that points itself on the decreasing number of plant-eating vertebrates which represent an important food of Common shrews (Churchfield and Rychlik, 2006). Adverse conditions during winters may also cause a decrease in the abundance of Common shrew when its surviving is lower comparing to the *A. agrarius* (Hayes and O'Connor, 1999; Ochocińska and Taylor, 2005).

A strong competitive pressure of *A. agrarius* on the other species of small mammals is a consequence of the species characteristics which support also its successful expansion such as great migration capability (Babinska-Werka et al., 1981; Liro and Szaki, 1987), high fertility (Stein, 1955; Pelikán, 1965), capability to occupy a wide spectrum of habitats (Stanko, 2014), but also a capability to colonize or recolonize habitats affected by floods (Balčiauskas et al., 2012). Miklós et al. (2015) thus suggested that in the south-western Slovakia, the intricate river branch system of Danube presents not only suitable living conditions but also ideal conditions for rapid spreading of this species. Gliwicz (1981) described the rapid reactions of *A. agrarius* on the increased capacity of the environment caused by experimental disposing of other species as a typical feature of the expansive species. The results indicate that the expansion of *Apodemus agrarius* and its increasing abundance may have a negative impact on the abundance of native species in small mammals' communities. The decrease of these species of small mammals, however, may be influenced by several-year fluctuations of populations of voles (Lambin et al., 2000; Tkadlec and Stenseth, 2001), shrews (Sheftel, 1989; Zub et al., 2012), Bank voles (Christiansen, 1983; Marcstrom et al., 1990) or Yellow-necked mice (Marcstrom et al., 1990; Fernandez et al., 1996).

Conclusions

In the course of six years, *A. agrarius* inhabited a substantial part of the south-western Slovakia, where it found a persisting population which is, at present independent from immigration. In the context of current knowledge, the species expansion in the south-western Slovakia is a part of the major expansion in the western border of its spreading within the Central Europe. In the period of our investigation, the expansive, less abundant species became a dominant element of the community and it might be influenced by largeness of populations of sympatric species such as *Apodemus flavicollis*, *Apodemus sylvaticus*, *Apodemus uralensis*, *Clethrionomys glareolus* and *Sorex araneus*. Another monitoring of the species expansion is needed because *A. agrarius*: (*i*) represent epidemiologically significant species; (*ii*) influence the changing of the composition of the original community of small mammals; (*iii*) could have potential impact on the syntopically glacial relict subspecies *Microtus oeconomus mehélyi* and its survival in the refuges of the south-western Slovakia is still unclear.

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Appendix 1. Year: site – coordinates (WGS84 format)

2010: Dunajské tŕstie 1 – 47.779997E,17.835476N; Dunajské tŕstie 2 – 47.773944 E, 17.857257N; Hamske tŕstie 1 – 47.769932N, 17.753508E; Hamske tŕstie 2 – 47.771344N, 17.746639E; Kľúčovec. Čobánsky chrbát – 47.802691N,17.688727E; Čiližska Radvaň. Hansky kanál – 47.839478N, 17.717974E;

2011: Mužla. Čenkovská niva. A – 47.7927N, 18.557499E; Mužla. Čenkovská niva. B – 47.7847N, 18.551901E; Čiližská Radvaň A – 47.840392N, 17.719425E; Čiližská Radvaň. Kanál pri obci – 47.833N, 17.684097E; Čiližská Radvaň – 47.840392N, 17.719425E; Kľúčovec – 47.79611111N, 17.73666667E; NPR Šúr – 48.24472222N, 17.23055556E; Kolárovo. Vrbové – 47.944049N 18.060239E;

2012: Lela. Barina – 47.864109N, 18.763636E; NPR Parížsky močiar. – 47.866861N, 18.503567E; CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; CHA Dropie. rameno Dudváhu – 47.873269N, 17.920103E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Krátke Kesy. močiar – 47.774230N, 18.273772E; Krátke Kesy. Želiarske pole 1 – 47.779089N, 18.257926E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Iža. Patinský kanál – 47.775440N, 18.255464E; Hurbanovo. Konkoly – 47.833875N, 18.186008E; Pataš. A – 47.8725N, 17.67111111E; Žitavský luh. B – 48.17716667N, 18.29652778E;

2013: Pod Kamenným. Studiensky kanál – 47.946134N, 17.935209E; CHA Dropie. rameno Dudváhu – 47.872758N, 17.918611E; Hliník. Hlinický kanál – 47.840097N, 18.081739E; Bodíky. A – 47.919466N, 17.45216E; Boheľov. A – 47.89722222N, 17.68916667E; Číčov. A – 47.767608N, 17.740673E; Číčov. B – 47.770393N, 17.753588E; Erčéd. A – 47.828535N, 17.589722E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Išpánoš. A – 47.840006N, 17.576885E; Kľúčovec. A. Vára – 47.81055556N, 17.73222222E; Kráľovská lúka. B – 47.90317N, 17.489167E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Marcelová. Šerke – 47.757837N, 18.284883E; Martovce. Hliník – 47.839973N, 18.08103E; Pataš. A – 47.8725N, 17.67111111E; Vojka. A – 47.96361111N, 17.38666667E; Vojka. D. Žofín – 47.957533N, 17.394728E;

2014: Tešmak. močiar – 48.066670N, 18.990861E; CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; Bodzianske lúky – 47.870016N, 17.907829E; Sokolce. Lák – 47.854353N, 17.854872E; Marcelová 1 – 47.760788N, 18.289746E; Pohrebisko 1 – 47.773999N,18.283697E; Iža. Patinský kanál – 47.775440N, 18.255464E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Chotín. Fialkový kanál 2 – 47.789606N, 18.229105E; Marcelová 3 – 47.784035N, 18.270747E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Sysľovské polia 1 – 48.030752N, 17.117165E; Jasová. VN – 47.996081N, 18.419655E; Bakanské rameno – 47.885767N, 17.505616E; Boheľov. A – 47.89722222N, 17.68916667E; Číčov – 47.767608N, 17.740673E; Erčéd. A – 47.828535N, 17.589722E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Kľúčovec. A. Vára – 47.81055556N, 17.7322222E; Bodíky. Kráľovská lúka. B – 47.903170N,17.489167E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Marcelová. Šerke – 47.757837N, 18.284883E; Martovce. C. Gamota – 47.84763N, 18.119854E; Martovce. Hliník – 47.839973N, 18.08103E; Pataš. A – 47.8725N, 17.6711111E; Vojka. A – 47.9636111N, 17.3866666E; Vojka. B/C – 47.96318N, 17.380706E; Vojka. D. Žofín – 47.957533N, 17.394728E;

2015: CHA Dropie. topoľový lesík – 47.873025N, 17.925220E; CHA Dropie. rameno Dudváhu – 47.873269N, 17.920103E; Marcelová 1 – 47.760788N, 18.289746E; Pohrebisko 1 – 47.773999N, 18.283697E; Marcelová 3 – 47.784035N, 18.270747E; Krátke Kesy. Želiarske pole 2 – 47.782672N, 18.248708E; Iža. Patinský kanál – 47.775440N, 18.255464E; Chotín. Fialkový kanál 1 – 47.794046N, 18.228470E; Chotín. Fialkový kanál 2 – 47.789606N, 18.229105E; Pohrebisko 10 – 47.771948N, 18.283965E; Chotín 8 – 47.784309N, 18.229651E; Pohrebisko 11 – 47.776490N, 18.271927E; Číčov. A – 47.767608N, 17.740673E; Chotín. Fialkový potok – 47.793862N, 18.229755E; Kľúčovec. A. Vára – 47.81055556N, 17.73222222E; Martovce. C. Gamota – 47.84763N, 18.119854E; Vojka. A – 47.96361111N, 17.38666667E; Vojka. D – 47.957533N, 17.394728E; Martovce. C. Gamota – 47.84763N, 18.119854E; Martovce. línia 1 – 47.848426N, 18.117697E; Čiližská Radvaň. KL1 – 47.84158N, 17.718818E; Veľké Kosihy. KL1 – 47.769274N, 17.859935E; Čiližská Radvaň. KL3 – 47.84158N, 17.718818E; Veľké Kosihy. KL1 – 47.769274N 17.859935E; Bodíky. Kráľovská lúka. B – 47.90317N, 17.489167E; Marcelová. Šérke – 47.757837N 18.284883; Martovce. Hliník – 47.839973N, 18.08103E; Marcelová. Pohrebisko – 47.77517N, 18.283306E; Išpánoš – 47.840006N, 17.576885E; Erčed – 47.828535N, 17.589722E.

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Nest site location and breeding success of Common kingfisher (*Alcedo atthis*) in the Danube river system

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Abstract

Turčoková, L., Melišková, M., Balážová, M., 2016 Nest site location and breeding success of Common kingfisher (*Alcedo atthis*) in the Danube river system. *Folia Oecologica*, 43: 74–82.

Common kingfisher, *Alcedo atthis* is a fish-eating species that preferentially breeds alongside natural watercourses or smaller water bodies. During the seasons 2012, 2014 and 2015, we monitored the density of kingfisher population, nest site location and its breeding success in the Danube river system from Bratislava to Gabčíkovo (Slovakia). Population density was estimated on 23–27 pairs/55 km of the length of river branches. Average distance between nesting holes occupied by different breeding pairs was 816 m ± 421 SD. Kingfishers used river banks and wind throws to dig a burrow. The nest site location, but not nest parameters, was affected by the maximal height of the suitable area of the wall. As wind throws had larger suitable area, the location of nests in wind throws differed from the location in riverbanks. Breeding attempts were successful in 86% cases. The reason of unsuccessful breeding was mainly predation. Almost 72% of pairs bred two times per season, 17.9% of pairs three times and 10.7% of pairs four times per season. The most successful were the second and the third breeding attempts. Breeding pairs produced on average 6.43 young per successful breeding and 14.95 young per season. In total, 58% of pairs alternated breeding attempts. The rest of pairs overlapped attempts using different holes. Average distance between the holes concurrently used by a pair was 113.73 m (min = 0.3 m; max = 372 m). Neither this parameter nor the date of the first egg-lying in previous attempt affected the duration of the overlapping.

Keywords

breeding success, burrow-nesting birds, nest site location, population density

Introduction

Kingfisher uses for breeding uncovered banks. They are created either naturally (e.g., meandering of the river, falling of the tree) or by anthropogenic activity (e.g., mining or dam construction causing subsequent erosion of the banks) (Morgan and Glue, 1977; Cramp, 1990; Hudec and Šťastný, 2005; Čech, 2007). In general, the soil composition is very important for the nest site selection of the burrowing birds (Heneberg, 2004, 2009, 2013). Banks along the streams must be soft enough to be excavated but secure enough to avoid the collapse of the bank (Heneberg, 2013). Nest site position within a bank "wall" is usually a compromise between the predation risk and the risk of flood (Straka and Grim, 2007; Čech, 2007, 2013). Except for the nest location, the other way how to avoid flooding is to create a tunnel inclining slightly upward to prevent water from running down to the nest chamber (Hudec and Šťastný, 2005). Birds select nest sites very cautiously, because they use

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the same nest hole for consecutive clutches. Many pairs use two or three nesting holes for successive breeding attempts within a season and between years (Cramp, 1990; Čech, 2009).

Kingfishers live solitarily outside the breeding season. During the breeding season part of the population is socially monogamous, but polygamic/polyandric pairs have been observed in up to 35% cases (Cramp, 1990; del Hoyo et al., 2001; Čech, 2009). Changing of the territory or a mate during the season is not uncommon. Birds are successful in 54–80% of breeding attempts (Cramp 1990; del Hoyo et al., 2001). In general, nests of burrowing birds, kingfishers included, suffer mainly from predation (Sieber, 1980; Cramp, 1990; Heneberg, 2005). Pairs have two or three breedings in a season (Fry et al., 1999; Kucharski, 2001; Hudec and Šťastný, 2005), rarely four attempts have been documented (Cramp, 1990; Novotny, 1994; Čech, 2006, 2010). The breeding attempts of one pair may alter or overlap. When a pair overlaps two breeding attempts, male broods and feeds hatchlings while female lays and incubates another clutch in a different burrow (Cramp, 1990). There is no information about factors, which can cause the altering/overlapping strategy or the length of altering/overlapping.

In our study, we focused on following topics: 1) Does maximal height of the suitable uncovered “wall” affect a location of a nest within a bank? As predation risk and possibility of flood mainly affect breeding, we can expect that in larger suitable areas birds will dig burrows in positions – far from the top to reduce possibility of predation and far from the bottom to reduce possibility of flooding; 2) Are the first breeding attempts more successful than the later ones? As in many bird species is the first clutch larger than the second one, depending on parents condition and available food resources, we expect the higher success of the first attempts; 3) Does distance between simultaneously used holes affect a length of overlapping between breeding attempts? As the flight between long distance holes takes time and energy needed for parental care, we can expect that a longer distance between the holes will cause shorter time of overlapping; 4) Does the date of laying the first egg in previous attempts affect a length of altering/overlapping between breeding attempts? A later date of the first egg laying can press the breeders to shorten the time of altering and elongate the time of overlapping between breeding attempts and hereby shorten the time of breeding period to finish it in time.

Material and methods

Data collection

Altogether we documented 74 breeding attempts of 35 pairs of kingfishers. Field work was carried out from April to September in the seasons 2012, 2014 and 2015 in the Danube river system from Bratislava to Gabčíkovo (Fig. 1). This area is a part of Protected Landscape Area Dunajské luhy in the south-western Slovakia. At the beginning of the breeding season we searched for new nesting holes and observed the gradual occupation of the old ones. When we had found an occupied burrow, consecutively we took measurements of its basic parameters - the width and the height of the entrance opening, tunnel depth, distance of the hole to the bank top and to the bottom, maximal height of the suitable area of the bank or wind throw. To each nesting hole we assigned GPS coordinates which were consecutively transmitted to Google Earth software to measure distances among individual nesting holes used by different breeding pairs. Breeding density was calculated as the number of breeding pairs estimated to the sum of the length of controlled river branches. We checked the burrows using a special inspection camera. When we had found fresh eggs or incubating female inside the hole, we started to control a breeding attempt in periodical intervals of seven days. If we found uncompleted clutch, we were able to estimate the date of laying the first egg, taking that laying interval in kingfisher females is one day (Cramp, 1990). In cases when we found full clutch, we estimated the date of laying the first egg according to the hatching date, as it is known that the incubation period usually takes 21 days (Cramp, 1990). In several cases, when we missed the hatching, we estimated the date of laying the first egg from the hatchling’s appearance (Čech, 2009). Several days after the young hatched, we captured parents, determined their sex and age and ringed them. Fledglings were ringed in the age of minimum 15 days. We consider a nest to be successful, when fledglings reached age up to 20 days. In this age they are fully plumaged and able to leave the nest (Čech, 2009). We continued to control the nest holes after the chicks ringing, because of the possibility of another breeding attempt. Parents of successful nests stayed near to the nest hole and continued in consecutive breeding process either in the same hole, or in another hole, close to the first one. For unsuccessful attempts we consider the nests destroyed by flood, wall slide and predation. In cases of predation we found excavated nesting chambers and destroyed burrows. We finished the field work in September when the last fledglings left the nests.

Statistical analyses

Measurements of nest holes and their location were collected during the season 2012, 2014 and 2015. Breeding data used in analyses were collected in the seasons 2014 and 2015. To differentiate between riverbanks and wind throws in the hole’s measurements and nest’s location we used the Canonical Correspondent Analysis (CCA). From twelve variables used in the analysis, six

Fig. 1. Map of study area. Danube river system between Bratislava and Gabčíkovo.

variables participated on 100 % variability (Table 1). Two variables which have been considered to have biologically significant relationship, were consecutively analysed using ANOVA test. The correlation between the height of a suitable "wall" size and nest location was tested by Pearson's correlation test. Breeding success (number of fledglings) was estimated only for successful nests. Single breeding attempt´s success was compared by Kruskal-Wallis test. The effects of the first egg laying date of the previous attempt and the distance between simultaneously used holes on the length of alternating/overlapping were tested by univariate linear regressions. All analyses have been done in SPSS Statistics software ver. 16 (SPSS Inc, 2007) and STATISTICA 8 (Statsoft Inc, 2013).

Table 1. Canonical loadings (i.e. correlations) for the wind throw/riverbank nest holes of the Kingfisher. Traits with correlations that are greater than or equal to an absolute value of 0.4 are considered to have biologically significant relationships (in boldface; McGarigal et al., 2000).

Trait	Axis 1
Maximal height of the wall	**0.67**
Maximal width of the wall	-0.08
Tunnel depth	-0.21
Height of the wall in nest location	**0.57**
Width of the wall in nest location	0.11
Water level	0.19
Eigenvalue	1.50
Cumulative % of total variance explained	1.00

Results

Density of studied population was estimated on 23–27 breeding pairs/55 km length of river branches. Distance between the breeding holes of different pairs measured during the first breeding attempt was 816 m ± 421 SD ($n = 34$, min = 24 m, max = 1,700 m). One nest wall was occupied by a single breeding pair. We have never observed two different pairs occupying the same nest wall.

Nesting sites and holes

Kingfishers preferentially used nest holes made in riverbanks or in wind throws. The average parameters of used holes are presented in the Table 2. Traits considered to have biologically significant relationship, differentiating nest location between riverbanks and wind throws, are the maximal height of the wall and the height of the wall in the nest location (CCA, Table 1). The wind throws were higher than river banks, the maximal height of the wall was significantly higher in wind throws ($F_{1,47} = 30.139$, $P < 0.001$), as well as the height of the wall in the nest location was significantly higher in wind throw ($F_{1,50} = 27.817$, $P < 0.001$; Fig. 2). Moreover, we found differences in the location of the nesting hole as the distance of the hole to the bank top was larger in wind throws ($F_{1,51} = 14.761$, $P < 0.001$) as well as the distance of the hole to the bottom ($F_{1,51} = 17.714$, $p < 0.001$; Fig. 3). According to the results from CCA these traits were not considered as significant variables differentiating holes in riverbanks and wind throws. Probably, it was caused by the large overlapping of these parameters between riverbanks and wind throws. Consecutively, we found significant positive correlation between the maximal height of the wall and the distance of the hole to the bank top (r = 0.63, *P* < 0.001, n = 49, Fig. 4a) as well as the distance of the hole to the bottom (r = 0.74, *P* < 0.001, n = 52, Fig. 4b). These results show effect of suitable wall size on the nest hole location. Individual parameters of a nest hole were not affected by a suitable wall size.

Table 2. Nest hole's parameters of the Kingfishers in riverbanks and wind throws

	All nests					Windthrow		Riverbank	
	n	Mean	Min	Max	SD	Mean	SD	Mean	SD
Height of the entrance opening	51	7.6	5.3	13.0	1.39	7.7	1.44	7.5	1.31
Width of the entrance opening	51	6.2	4.5	12.0	1.36	6.1	1.38	6.4	1.35
Tunnel depth	44	55.0	24.5	85.0	12.08	52.3	11.97	58.5	11.60
Distance of the hole to the bank top	53	69.6	20.0	270.0	43.25	85.4	45.86	43.6	20.70
Distance of the hole to the bottom	53	141.0	52.0	313.0	53.40	161.9	49.44	106.5	40.94
Distance between hole and left edge	53	116.6	16.0	427.0	81.47	134.6	93.38	86.9	44.59
Distance between hole and right edge	53	125.4	22.0	487.0	98.07	121.2	97.72	132.5	100.76
Height of the wall in nest location	52	192.7	75.0	410.0	79.37	228.3	75.10	130.7	37.97
Width of the wall in nest location	53	241.5	68.0	567.0	129.68	254.9	134.54	219.4	121.28
Maximal height of the wall	49	206.0	75.0	422.0	87.65	251.0	83.30	140.7	39.98
Maximal width of the wall	48	300.8	90.0	600.0	128.08	292.3	119.66	313.6	142.38
Water level	53	24.9	0.0	120.0	26.05	28.5	27.91	19.0	22.04

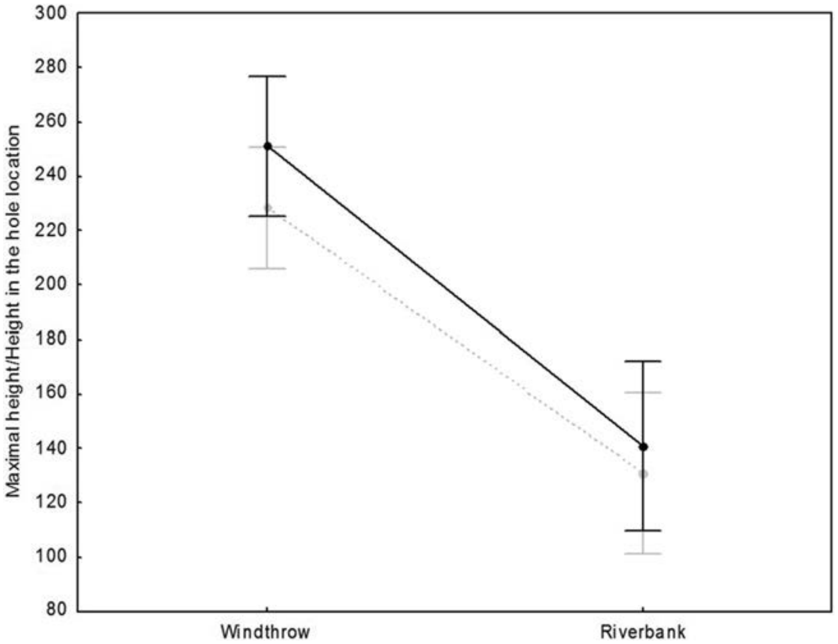

Fig. 2. Differences in maximal height of the suitable wall and the height of the wall in the nest location (cm) between banks and wind throws. Dots denote means, vertical bars denote 95% confidence intervals. Black line shows maximal height of the wall, dashed line shows height of the wall in the nest location.

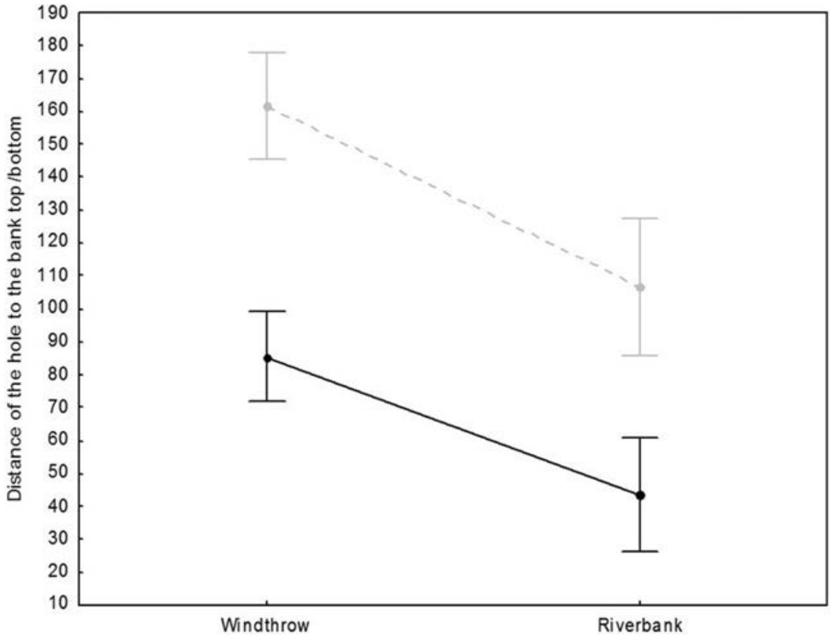

Fig. 3. Differences in nest hole location in riverbanks and wind throws. Dots denote means, vertical bars denote 95% confidence intervals. Black line shows distance of the hole to the bank top, dashed line shows distance of the hole to the bottom.

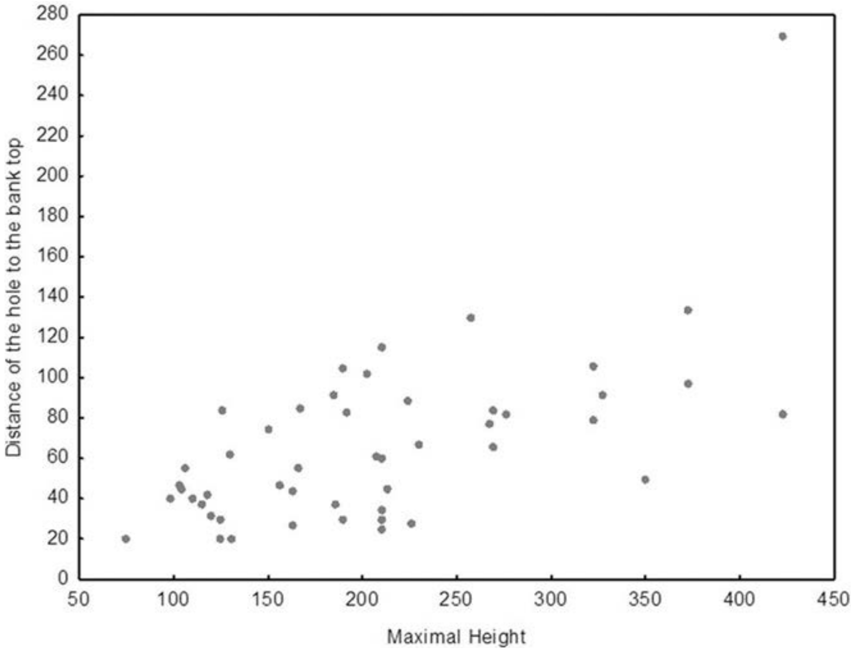

Fig. 4a. Positive correlation between maximal height of the wall and distance of the hole to the bank top.

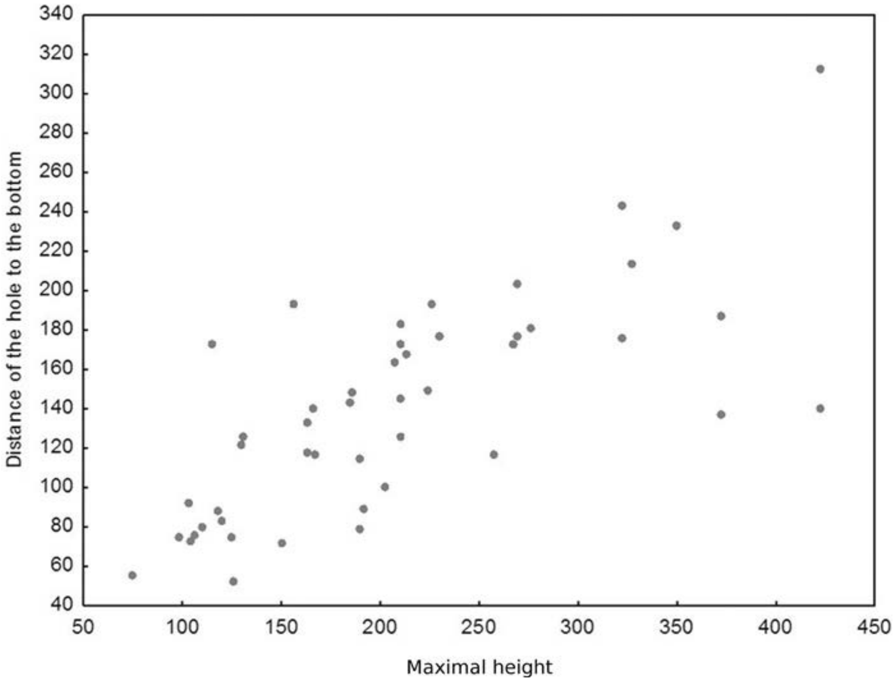

Fig. 4b. Positive correlation between maximal height of the wall and distance of the hole to the bottom.

Breeding biology

Breeding success of kingfishers in the Danube branches reached 86% (n = 64). The reason of unsuccessful breeding was mainly predation (five cases of documented nest losses), bank slide (one case), disintegration of a wind throw (one case), flooding the nest hole (one case), and abandonment of the clutch (one case). In one case the reason was unknown. Majority of breeding pairs (23 pairs) bred two times per season. Three breeding attempts were recorded in seven pairs. Three pairs were observed to breed four times. Breeding success of individual breeding attempts was different (Kruskal-Wallis Test χ^2 = 11.407, P = 0.010). The largest number of fledglings was produced in the second and the third attempts, while the least successful was the fourth one (Fig. 5). Breeding success of one pair was on average 6.43 ± 0.88 SD young per nest (breeding attempts: n = 64, min = 3, max = 8) and altogether 14.95 ± 4.85 SD young per season (breeding pairs: n = 19, min = 6, max = 26).

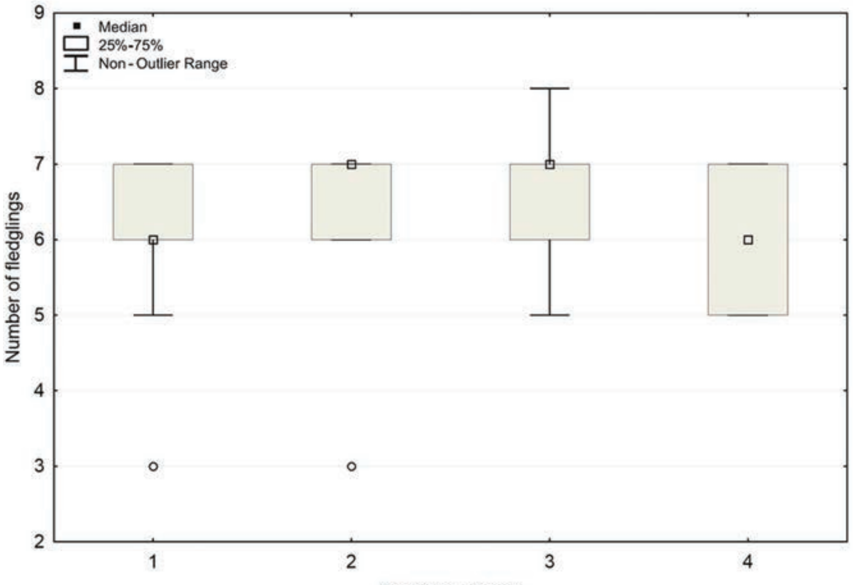

Fig. 5. Number of fledglings produced in different breeding attempts.

Kingfishers used two different breeding strategies: 58% of pairs altered and 42% overlapped the consecutive breeding attempts. The former started another breeding after finishing the previous one, with a pause between breeding attempts of 11.85 days ± 5.91 SD (n = 13, min = 5, max = 22). In the latter, the male fed the young in one hole, while female concurrently /laid/ or incubated another clutch in a different hole. The length of overlapping was 12.56 days ± 5.56 SD (n = 32, min = 5, max = 23). Birds used two different holes simultaneously when overlapping. Seven pairs used nest holes being far from the previous nest, at a different nest wall (min = 31 m, max = 372 m). Five pairs used nest holes within the same nest wall (min = 0.3 m, max = 43 m). Distance between the simultaneously used holes was not correlated with the length of overlapping (linear regression: $r^2 = 0.173$, F = 1.671, $P = 0.232$, n = 9). The date of laying the first egg in the previous attempt also did not affect neither the length of the pause when the birds were altering (linear regression: $r^2 = 0.00$, F = 0.02, $P = 0.965$, n = 12) nor the length of overlapping (linear regression: $r^2 = 0.168$, F = 3.0376, $P = 0.102$, n = 16).

Discussion

Nesting sites

Parameters of our kingfisher's holes are very similar to the parameters recorded from other populations mainly in the Czech Republic (Heneberg, 2004; Hudec and Šťastný, 2005; Straka and Grim, 2007). Our results showed that the maximal height of a suitable wall area affects the nest location, but not its parameters. Birds avoid being in vicinity to the bank top as well as to the bottom and try to dig holes in the middle of the wall. Birds nest higher from the water level to avoid flooding of the nest or predation by predators which scratch up tunnel through the entrance opening, as rat, weasel, marten or otter (Čech, 2007). On the other hand, nesting holes localised under the bank top could be dug out through nest chamber by predators such as Red fox (Cramp, 1990; Heneberg, 2005; Čech, 2007). We observed both cases, excavation from the entrance opening even from the top of the bank. Predation was the factor that affects the most nests losses. In spite of it, breeding attempts were successful in 86% of cases. It is known that lower predation risk enables birds to have larger clutch size and high breeding efficiency (Martin, 2004). In the case of kingfisher, high survival probability of chicks at the beginning of their life is reduced by the high death rate during the first winter (Morgan and Glue, 1977; del Hoyo et al., 2001).

Long breeding season (from March to September) allows for more breeding attempts of one pair. We documented up-to four breeding attempts of pair per season. Our results are consistent with the observations of the Czech population (Čech, 2009, 2010), but different from Polish, where there have never been recorded four breeding attempts of one pair. It was argued by shorter breeding season (Kucharski and Čech, 2009). Overall breeding success of our birds was established on average 6.43 young per nest and 14.95 young per season. When comparing with populations of kingfishers in other European countries where reproduction success was estimated from 5.19 to 5.63 young per nest (Morgan and Glue, 1977; Cramp, 1990; Hudec and Šťastný, 2005; Čech, 2009, 2010), we can state that Slovak kingfishers have a little higher reproduction success. We assume that a long breeding season could be caused by the rich choice of food in the Danube river system as it is known that food availability may limit breeding and affect clutch size (Lack, 1947; Ricklef, 2000). When kingfishers lay three or four clutches each containing of six or seven eggs, they can produce up to 26 young's per season (21% breeding pairs produced from 20 to 26 fledglings, own. obs.). It was documented that parents feed their chicks by fish of specific size (from 4 to 7 cm) (Campos et al., 2000; Isotti and Consiglio, 2002; Čech and Čech, 2007; Vilches et al., 2012) and every day deliver 62.6 ± 0.2 (SE) pieces of fish prey to a nest (Vilches et al., 2013). For both parents it is necessary to be in top condition to be able to hunt for such amount of fish. We assume that food availability determines the length of the breeding season and together with the parents' condition they are the key factors that determine the number of breeding attempts and consecutively overall breeding success. Such enormous effort of parents has its costs in the fact of worsening of the body condition and a lower probability of survival. It is well known that birds underlie trade-off between reproduction and survival (Stearns, 1992). Many breeding attempts and the production of many offspring shorten their lifetime as it was recorded in the Czech and British population (Morgan and Glue, 1977; Čech, 2009).

Kingfishers can breed three or four times in a given season due to a special strategy of overlapping two breeding attempts. Overlapping has been observed in other populations in different amount of cases (Cramp, 1990; Hudec and Šťastný, 2005; Kucharski and Čech, 2009). We recorded that 42% of breeding pairs used this strategy. Birds used two different holes for overlapped breeding. Long distance flight between two concurrently used holes could take time and energy that birds should use to parental care. On the basis of that assumption we expected that shorter distance enables longer overlapping period, but we did not confirm it. Other factor, such as the first egg laying date of the previous attempt, could influence the length of altering or overlapping. We expected that later date could press birds to elongate overlapping/shorten altering to manage the finishing the breeding process in time. In both cases we found no correlations, which can be explained by a low number of cases included in our analyses.

Conclusions

Finally, we can state that kingfishers from the Danube nest in riverbanks and wind throws. The maximum height of a suitable wall affects the nest location, however, not burrow parameters. Breeding success was observed in 86% of attempts. The main cause of unsuccessful breeding was predation. Pairs perform two, three or four breeding attempts, which they can alter or overlap. Many breeding attempts enable them to gain high breeding success.

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Short communication

The occurrence of Pannonian root vole (*Microtus oeconomus mehelyi*) in small mammals' communities in Danubian Plain

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Abstract

Ambros, M., Baláž, I., Klimant, P., Tulis, F., Dudich, A., Stollmann, A., Somogyi, B., Horváth, G., 2016. The occurrence of Pannonian root vole (*Microtus oeconomus mehelyi*) in small mammals' communities in Danubian Plain. *Folia Oecologica*, 43: 83–88.

Two orographic units, Podunajská rovina (Danubian Plain) and Hronská pahorkatina Highlands represent the border of Pannonian root vole's central European population distribution area, where it colonises wet habitats. Communities of small mammals, especially the occurrence of Root vole, were investigated during the period 1981–2015 along the rivers Danube, Váh, Nitra, Žitava and Ipeľ. We investigated 146 sites and the occurrence of Root vole was confirmed in 39 localities (177 ind.), where it occurred together with other 18 small mammal species (1610 ind.). Root vole, Bank vole and the Common shrew were eudominant species in these communities. The character of recent Root vole population in these areas is not well studied. The isolation of habitats, recent knowledge about dynamics of its demography or possibilities and abilities for migration, indicate a prospect of metapopulation structure of this population. The answers to these questions will provide fundamental consequences for modifying or changing the conservation management strategy of this species.

Keywords

community, habitats, rodents, Slovakia, small mammals

Introduction

One of the rare and endangered species of the mammal fauna in Slovakia is the Pannonian root vole, *Microtus oeconomus mehelyi*. This glacial relict subspecies occurs only in the southern part of Slovakia on the Pannonian Lowland (Danubian Plain). Besides Slovakia, this rare subspecies occurs locally in Northern Austria and in some isolated localities in Hungary (Miklós et al., 2014). In Slovakia, *M. oeconomus mehelyi* inhabits habitats created by the activity of rivers, such as meander, blind stream branch and secondarily, river-basins (side streams – bifurcations), which are currently isolated in agricultural areas and in different phases of succession

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of semi-natural vegetation. The distribution of Pannonian root vole in the territory of Slovakia is characterised by the change of the landscape and its natural conditions in the postglacial age. The population was negatively influenced by the change of post-neolitic land use activity which formed agricultural steppe and reduced the suitable natural and semi-natural habitats for species. The currently proceeding fragmentation process of species distribution is caused by reduction and loss of habitats. Decline in food offer have negative effects on the survival of local populations. The agricultural landscape of the southern part of Slovakia has undergone significant changes over the past 150–200 years, especially since the 1950s. These are for example, interventions in the hydrological mode of landscape, land consolidation, functional changes of particular landscape units, spreading of alien species, mechanisation and application of chemistry. These changes and processes had a negative impact on the biodiversity of agricultural landscapes and numerous species have become rare or completely extinct. However, new approach in evaluation of the structure and functions of agricultural landscape may help to solve these problems (Izakovičová et al., 2008).

The results of the mapping of the occurrence and the distribution of the Pannonian root vole before 2010 have been presented in a number of studies. The first indication of the presence of this species from the studied region is stated by Binder and Štollmann (1975). Other information from the territory among the rivers Váh, Nitra, Žitava, Hron, Ipeľ are stated by Ambros (2010a, b, 2011, 2013), Ambros et al.(1999a, b, 2001, 2003, 2005), Baláž et al. (2003), Bridišová et al. (2006), Gubányi et al. (2009), Jančová et al. (2008), Krištofík and Stollmann (2012). The eastern boundary of the species distribution in Slovakia is currently defined by the locality Parížske močiare – swamps near the village Gbelce (Ambros et al., 1999b, 2005; Ambros and Baláž, 2002).

In this short communication, we summarize new, as yet unpublished data on the occurrence of Pannonian root vole in Slovakia. Based on knowledge of metapopulation ecology, we present different perspective on the function of the recent population of Pannonian root vole in the investigated part of its range of distribution, so we can provide the proper management and long-term conservation of the Slovakian population or subpopulation of this subspecies. We complete and specify information about the position of this species in small mammals' communities.

Material and methods

The study area represents the eastern part of the distribution range of Pannonian root vole in Slovakia. It consists of basins of five rivers that flow down in the direction north–south from the slopes of the Western Carpathians to the Danube: Váh, Nitra, Žitava, Hron, and Ipeľ. The studied area is delimited by the flow of river Váh from the west and by the flow of the Danube from the south. The eastern border of the studied area is formed by the river Ipeľ. The northern boundary goes in the direction east–west on the level city Nové Zámky. In the past, extensive flood-protection interventions were realised in the river channel of these rivers, which changed the direction and hydrodynamics of their flows. It had an impact on the hydrological regime in the land and, consequently, to natural conditions. In parallel with these activities, continued the construction of the system of channel network with the function of irrigation as well as the aridification of agrocenoses of surrounding area. The natural dynamic processes of the flows, their subsequent modification, water channel system and the gradual change in the functions of grasslands (meadows) in favour of agricultural cultures created the conditions for the emergence of habitats which represent preferred habitats for the Pannonian root vole. The identification of localities, where the Pannonian root vole occurs, was carried out in the defined sampling area during 1981, 1990, 1999–2006 and 2010–2015. Small mammals were trapped with snap traps arranged in line transect (50 pcs) with a two-day exposition in the field.

Results and discussion

The presence of Pannonian root vole was detected in 39 of the 146 investigated sampling plots, in total in 18 sites (Fig. 1, Appendix 1). From 2010 to 2015 we have confirmed the occurrence of other local populations of the root vole in the area between the Váh and channel of Stará Nitra and in the other localities that are remnants of meanders, blind streams or secondary distributaries of nowadays non-existing continuous flow of the river Žitava.

The recent habitats of Pannonian Root Vole represent places that are: (1) units of natural hydrodynamic processes of rivers (2) accessory products of river system modification of Váh, Nitra, Žitava, Hron and Ipeľ rivers or (3) the rest of previous primary grasslands of partially preserved original grasslands (flooded meadows and pastures) situated between rivers. Nowadays the occurrence of Pannonian root vole in underflooding meadows and pastures with ruderal association is considered to be unique, rare and suboptimal for the species (Miklós et al., 2011). The creation and variety of these elements of the river system is closely linked to the dynamics and physical characteristics of the considered Carpathian Rivers' flow before they flow into the Danube. A slowdown in the rate of flow at a given volume of water, morphology and elevation of terrain of this part accelerates the sedimentation of materials.

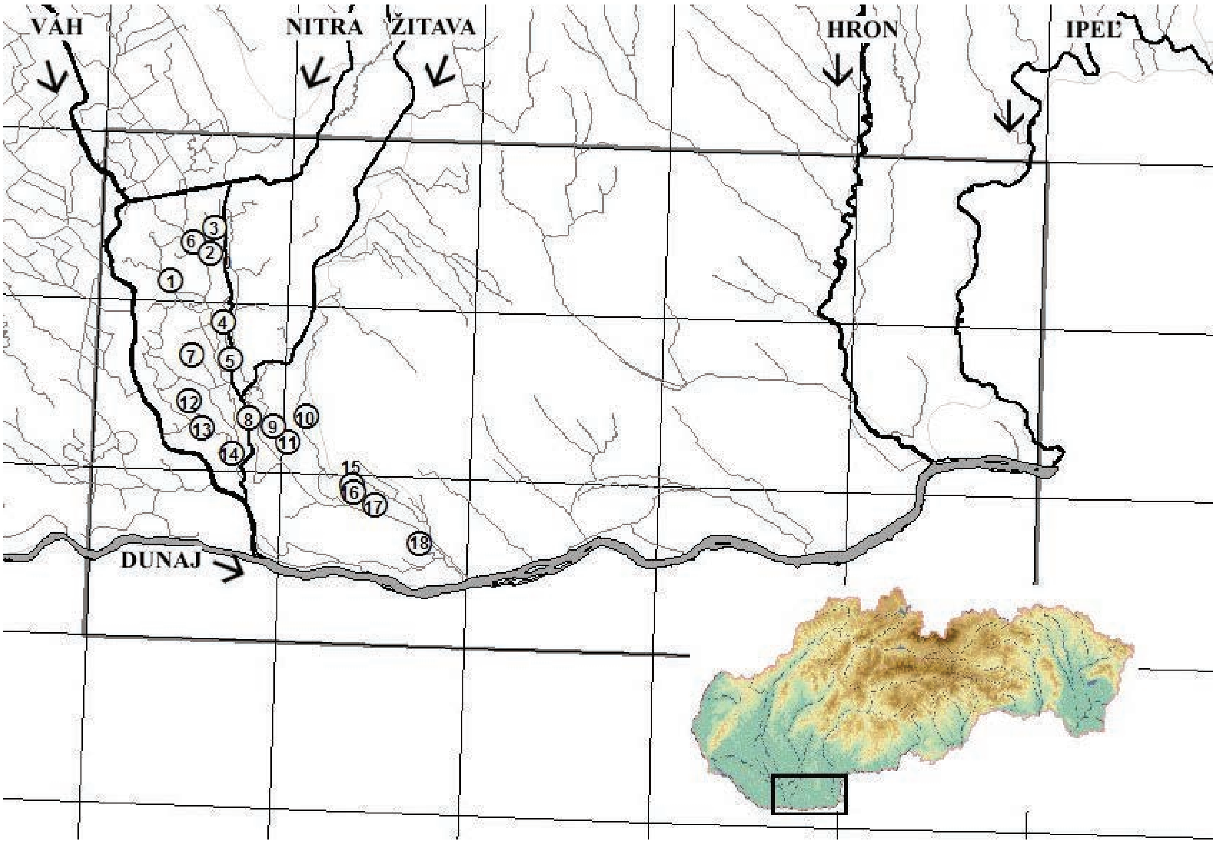

Fig.1. Map of the sites (details see in Appendix 1) with occurrence of the Pannonian root vole in the catchments areas of lower flows of Carpathians rivers (Váh, Nitra, Žitava, Hron, Ipeľ) after 2010.

This is reflected in the relatively fast alternation of the formation and termination of meanders and side arms in this area. After the modification (channel straightening) of the main flows of these Carpathian Rivers, some branches were completely or partially cut off the supply of water, with the subsequent infilling and succession. In addition to aridification, also intensive meliorative modifications occurred, in the form of a dense network of drainage channels. Water management constructions (if they are currently working) on the one hand, drain the wetlands, on the other hand, they are the source of at least the minimum amount of water that keeps and stabilises the habitats suitable for the surviving of the species.

Our results showed that small mammal community in the investigated areas with Pannonian root vole consists of 18 species of small mammals (insectivores and rodents). In the vast majority of samples the eudominant species were Bank vole *Clethrionomys glareolus*, Common shrew *Sorex araneus* and Root vole *Microtus oeconomus*. Dominant constituent of these assemblages were Pygmy field mouse *Apodemus microps*, Wood mouse *Apodemus sylvaticus*, Harvest mouse *Micromys minutus* and Striped field mouse *Apodemus agrarius*. The subdominant species include Common vole *Microtus arvalis*, Yellow-necked mouse *Apodemus flavicollis*, Pygmy shrew *Sorex minutus*, Miller's water shrew *Neomys anomalus*, Common pine vole *Microtus subterraneus*, Eastern house mouse *Mus musculus*, Steppe mouse *Mus spicilegus*, Bi-coloured white-toothed shrew *Crocidura leucodon*, Lesser white-toothed shrew *Crocidura suaveolens*, Water shrew *Neomys fodiens* and Water vole *Arvicola amphibius*.

We assume that in the past (at least at the end of the 18th century) the root vole population expanded in natural conditions among Váh–Nitra–Žitava–Hron–Ipeľ rivers in a spatially continuous way. We can support this assumption with only relatively insufficient information from the comparison and evaluation of historical sources (1st and 2nd Military Mapping Survey of the Habsburg Empire) with our knowledge. Based on our knowledge, the distribution of populations or subpopulations of this species increase in the remaining original wetlands habitats, and it determined by the connectivity between remaining habitats what provides the dispersal of the individuals between the given subpopulations. Some indirect evidence, such as the recent osteological records from owl pellets (Šilhár, 1975; Noga and Obuch, 2003) suggest that the species may still live in an enclosed area in the investigated distribution range. The survival of local populations in the fragmented regions depends on the migration ability of the species between particular fragments with different topic and trophic propositions and so to maintain the gene pool among the subpopulation (Andrén, 1994). The population of Pannonian root vole in the area between Váh, Nitra, Žitava, and Hron rivers was characterized by the local subpopulations with its own structure and dynamics, which together form a metapopulation structure. In this case, it is necessary to investigate and evaluate the dynamic of the subpopulations and role of connectivity of refugial habitats as well as plan appropriate conservation management based on metapopulation ecology approach.

The typical landscape cover of the studied area with a dense network of linear units (water channels) offers the premise that they also function as random and temporally non-determined migration routes. In the case of fragmented environment, there is a network of these real and presumptive migration corridors in the studied area, formed also by the rest of underflooding meadows, pastures, and meanders at different stages of vegetation succession. Their function as migration corridor is highly variable and unstable and depends on several factors, such as the course of weather in a given season, the technical status of water construction works and implementation of land consolidation. Part of this network of migration routes may be in a latent stage and the "migration gates" can open just after suitable (e.g. climatic) conditions activated, for colonisation of suitable habitats. It happened in 2009, when after an unusual rainy spring season, landscape depressions and unfilled riverbeds of non-existing watercourses were filled with water and in the following years they temporarily created the appropriate topic conditions for migration.

In conclusion, it is necessary to point out some of the facts related to the local root vole population in the current landscape structure in the catchment areas of the studied Carpathian Rivers. Generally, the isolation of small populations leads to their gradual extinction. The partial isolation of some species may be the reason for their successful survival. If the environment is fragmented over a long period, the organisms that colonise it are adapted to the fragmentation of habitats or they are dependent on it (Storch, 2000). The characteristics of the fragmented environment are augmented by the proportion of border structures that causes further changes in biotic as well as abiotic conditions of fragmented patches. This phenomenon, also known as the edge effect, has a dynamic nature depending on the productivity of the ecosystem, landscape, and natural sites of particular region, such as the state of the shrubs and trees, the stage or density of vegetation cover (Paton 1994; Donovan et al., 1997). The successful survival of the populations of Pannonian root vole in the particular region thus depends on the dynamics of the development, quantitative and structural changes and properties of local subpopulation and on the success of the migration of individuals between them.

The protection and conservation of the populations of the Pannonian root vole between Váh–Ipeľ Rivers are currently ensured by law with a system of protected areas of different categories and different degrees of protection. From the previous parts follows that the systematic protection of root vole is not only based on the protection of the areas in which the population of species occurs in real time. It is necessary to consider also those areas that are the vole's potential topic, trophic and migratory habitats.

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Appendix 1. Site name – as it was named according to the collector or as it was quoted in literature, Code of basic map unit of the Databank of Slovak Fauna (DFS), site coordinates in coordinate system (WGS84 format), municipality cadastre (m.c.), date (day, month and year) of collecting, number of trapped individuals of *Microtus oeconomus mehelyi* (ind. MOE) and name of the collector (coll.).

1. Hantovský channel, DFS 8074, longitude (lon.): 18.061124; latitude (lat.): 47.911893, m.c. Nesvady, 12 May 2011, 1 ind. MOE, coll.: Ambros; 2. Malá Aňala, channel, DFS 8074, lon.: 18.095607; lat.: 47.928989, m.c. Nesvady, 6–7 October 2011, 4 ind. MOE, coll.: Stollmann; 3. Stará Guta, DFS 8074, lon.: 18.098418; lat.: 47.943811, m.c. Nesvady, 7 October 2011, 1 ind. MOE, coll.: Ambros; 4. channel Ďotva, DFS 8174, lon.: 18.109175; lat.: 47.887785, m.c. Imeľ, 17 June 2011, 1 ind. MOE, coll.: Ambros, Stollmann; 5. Detvické meadows, DFS 8174, lon.: 18.116362; lat.: 47.866270, m.c. Martovce, 29 April 2011, 3 ind. MOE, coll.: Ambros, Stollmann; 6. Martovský channel, reed 1.5 km north west of the village, DFS 8174, lon.: 18.106083; lat.: 47.867450, m.c. Martovce, 12 May 2011, 2 ind. MOE, coll.: Ambros; 7. channel Tátoš, DFS 8174, lon.: 18.082606; lat.: 47.867503, m.c. Martovce, 16 June 2011, 4 ind. MOE, coll.: Ambros, Stollmann; 8. Katica Szög, DFS 8174, lon.: 18.134639; lat.: 47.831307, m.c. Hurbanovo, 13 September 2011, 3 ind. MOE, coll.: Ambros; 9. Horný Komočín, DFS 8174, lon.: 18.157092; lat.: 47.827449, m.c. Hurbanovo, 16 August 2012, 28 August 2012, 17 ind. MOE, coll.: Ambros; 10. Hurbanovo, Konkoly, DFS 8175, lon.: 18.186060; lat.: 47.833929, m.c. Hurbanovo 16 August 2012, 4 ind. MOE, coll.: Ambros, Dudich, Stollmann; 11. Dolný Komočín, DFS 8175, lon.: 18.169900; lat.: 47.818393, m.c. Svätý Peter, 16 August 2012, 2 ind. MOE, coll.: Ambros, Stollmann, Dudich; 12. Hliník, Hlinický channel, DFS 8174, lon.: 18.081791; lat.: 47.840147, m.c. Vrbová nad Váhom, 12 July 2011, 23 April 2013, 13 October 2013, 9 ind. MOE, Ambros, Horváth; 13. Kava, Vrbovský channel 1, DFS 8174, lon.: 18.094195; lat.: 47.824523, m.c. Komárno, 12–13 July 2011, 2 ind. MOE, coll.: Ambros; 14. Landor, channel, DFS 8174, lon.: 18.120599; lat.: 47.810330, m.c. Komárno, 13 July 2011, 1 ind. MOE, coll.: Ambros; 15. Fialkový channel 1, DFS 8275, lon.: 18.228527; lat.: 47.794099, m.c. Chotín, 15 April 2012, 28–29 October 2014, 15–17 April 2015, 28–30 July 2015, 16–19 October 2015, 8 ind. MOE, coll.: Ambros, Baláž, Horváth, Klimant, Somogyi, Tulis; 16. Fialkový channel 2, DFS 8275, lon.: 18.229163; lat.: 47.789662, m.c. Chotín, 15 April 2012, 28–29 October 2014, 15–17 April 2015, 28–30 July 2015, 16–19 October 2015, 8 ind. MOE, coll.: Ambros, Baláž, Horváth, Klimant, Somogyi, Tulis; 17. Želiarske field, DFS 8275, lon.: 18.248764; lat.: 47.782723, m.c. Krátke Kesy, 28–29 October 2014, 15–17 April 2015, 28–30 July .2015, 16–19 October 2015, 17 ind. MOE, coll.: Ambros, Baláž, Horvath, Klimant, Somogyi, Tulis; 18. Lieskovský channel, DFS 8275, lon.: 18.289806; lat.: 47.760844, m.c. Marcelová, 28–29 October 2014, 15–17 April 2015, 28–30 July 2015, 16–19 October 2015, 11 ind. MOE, coll.: Ambros, Baláž, Horváth, Klimant, Somogyi, Tulis.

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Short communication

The activity of bats in the Badínsky prales primeval forest

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Abstract

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Primeval forests with their large heterogeneity with regard to composition of tree species, age of trees or canopy coverage are excellent locations for studying various animals, especially bats. In Slovakia, where primeval forests comprise just 0.48% of total forest area any coherent knowledge about basic composition of bat species is lacking. To contribute to knowledge about the occurrence of bat species in Slovakia's natural (primeval or old grown) forests, this study presents a first summary overview of bat species composition with regard to vertical utilization of their foraging habitat. We collected data in the Western Carpathian (Kremnické vrchy Mts) in old-grown primeval beech forest (>200 years) using the passive automatic bat-detector. The device was set up to the tree trunk in 5, 10 and 15 meters above the ground. Altogether was recorded 72 minutes (n = 22,544 bat calls, 311 records in average per night). The total of 10 bat species was determined. The number of recording varied according to height. Number of *Myotis*-group calls did significantly differ in individual recording heights but only between 5 and 15 meters, however such differences were absent in the case of non-*Myotis* group calls, as well as in both types' calls merged together. Calls of *Myotis*-group were the most abundant whereas they represented 96.5% from all determined calls at 5 m above ground, but only 22.7% at height of 15 meters. The family Rhinolophidae (CF; frequency > 80 kHz) was not recorded. Only a small percentages of fast hawking species *Nyctalus noctula* and *Nyctalus leisleri* (≤1%) was recorded. In general, the results are in accordance with similar studies dealing with activity of bats in forests.

Keywords

bat calls, Central Slovakia, primeval forest, tree canopy

Introduction

Primeval forests are complexes of horizontal and vertical structures of living and dead vegetation, that have been shaped or maintained largely by natural disturbances and have enormous biodiversity (Halkka and Lappalainen, 2001; Gilg, 2005; Parviainen, 2005). These unique and rare habitats represent only 1.7% of the total forest area in Europe (Diaci, 1999). Large heterogeneity of these forests with regard to composition of tree species (Jung et al., 2012), tree age (Patriquin and Barclay, 2003) or canopy coverage makes them excellent locations for studying various animals, especially bats. Bat occurrence in forests is associated especially with the presence of tree cavities, crevices, or cracks (Barclay and Kurta, 2007) which bats use as place for roosting, pup rearing and also as a protection against harsh weather (Kunz, 1982). Numerous bat species with various foraging strategies are able to exploit such environment ranging from those who forage on airborne prey, glean food items from the ground or vegetation, or even forage above water surfaces (Russo and Jones, 2003; Kusch et al., 2004, Denzinger and Schnitzler, 2013).

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Numerous studies on bats have been conducted in various European primeval forests, such as the Białowieża Forest in Poland (Rachwald, 1995; Ruczyński, 2006; Ruczyński and Bogdanowicz, 2008), the Carpathian Biosphere Reserve in Ukraine (Postawa et al., 2000), the Bavarian Forest National Park in Germany (Müller et al., 2012; Müller et al., 2013), and the Thayatal National Park in Austria (Plank et al., 2012), mainly with the aim to understand ecological requirements and/or roosting strategies of these animals. In Slovakia, where primeval forests comprise just 0.48% of total forest area (Oz Prales unpublished data) any coherent knowledge about basic composition of bat species is lacking. Attention towards this topic has been paid only recently, and mostly the results were only in the form of faunistic data (e.g., Danko et al., 2007). Using combination of mist netting and ultrasound monitoring techniques some studies examined flight and foraging activity (Ceľuch and Kaňuch, 2004a, b), altitudinal patterns in occurrence of bat species (Kaňuch and Krištín, 2006), or habitat use (Ceľuch and Kropil, 2008) in such forest habitat.

This short communication aims to contribute to the knowledge about the bat species composition and their relative activity with regard to vertical utilization of the foraging habitat in a primeval temperate forest in central Europe.

Material and methods

Data collection was conducted in Badínsky Primeval Forest, central Slovakia, Interior Carpathians (Kremnické vrchy Mts; 48°41′N, 19°03′E; 785 m asl; quadrant 7380 in the Databank of Slovak Fauna; forest stand No. 801; Fig. 1) during June, August and October 2014. Area is characterized as a moderately cold climate region with mean January temperature of –4 °C and mean annual precipitation of 800 mm (Lapin et al., 2002) with predominantly north-eastern exposure. Forest can be characterized as *Fagetum pauper* type with *Dentaria bulbifera-Fagetum* phytocenology (Hačinský, 1972) and Ls5.1 beech and fir–beech forests biotope (Stanová and Valachovič, 2002). Age of trees is estimated to be more than 200 years.

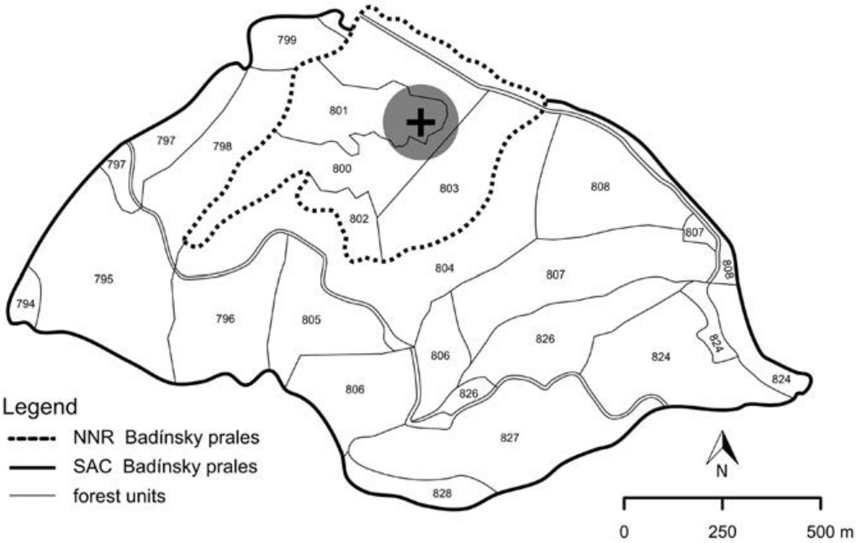

Fig. 1. Study area Badínsky prales primeval forest. Explanations: NNR, National nature reserve; SAC, Special areas for conservation. Location of ultrasound detector is marked with cross.

Recording device – an ultrasonic detector (Batlogger®, Elkon, Switzerland) – was affixed to a same tree trunk at three different heights (5, 10 and 15 m) above ground (five consecutive nights in each height) in at least 100 m distance from the forest edge to minimize ecotone effects (Pettit, 2011). Ultrasonic microphone was fixed in horizontal position (0–180º). Recording began 30 minutes before sundown and continued for 2.5 hours. Recording by Batlogger is not continuous in order to avoid memory overload – it records only sound above some threshold of intensity/frequency (pre-trigger parameter 500 ms, post-trigger parameter 1,000 ms, trigger max time 3,000 ms). Device recorded all frequencies from 15 to 155 kHz. All data collection was performed under ambient temperature from 10 to 18 °C (mean 13.8 °C).

Bat calls were analysed using BatExplorer software (Elekon) with subsequent species and genus determination according to identification keys (www.ceson.org; Ahlén and Baagøe, 1999; Ahlén, 2004; Obrist et al., 2004; Baradaut, 2015). Species-level determination based on parameters of echolocation calls is not possible in some bat species. Strong structural similarity of calls exists between *Myotis mystacinus, M. brandtii* and *M. alcathoe*, therefore, if some calls exhibit parameters similar to calls of these species, we consider them all as Whiskered bats (*M. mystacinus* complex). Similarly, Greater mouse-eared and lesser mouse-eared bat (*Myotis myotis/blythii*), Bechstein's bat and Natterer's bat (*M. bechteinii/ nattereri*) were determined as a dual taxon. We categorized bat calls into two groups: *Myotis* group (genus *Myotis*) and non-*Myotis* group (genus *Barbastella*, *Eptesicus*, *Nyctalus* and *Pipistrellus*).

To test the relationship between the number of recordings and recording height for each group (*Myotis*, non-*Myotis*), we used Kruskal-Wallis ANOVA followed by pairwise test for multiple comparisons of mean rank sums (Nemenyi-tests) with significance level of $P = 0.05$ (R-package 'PMCMR'; Pohlert, 2014). All analyses were conducted in R 3.2.2 environment for statistical computing (R Core Team, 2015).

Results and discussion

Only 72 minutes out of 2,700 minutes of recording time contained some sound activity. Totally, 1,559 recordings contained 22,544 calls. Only five species we were able to identify clearly bat species: *P. pipistrellus, B. barbastellus, E. nilssonii, N. noctula, N. leisleri* while others were determined as a dual taxon: *M. myotis/blythii, M. bechsteinii/nattereri, M. mystacinus* complex. Remaining positive recordings were negative for bat calls (sound of rain, wind, and the rustling of leaves and branches). Mean number of recordings per recording night was 74 (range 2–589; both extremes were observed during June). Call frequencies ranged from 16.0 to 68.4 kHz, whereas their substantial part (>580 calls) fell within 40.1–45.0 kHz. Bat calls mean length 4 ms (range 1–37 ms). The median peak frequency (predominantly steep-FM call shape) was 40.6 kHz, which corresponds with *Myotis*-group species (67.9% of all records). Calls with the 15–35 kHz quasi-constant frequency (QCF) signal range (the genera *Barbastella, Eptesicus, Nyctalus* and *Pipistrellus*) represented only 9.1% of records (Fig. 2).

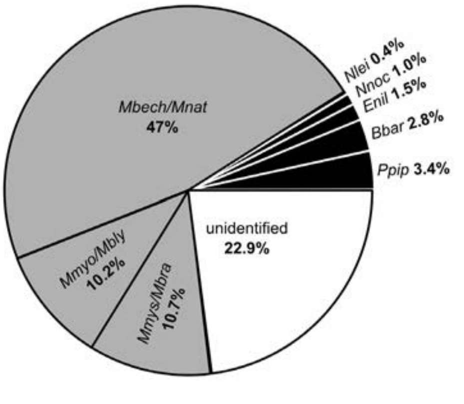

Fig. 2. Percentage of all bat records.

The number of recording varied according to height (Fig. 3). Number of *Myotis*-group calls did significantly differ in individual recording heights ($\chi^2 = 6.0$, df = 2, P = 0.049) but only between 5 and 15 meters (post-hoc test: P = 0.045) however such differences were absent the case of non-*Myotis* group calls ($\chi^2 = 1.7$, df = 2, P = 0.43), as well as in both types calls merged together ($\chi^2 = 3.3$, df = 2, P = 0.19). Calls of *Myotis*-group were the most abundant whereas they represented 96.5% from all determined calls at 5 m above ground, but only 22.7% at height of 15 meters (Fig. 4). The family Rhinolophidae (CF; frequency > 80 kHz) was not recorded. The dominant group comprised mainly such *Myotis* species as *M. bechteinii*/*M. nattereri* (frequency of occurrence = 47.0%, *n* = 469), *M. mystacinus* complex (10.7%, *n* = 107), and *M. myotis/blythii* (10.2%, n = 102). The other recorded species were *B. barbastellus* (2.8%, *n* = 28), *E. nilssonii* (1.5%, *n* = 15), and *P. pipistrellus* (3.4%, *n* = 34). The fast hawking species *N. noctula* (1.0%, *n* = 10) and *N. leisleri* (0.4%, *n* = 4) occurred in only small proportions. Unidentified bat calls represented 22.9% (*n* = 299) of all records (Fig. 2). We identified 31.5% (*n* = 491) of bat calls only to the genus *Myotis*. The most such undetermined records were recorded at 10 m above ground (38.6%) and the fewest at 5 m (4.8%).

This research provides data on the spectrum of bat species occurring in natural forest of the Western Carpathians. Given the research type and duration, the data have predominantly faunistic value. For more detailed insight into bat assemblages it will be necessary to conduct data collection of larger spatio-temporal scale, especially it would be necessary to make recordings from the entire vertical structure of the forest (i.e. within the range of 0–30 m and including tree crowns and above the tree canopy; see Hayes and Gruver, 2000; Plank et al., 2012; Müller et al., 2013). We therefore present these results only as preliminary research. The recordings are also disproportionate inasmuch as we obtained only 75 recordings at 15 m, and that was just 4.8% of all recordings.

Data on the spectrum of bat species in natural (primeval) forests in Slovakia are relatively scarce and can be found only in the study by Danko et al. (2007). Those authors had summarized data from 160 forest locations in Slovakia. Of those locations, just 3.1% (Badín Primeval Forest, Boky National Nature Reserve (NNR), Hrončecký Grúň NNR, Nad vodopádom [Bystrô], and Sitno NNR) occur in the Slovak primeval forest database (Oz Prales 2015 unpubl.). In the Badín Primeval Forest, Danko et al. (2007) had reported the occurrence of three species: *M. bechsteinii*, *M. myotis*, and *M. mystacinus* compley. Within Central Europe, the species spectrum of bats in forests is relatively constant and is above all limited only by habitat preferences, food, and temperature or elevation (Rachwald et al., 2001; Postawa et al., 2000; Kaňuch and Krištín, 2006; Riegel and Nagel, 2007; Plank et al., 2012; Müller et al., 2013).

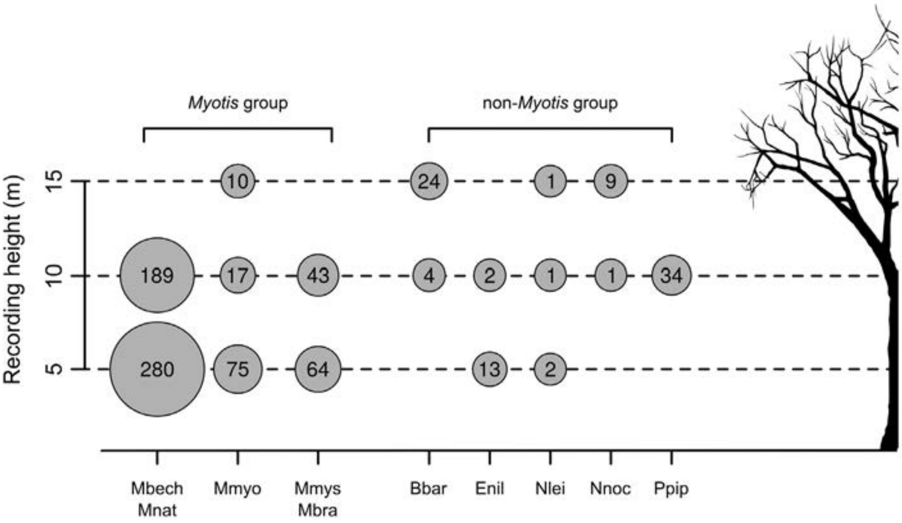

Fig. 3. Number of species records in different height in the tree canopy.

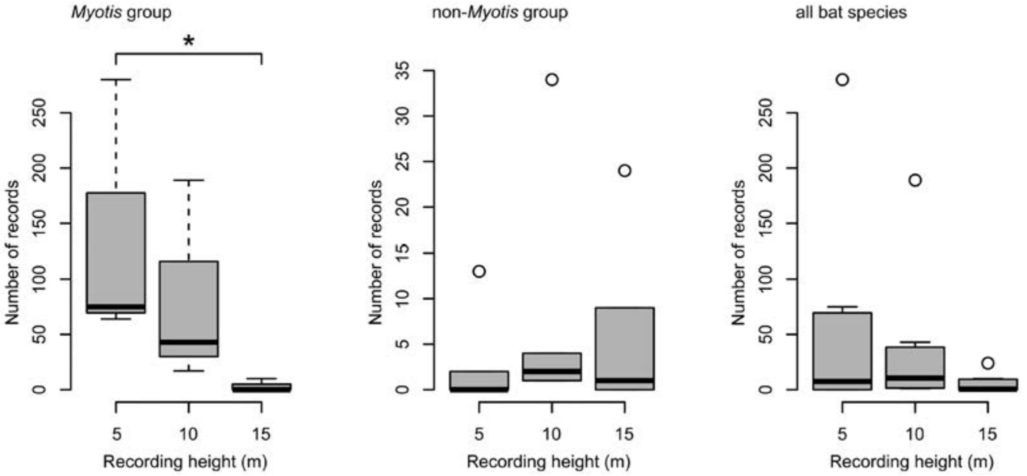

Fig. 4. Comparisons of the number of bat records in different height in the tree canopy according to *Myotis* group, non-*Myotis* group and all bat species. Box-plots represent median, quartiles and non-outlier ranges (outliers are marked as open circles). * – $P < 0.05$.

Comparing the bats' frequency of occurrence and habitat preference in forest environments, we relied mainly upon the study by Kaňuch et al. (2008), who had analysed forest habitat parameters, in relation to bat occurrence. Those authors had determined *E. serotinus* occurrence in beech forests to be positively correlated with the forests' naturalness, which can be characterized by whether they are natural or old-growth forests. We did not capture this species in our recordings. According to Dietz et al. (2009), this species uses primarily forest such corridors as roads and clearings, which confirms that their hunting strategy is open-habitat foraging (Müller et al., 2012). In contrast, the occurrences of *P. pipistrellus* and *N. leisleri* correlated with forests of different ages (Kaňuch et al., 2008). We determined both these species at the present location with occurrence frequencies of 3.4% and 0.4%, respectively. In the same mountain range, 15 km to the south, Ceľuch and Kropil (2008) and Ceľuch and Kaňuch (2004b) had detected at beech–oak forest locations a similar species spectrum as found in our study and with a dominant proportion of species primarily from the *Myotis* group: *M. mystacinus*/*brantii, M. myotis, M. bechsteinii,* and *M. nattereri*. Despite the rather largely disproportionate data from the forest's vertical structure, the proportion of our records from the non-*Myotis* group did increase towards the tree crowns where the canopy is more open and there probably are more gaps in the forest growth. The data obtained only confirm the generally known fact that the vertical occurrence of *Myotis*-group species within the forest stratification corresponds to their hunting strategies and the prey-species spectrum

(Müller et al., 2012). In contrast, non-*Myotis* group species uses in forests primarily open spaces, open edges, and the forests' ecotones. Schnitzler and Kalko had (2001) defined three basic bat foraging guilds: open-habitat foragers (genus *Nyctalus* and *Eptesicus*), edge-habitat foragers (*Myotis*-group, genus *Barbastella,* and *Pipistrellus*), and closed-habitat foragers (*M. bechteinii*/*nattereri* and *Plecotus* sp.). Although the present study found representatives of all three guilds, dominating were closed-habitat foragers from the taxa *M. bechteinii*/*nattereri* and *M. mystacinus* complex, which together comprised nearly 40% of all records. We did not capture records of *Plecotus* sp.

No CF signals, which are typical of the family Rhinolophidae, were captured in our recordings. These are relatively rare species which occur in canopied forests, as seen also in findings from Slovakia (<5% of all records; Kaňuch et al., 2008; Ceľuch and Kaňuch 2004a). Contributing to their rarity in recordings is the fact that when horseshoe bats' echolocation frequencies exceed 80 kHz the signal intensity is relatively weak and so the detector cannot capture them from far away (Motte and Libois, 2002). Data from continuous recording of forest bat species in natural forests within Slovakia is not sufficient. Several primeval forest locations in Slovakia are included within NATURA 2000, which considers the occurrence of bats as one reason for species protection within Special Areas of Conservation (Habitats Directive, Council Directive 92/43/ECC). In general, however, data on the occurrence of bats in such protected locations are for the most part lacking.

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Short communication

Winter activity of European badger (*Meles meles*) in Slovakia

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Abstract

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In wide geographical distribution, the European badger is adapted to various climates, habitats and feeding conditions. At latitudes with severe winters, badgers build fat reserves in autumn and rest in winter. The effect of different temperature and climate to winter diurnal activity of badgers was studied in seven sites of the Javorie Mts and Pliešovská kotlina Valley in central Slovakia. Data were obtained from camera traps installed at badger setts and from snow tracking in three consecutive winters 2012–2015. As the considerable differences of weather conditions were found, also differences in diurnal activity in different winters appeared. The result shows that winter diurnal activity of badgers strongly depends on climate and air temperature. In average, badgers on five different setts were active more than 50% of days during January 2015 (average temperature –0.4 °C). Badgers were mainly nocturnal in winter months. Few cases of daylight activity were recorded only in second half of February, when also mating was recorded.

Keywords

camera trap, central Slovakia, diurnal activity, European badger, winter

Introduction

For wild European mammals, the winter season, even in Southern temperate regions, is a critical period for survival. In addition to unfavourable climatic conditions (low temperatures, frost and snow), natural sources of food are scarce and sometimes even disappear completely (Maurel and Boissin, 1983). In wide geographical distribution, the Eurasian badger is adapted to various climates, habitats and feeding conditions. At latitudes with severe winters, badgers build fat reserves in autumn and rest in winter (Bevanger et al., 1996). Reduced activity and confinement within sheltered setts, together with reduced body temperatures, enable the badgers to rely heavily on energy stored in adipose tissue during the autumn (Fowler and Racey., 1988). In central European conditions, badgers build fat reserve in autumn and spend winter time in rest and its duration depends on climate factors (Červený et al., 2004), but detailed information of their winter activity is missing from this area. Using the radio tracking it was found that badgers were largely inactive in December and January in eastern Poland (Kowalczyk et al., 2003). During these two months short-time emergences connected with short-distance excursions were recorded for 2–6% of days. This research was conducted from 1997 to 2001 with the coldest month January (average daily temperature –2.3 °C). Badgers used only the main sett for day time shelter in winter (Kowalczyk et al., 2004). In central Poland it was found that badgers restricted their activity to immediate vicinity of their setts in first half of winter (Goszczyński et al., 2005). Badgers left their setts in average once in 48 hours, while the longest period of uninterrupted inactivity recorded during study was two weeks. Do Linh San et al. (2007) study reports the first time data on the spatio-temporal

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ecology of badgers living in cold and wet mountain region of Swiss Jura Mountains. Nocturnal activity of badgers was low in winter and very high during all other seasons. Winter nights were characterized by an alternation of resting periods inside the sett with short over ground excursions lasting generally between 15 and 30 min. During the cold season badgers did not emerge from their sett more than 70% of night.

The aim of study is to describe the effect of air temperature on winter diurnal activity pattern of European Badger *Meles meles* in conditions of Slovakia.

Material and methods

The study area was located in the Javorie Mts and Pliešovská kotlina Valley in central Slovakia 48°27′–48°35′N, 19°06′–19°25′E). The altitude ranges from 270 to 1,043 m asl, the annual precipitation (in reference period 1961–1990) varies from 600 to 900 mm and mean average annual temperature from 6.2 to 7.9 °C. Duration of snow cover lasts from 60 to 85 days per year (source: Slovak Hydrometeorological Institute). The area is covered mainly by beech, oak-hornbeam and mixed deciduous woodlands (50%), meadows and pastures (26%) and arable land (16%) (source: National Forest Centre). Human settlements (except for urban areas) are mostly found in hamlets and farms surrounded by many abandoned orchards and gardens.

Badger belongs to common species currently inhabiting approximately 86% of Slovakia area (Krištofík and Hell, 2012). The latest estimate in 2014 refers to 10,454 individuals (Anonymus, 2014), which means density of 0.25 individual per square kilometre. Badgers live in pair or in groups with cubs and occupy underground setts used as daily shelters throughout the year. Some of badger's setts are very extensive and badgers are living there for several generations (Červený et al., 2004). Classification of badger sett is suggested by several authors. By Roper (1992a), they vary considerably in size, ranging from simple single-entrance burrows to complex tunnel systems hundreds of metres long with multiple entrances and underground chambers. A typical badger territory contains a main sett which acts a permanent home to the social group, plus several outlier setts which are used less consistently. Individuals usually rest alone within the main sett, except in winter when they sometimes clump together (Roper, 1992b). In conditions of Czech Republic, Matyáščík et al. (2000) defined four types of badger sett, including main and so-called subsidiary sett. By their knowledge, badgers use this type of sett characterized with 1–2 entrances with small or without spoil heaps, mainly in winter. In contrast of this, Roper (2010) found that badgers rest only in main sett in winter.

We used camera traps installed at badger setts and snow tracking to obtain badger's winter diurnal activity data. Camera traps allow to extend observations through time, space and to create a permanent record of passing animals (Kays and Slauson, 2008). Monitoring was conducted during the period of three consecutive winters 2012/13, 2013/14, 2014/15 in months December–February (Table 1). We used two models of camera traps, Reconyx PC900 and Keep Guard 680 KG. These were placed near (4–6 m) the most used sett entrance. The images were downloaded during one or two-week intervals. We evaluated the badgers over ground activity near the sett in different hours, days and months, badger activity at sub-zero temperatures and their behaviour. Occurrence of other animals near the setts was also recorded.

Table 1. Overview of monitored sites with active camera traps (x)

Sett	Area	Sett type	Number of sett's entrances	Winter 2012/13	2013/14	2014/15
A	Javorie Mts	Main	8	x	x	x
B	Javorie Mts	Main	18	x	x	x
C	Javorie Mts	Main	7	x		
D	Javorie Mts	Main	12		x	x
E	Javorie Mts	Main	19		x	
F	Javorie Mts	Subsidiary	2			x
G	Pliešovská Kotlina Valley	Main	15			x

Habitat characteristic of seven monitored badger setts

(A) Southern slope of a 40-year old oak (*Quercus petraea*) forest stand (630 m asl), distance from a permanent human settlement is 900 m (region Zvolen); (B) Southern slope of an 80-year old beech (*Fagus sylvatica*) and maple (*Acer pseudoplatanus*) forest stand (780 m asl). Its basis is formed by two large rocks. The sett is within 670 m of the nearest permanent settlement (region Detva); (C) The edge of a 100-year old forest stand consisting of beech, ash (*Fraxinus excelsior*) and hornbeam (*Carpinus betulus*), 625 m asl. The nearest permanent settlement is located 980 m away. The sett in area C is within 1,240 m from site B. The entrances were dug into the soil accumulated by machines during the reclamation of neighbouring pastures (region Detva); (D) In 90-year old forest stand consisting of beech, maple (*Acer platanoides*), oak and hornbeam (350 m asl). The nearest permanent settlement is located 350 m away (region Zvolen); (E) In 80-year old beech stand (450 m asl). The nearest permanent settlement is located 400 m away (region Zvolen); (F) North-eastern slope of 80-year old forest stand consisting of beech, oak and hornbeam (400 m asl). The nearest permanent settlement is located 1,020 m away (region Zvolen); (G) Small forest between two fields (405 m asl). The nearest permanent settlement is located 680 m away (region Sása).

Data of daily air temperatures were obtained from the weather station near Zvolen. In winter 2012/13, permanent snow cover was recorded from 4 December to the end of February. The average daily temperature in December was –2.6 °C, –2.8 °C in January and –0.3 °C in February. Following winters were, comparing to the previous one milder, with average daily temperatures 1.5 °C (December), 2.0 °C (January), 3.8 °C (February) in 2013/14 and 1.3 °C (December), –0.4 °C (January), –0.2 °C (February) in 2014/15. In both winters (2013/14, 2014/15), permanent snow cover was not recorded. Due to the fact that badgers activity was mainly nocturnal, the data of the lowest daily temperatures were used for analysis. To find relationship between the over-ground activity of badgers (hereafter OAB) and air temperature, Spearman's rank-correlation was used.

Results and discussion

We obtained 2,803 records of badger's movements near the setts (one record per one individual per one minute) by analysing more than 24 thousand photos frame by frame. As the considerable differences of weather conditions were found, also differences in frequency of OAB in different winters appeared. While the OAB was recorded in max of 6% and 3% days during December and January in winter 2012/13, during following mild winters (2013/14, 2014/15) it was in 24% days and in 49% days (December) and in 42% days and 51% days in January. Differences in OAB during study period were found in February, too. While OAB was recorded in average only in 36% of days of winter 2012/13, in winter 2013/14 it was already in average in more than 80% of days (Fig. 1). On site C, OAB was recorded during 100% of days and it was possible to observe also mating of badgers.

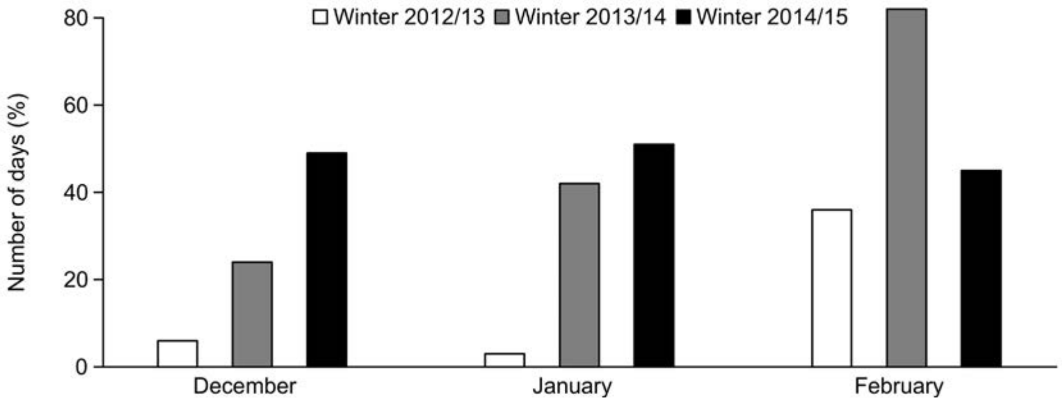

Fig. 1. Over-ground activity of European badgers near the sett during three winters (averaged values).

Previous results suggested the dependence of frequency of OAB in relationship to the air temperature in winter. To confirm these results, we focused to analyse obtained data by more detailed way. A situation at site D in December 2013 is provided as an example (Fig. 2). The number of OAB records decreased with decreasing air temperatures below zero and after subsequent warming increased again. In this case, OAB was not registered during 19 days and only some foxes were recorded near the sett in this period. A similar pattern was recorded at several sites. In the case the OAB was really affected by low temperatures, it was necessary to determine whether this dependence is statistically significant. The set of data was created, where the number of records was assigned to the relevant air temperature below zero which had been measured. More than 70% (n = 1 964) of all obtained records were assigned. It was found that the relationship of OAB with the air temperatures below zero is highly significant (r = 0.94, P < 0.001; Fig. 3). It should be emphasized that a considerable proportion of OAB records in days with air temperatures below –5 °C were recorded mainly in the second half of February, or in days with sudden fluctuations of temperatures.

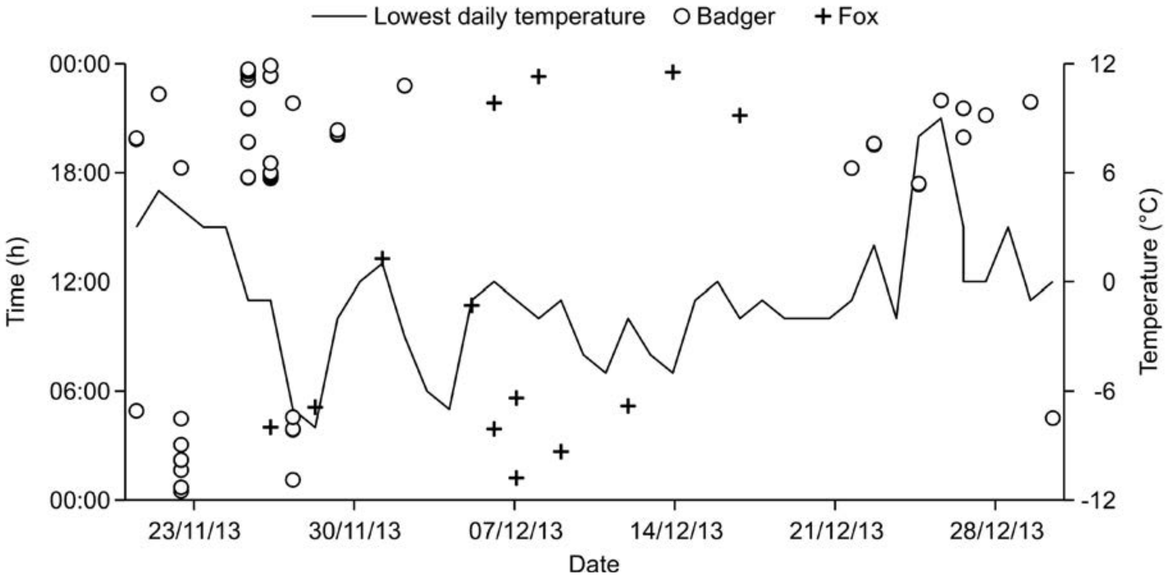

Fig. 2. Frequency of records of over-ground activity of European badgers and air temperature at site D in December 2013.

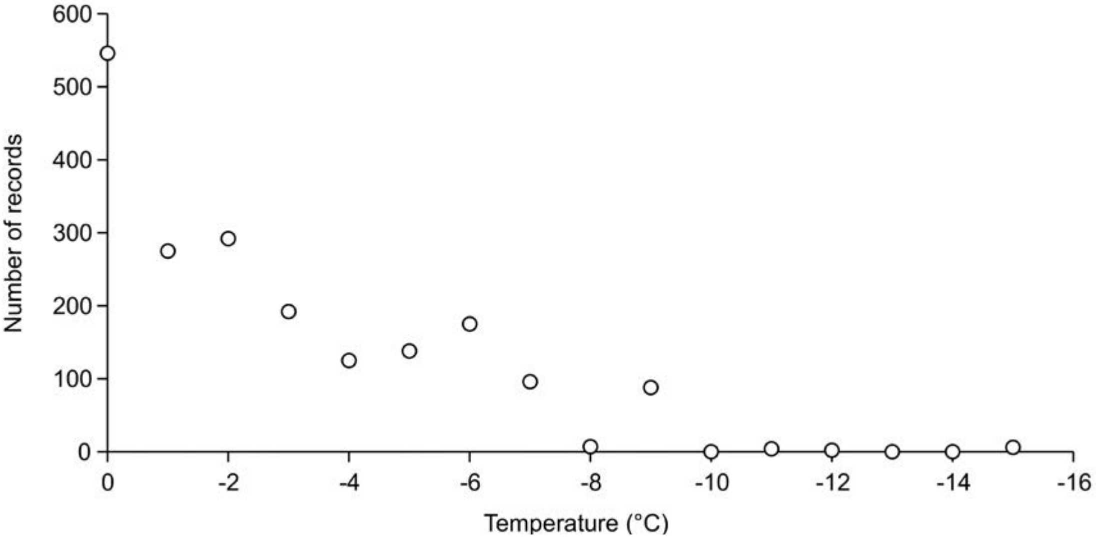

Fig. 3. Relationship of over-ground activity of European badgers number with the air temperature.

The badgers were mainly nocturnal. Peak of OAB near the sett was found between 18:00–20:00 hours (25.8%). However, the frequency of OAB between four following intervals (20:00–4:00 CET) was very high, too. Diurnal OAB was observed only in rare cases (Fig. 4). The number of individuals recorded on different locations ranged 1–3. Badgers avoided fresh and deep snow. In the case that more badgers wintered at the same sett, the night games and wrestling was running there. Mating of badgers was recorded at site B by two consecutive nights on February 23, 2014 (1:50–2:06) and February 24, 2014 (2:04–3:28) near the entrance of the sett. Diurnal OAB was recorded at various locations and in different years, but equally between 20 and 22 February. On site F, there was recorded wintering of badgers in additional (or subsidiary) sett. Setts were often visited by foxes, but particularly at the time when badgers were inactive. From the other carnivores, Grey wolf *Canis lupus*, Eurasian lynx *Lynx lynx* (in the sett entrance), Wild cats *Felis silvestris*, and Polecats *Putorius* sp. were recorded near badger setts. However, inter-specific interactions were not recorded.

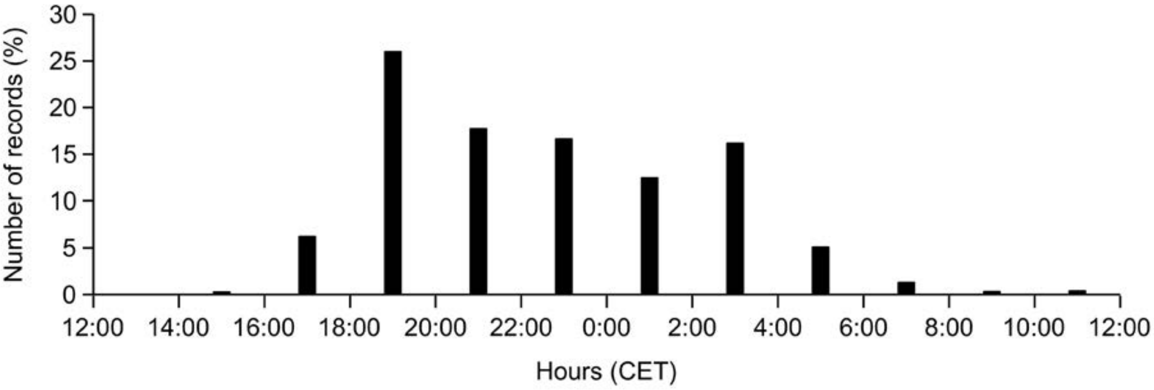

Fig. 4. Circadian pattern of over-ground activity of European badgers near the sett during winter days.

Behavioural pattern found during cold winter 2012/13 corresponds with data from Poland (Kowalczyk et al., 2003), Switzerland (Do Linh San et al., 2007) and from Bulgaria (Racheva et al., 2012). Badgers survived the cold winter in their setts and their over-ground activity was mainly in December and January very low. Their increase was observed since the first half of February, even when the cold weather continued. Setts emergences were registered even in snow and temperatures below –10 °C. But it was not unusual, similar findings are described by Clark (2010) and Pearce (2011). I assume, that winter resting of badgers in this period (February) ends and furthermore seems to be not significantly affected by climatic factors. Hell et al. (1988) stated that badgers in Slovak condition can mate from the spring to autumn, but most frequently it is in spring, soon after birth cubs. OAB increase could therefore be affected by mating time, which was found in late February. Summary of reproductive cycle of badgers in south England shows, that the mating time is possible to occur all year round, but most likely in February (Roper, 2010). Increase of badgers' activity in February (more than 40% of days) found Kowalczyk et al. (2003).

Behavioural pattern which was found during two following mild winters is more characteristic for the Mediterranean (Rodríguez et al., 1996), as for our region. In January 2015, OAB was recorded in over 50% of days on four different setts and even to 100% of days in February (2014, site C). Activity decrease was recorded only during coherent frosty weather in December and January. Macdonald et al. (2002, 2010) found that fecundity of badgers during any given year correlated with conditions in the preceding autumn, and badger survival also correlated with late winter weather conditions. By Byrne et al. (2015), there is prediction, that the climate change could increase the badger population. Size of badger social groups wintering at the single sites in the study area corresponds with result of Mysłajek et al. (2012) from southern Poland (mean 2.3 individuals). It is universally acknowledged that badgers are nocturnal, though they are certainly capable of diurnal activity if undisturbed (Roper, 2010). Indeed, most authors describe badgers diurnal activity in less disturbed mountainous areas, also in summer, and particularly by young individuals. Daily OAB in the winter months is rare. By Clark (2010), badgers daylight activity is generally associated in remote sites where there is less human disturbance or in hot summer, which may correspond with a very dry periods when badgers are hungry. Clark (2010) did not observe winter daylight emergence. Based on comparison of winter and summer circadian OAB (Slamka, 2015) we can assume that the badgers are mostly staying nearby setts in the winter. This is confirmed by the results of snow tracking and also published works from similar conditions (Kowalczyk et al., 2003; Goszczyński et al., 2005).

There was one important drawback related to our method of camera trapping of animals around the badger setts. All of setts included in the study comprised several entrances; therefore monitoring only limited number of them could lead to the omission of some individuals. Despite this, camera trapping can be useful tool for studying the utilisation of setts by badgers and other similar burrow-dwelling species.

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Abstracts of conference papers presented at FJT100

Large carnivores in the Czech Republic: the past and the future

Jan Andreska[*], **Dominik Andreska**

The possible and the actual return of the described species Brown bear (*Ursus arctos*), Grey wolf (*Canis lupus lupus*) and Eurasian lynx (*Lynx lynx*) to the region of their original range raises an important question: exactly when, why and under what circumstances a particular species was pushed out of this area. Finding the right answer may be crucial for future successful protection of large carnivores in the area of densely populated Central Europe. The aim of the research was to obtain specific information about past occurrences of the aforementioned species in concrete regions of the Czech Republic, particularly to find evidence of last recorded occurrence of whelps. Available sources, both literary and archival ones were excerpted. As a result, several hundred records about historical occurrences of individual animals on the territory of the Czech Republic (in today's borders) and adjacent regions of neighbour countries were accumulated. Specific information about the last bear cubs catch was noted in the Šumava Mountains in 1800; the last wolf pups were recorded in 1823 in the Beskydy Mountains in the Carpathian range. As for the lynx cubs, it can be speculated that the last ones were hunted down in 1824 in Southern Bohemia. While comparing with similar works from abroad it was found that time frame of the extirpation of large mammalian predators from the Czech territory corresponds well with the data from the wider Central European region.

Riparian vegetation of the Bešeňová water dam as an important habitat for migrating passerines – results of bird ringing

Michal Baláž[†], **Lucia Hrčková**, **Michaela Ďurkáčová**

Migrating birds often use the same places for migration paths and migration stop-overs for many years. These places are considered to be important habitats for birds and their identification and protection can help in bird conservation. Migratory bird assemblages were studied in riparian vegetation around the Bešeňová water dam (Liptovská kotlina Basin, northern Slovakia) during the spring and autumnal migration periods of 2007–2015. Numbers and species composition of birds was determined using ornithological mist-nets and CMR method. Mist-nets were situated in small willows and tall grasses in the water dam vicinity from the evenings to the next mid-days. Altogether 1,376 birds (51 species) were ringed during 47 trapping phases. The most frequent species were Blackcap, *Sylvia atricapilla* (21%), European robin, *Erithacus rubecula* (12%), Willow warbler, *Phylloscopus trochilus* (10%) Chiffchaff, *Phylloscopus collybita* (8%) and Garden warbler, *Sylvia borin* (8%). We have re-trapped ca. 6% of marked birds during next seasons and we have registered several migrants twice (or more than twice) in this place during the migration periods. To the most interesting records belong a Willow warbler re-trapped after four years (spring 2009–spring 2013), two Blackcaps re-trapped after three years (autumn 2009–spring 2012; spring 2011–spring 2014), Garden warbler re-trapped after two years (autumn 2013–spring 2015) and several birds re-trapped after two years or during the next year or next migration season. Based on these results, this place seems to be an important habitat for migratory birds, manly passerine species.

(*poster*)

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The impact of altitude and forest management on the bird assemblages of montane spruce forests in Západné Tatry Mts

Michal Baláž[*], Ľudovít Kocian

Differences in the structure of breeding bird assemblages caused by different environmental conditions associated with different altitude have been studied for a relatively long time. Nowadays we know that the increasing altitude has negative impact on the species richness, densities and some other structural characteristics of breeding assemblages. However, some opposites can be found in mountains of tropical regions, where the species richness in the lowest altitudes is mostly poorer than in middle altitudes. Here we focused on differences in species richness between breeding assemblages of montane (900–1,100 m asl) and supramontane zone (up to 1,500 m asl) of spruce forests in Západné Tatry Mts (northern Slovakia) in two time periods (1974–1979 and 2004–2006) using two different methods (Turček's time-square method and territory mapping method). We supposed that we would find higher species richness in higher elevated plots than in lower elevated due to stronger impact of forest management in lower altitudes. We recorded altogether 65 bird species–46 species (26 breeding) in the montane zone and 60 species (35 breeding) in the supramontane zone. Species richness in the supramontane zone reached higher values in both time periods. Based on these results, we suggest that forest management in study area has more negative consequences on breeding bird assemblages than harsh environmental factors associated with increasing altitude.

(*talk*)

Use of checklists of observed species for a local bird survey

Vojtěch Brlík[*], Jaroslav Koleček

Collecting checklists of observed species is a simple semi-quantitative method for the study of bird assemblages without counting birds. This method enables to calculate indices of abundance as the proportion of checklists with the occurrence of individual species. We introduce a simple analysis of checklists collected during 121 visits at the study site of Metylovičky (Podbeskydská pahorkatina Hills, Czech Republic) from January 2011 to December 2012. We use these data to calculate the proportion of visits with confirmed occurrence of the particular species (positive visits) and to record arrivals and departures of migratory species. During visits carried out at varying time of the day and on varying routes, VB went through all habitats at the site and set up a checklist of all observed species. Simultaneously, birds were counted along the path. In total, 85 bird species were recorded including 64 species occurring in the breeding season. The proportion of positive visits correlated with the mean abundance during a positive visit. Arrival and departure dates of 14 migratory species were in accordance with published data. Contrary to the standard quantitative methods, the study site should be visited more frequently to obtain precise indices of abundance in the short term. However, this method enables to collect data even during regular non-targeted visits (e.g. travel to work) and to cover larger areas and longer periods. For further critical evaluation of the method we encourage to perform comparative studies using different modifications of the method in various habitats, spatial and temporal scales.

(*talk*)

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Hidden components of biodiversity: bird-parasite associations in five continents

Miroslav Čapek*, Ivan Literák, Oldřich Sychra, Tomáš Najer, Filip Kounek, Martin Havlíček et al.

Parasites are an important, though usually overlooked, component of the biodiversity of ecosystems. They can cause disease and death of the host or regulate host populations and influence host community structure. We studied host-parasite systems in the Neotropical (Central and South America), Afrotropical (Western Africa), Indomalayan (Southeast Asia) and Palearctic (Central Europe) Regions. Examination of a total of 7,482 birds belonging to 660 species, 18 orders and 79 families revealed five genera and 73 species of parasites new to science as well as new host-specific associations. Moreover, a number of parasite species were recorded for the first time in the study areas. Parasitic infections caused by trematodes and bacteria were found in birds and ticks from Costa Rica, Brazil and Peru. Eye trematodes *Philophthalmus lucipetus* were found in Many-colored rush tyrants *Tachuris rubrigastra*. Ticks collected from birds were tested for the presence of *rickettsiae*. Those of the genera *Amblyoma* and *Ixodes* tested were found to be infected with a *Rickettsia parkeri*-like agent, *R. bellii*, '*Candidatus R. amblyommii*', and a novel *Rickettsia* sp. agent. *Hyalomma* ticks were recorded from birds in the Czech and Slovak Republics. Sixteen individuals of six passerine species were found to transport 30 ticks, identified as individuals belonging to the *H. marginatum* species complex, during five spring seasons. Ticks of the genus *Hyalomma* are well-known vectors transmitting infectious agents, which can result in severe and potentially fatal diseases in humans. Migratory birds may carry infected ticks over long distances.

(*talk*)

The Striped field mouse *Apodemus agrarius* in the High Tatras

Gabriela Chovancová†, Ladislav Hlôška, Barbara Chovancová

The occurrence of the Striped field mouse in the Slovak part of the Tatras has not been documented yet. It was discovered in the area of Zuberec (1888); and in Zuberec and Tatranská Javorina (1974). As for the Polish part of the Western Tatras, rare occurrence was registered in the area of Kominiarski Wierch (1973). Our research was performed in the territory of the High Tatras (Skalnatá dolina Valley, Jamy, altitude 1,054–1,078 m asl). A permanent research area was established for the purpose of the research project – Succession of small terrestrial mammals on post-calamity areas of TANAP and represents a biotope disturbed by wind and left without human intervention. We were using the CMR method in the period of years 2006–2015, in spring and autumn. A line transect was established on this permanent research area (points A1, A2 ... F5, F6, in total 36 points). During the given period, we caught 184 small terrestrial mammals of two insectivore species (Eulipotyphla) and five rodent species (Rodentia). The striped field mouse was registered for the first time in autumn 2014 (point B2, one individual) and in spring 2015 (points C5, D5, E3, E5, F5, four individuals). The occurrence of the Striped field mouse in the High Tatras has not been published yet and there are no sub-fossil and fossil items that would document its occurrence in this territory. The presented results add a new fauna taxon to the area of the Tatras.

(*poster*)

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An intellect at the turn of ages and on boundaries of world orbits – F. J. Turček

Alexander L. G. Dudich*

A lot of papers by prominent authors in this volume are to celebrate the centenary birthday of a leading personality in Slovak zoology and one of Europe's foremost specialist in terrestrial vertebrate ecology and a founder of the contemporary concept of complex biocenological research of forest ecosystem. As a self-educated person without professional supervision František J. Turček made his path from amateur-zoologist to a scientist of universal weightiness. Science and scientific research for Turček was a personal avocation. He truly followed motivating ideas of his life, working, finishing and publishing. Insufficient understanding of his intellectual potential, as well as his vast international contacts put him in the category of a suspicious individualist who dared to establish his own rules, paying no respect to mandated regulation in the field of research and science. Already in the 1950s, Turček became friends with a number of foreign colleagues, including Charles S. Kendeigh, Masaru Udagawa, Miklós Udvardy, Endre Dudich and in particular János Balogh, on whose 1958 monograph he took part, that on the terrestrial communities of animals became one of the most important foundation stones of the contemporary zoocoenology. By the 1960´s F. J. Turček had gained considerable international reputation. With the political thaw in 1968 he could come into close contact with colleagues from countries laying west of the infamous Iron Curtain and he got chance to visit some prominent institutions in Eastern Europe. F. J. Turček is held in high esteem by everyone who could met him personally not only because of his scientific achievements, but also for his good-heartedness, his pronounced sense of humour and helpful attitude to his fellows. He belonged to scarce perfect examples of homeland's insufficient acknowledgement of its great individuals in the field of science; even if abroad – in an undoubtedly more critical environment – they have already respected.

(*talk*)

Predator impact on the emergence activity of a nursery colony of *Myotis myotis* and *Myotis blythii*

Vladimíra Dudová, Peter Kaňuch, Marcel Uhrin†

Studies of impact of predators on emergency activity of bats provide ambivalent results in temperate zone. In the study, emergency activity of large nursery colony (up to 8,000 individuals roosting in church loft in Ratková village, central Slovakia) of *Myotis myotis* and *Myotis blythii* was investigated using visual counts and video recordings. Counts were conducted in decades in April–September 2012 under three conditions, (1) without predator impact, (2) with predator dummy (*Tyto alba*) and (3) with artificial subject of predator size. Video recordings were conducted inside the church tower; three behavioural components were evaluated (emergence flights, enter flights, inside circle flights). All data were evaluated in three seasons, (1) pregnancy, (2) lactation, (weaning) using GLM models and Fisher's exact test of pivot tables of behaviour elements. Emergence activity of more than 8,000 bats (min 116–max 8,141) lasted min 35 and max 75 minutes. Only reproductive period had significant impact on number of emerging bats and on emergence span. Predator presence had not explained variability of both, (1) emergence activity and (2) flight behaviour inside the roost. Our experiment did not confirm hypothesis that predator presence influences emerging activity. This impact probably should be studied using different methodological approaches.

(*talk*)

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F. J. Turček: ten arguments for ecology

Pavol Eliáš*

In Slovak and also in international biological/biographical literature F. J. Turček (1915–1977) have been frequently designated as Slovak zoologist, in last years he is also recognized as Slovak ecologist. We analysed and evaluated Turček's published papers (from 1941 to 1980) and finished research projects by topics/subjects, research methods, results and their applications. Ten ecological research fields and activities were distinguished which showed that F. J. Turček was Slovak ecologist, esp. animal ecologist. In this paper I present the results/conclusions of the analysis and evaluation. (1) He studied interactions between animals and plants, his two/three main monographs (published in Slovak and German languages) deal with interactions of animals (birds and small mammals) and plants in seed/ fruit dispersal in a forest. (2) Topics of his field research were ecological ones: population density, spatial and age structure, dynamics ..., consortia (*Populus, Nardus*) structure, zoocoenoses (stratification), biomass production, food chains and energy. (3) He introduced and/or developed several ecological (sub-)disciplines in Slovakia (and former Czecho-Slovakia): production biology, population ecology, zoocoenology, quantitative ecology. (4) He used/applied quatitative ecological methods for birds and mammals populations studies and estimation of biomass production, published a book of methods on this topic in 1956. He developed nido-areal method for ecological analysis of birds populations in forests. (5) He participated in several projects of International Biological Program (I.B.P.), in IBP Working Group on Granivorous Birds *Passer domesticus* as an expert for biomass production research methods and in IBP-PT Grasslands as project leader and researcher. (6) In his papers he used ecological terminology and contributed to development of Slovak ecological terminology for populations. (7) Results of quantitative ecological analyses he published in ecological journals, e.g. INTECOL Bulletine, Ekologia Polska, IBP publications, Biologia (Bratislava), Acta Ecologica and others. (8) He studied current ecological books and papers published in the world (East and West), published references and supported information exchange between East and West countries scientists. (9) He participated in education of the Diploma and PhD students as an adviser for forest and grassland ecosystems. (10) He organized and supported team research of ecosystems (not only populations of animals but also plant species) in a landscape (Liptovská kotlina Basin). Additional arguments could include information exchanges by letters and personal contacts with ecologists of the world (Novikov, Formozov, Tischler, Kendeigh, Pinowski and others). Holistic or ecosystem approach dominated in the F. J. Turček work focused mainly on quantitative ecology and biocoenology.

(*talk*)

Functions and services of ecosystems and animals

Pavol Eliáš*

Animals are integral part of ecosystems, their trophic structure, being (as heterotrophic organisms) consumers of biomass (herbivors, carnivors, predators and decomposers). They are included in principal ecosystem processes: energy flow, nutrient cycles, information exchange and biomass production. They have ecological functions and provide some ecosystem services. In his early papers F. J. Turček recognized non-woody products of a forest and other functions of game animals. In his holistic/ecosystem approach to a forest (following G. F. Morozov, V. N. Sukačev and others) he recognized forest functions, regulations functions and services, e.g. in water regulation, water-erosion protection, climate

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regulation etc. In 1967 he published paper on beneficial effects of wildlife to forest: wildlife is an integral part of the forest community or biocenosis, some useful effects of wildlife in general, and esp. game animals. They take part in the dissemination, the distribution of plants etc. Turček's quantitative ecological studies of small mammals, birds as well as some invertebrates have contributed well to assess of supporting and production services of forests and grasslands in Slovakia (data on biomass, secondary and primary production, energy contents, consumption, decomposition etc.). But also to cultural services such as wildlife for hunters, game animals management, birds as biological indicators, animal species conservation, contribution of animals of water reservoirs to recreation as well as role of animals in a landscape. In the paper we critically analyse current categorizations/ classifications of ecosystem services (MA 2005, TEEB 2011, CICES 2013) with the point of view wildlife or native animals. Deductive approaches (top-down) to identifying and valuation of the ecosystem services prevailed. Inductive approaches (bottom-up) which better quantified animals role and services need more quantitative data on animal populations and biocenoses. Turcek's data can be used for comparison.

(*poster*)

Energy in the land, the land for birds?

Marek Gális*, Roman Slobodník

Issues of bird collisions with power lines have been dealt with very often in the last few decades in Slovakia as well as abroad in many countries (EU, USA, South Africa). In Slovakia, it is the ornithological public in cooperation with the electric companies who is concerned with this issue approximately from 1990. On the basis of discovered findings, the LIFE Energy Project was initiated in 2012 where the field monitoring is the key component for proposing a solution. Distribution power lines (22 kV and 110 kV), has been monitored in 13 SPA projects in 2015. Monitoring consisted of two phases (1st phase: January–March, 2nd phase: April–September, still in progress until February 2016). In total, 3,293 bird carcasses (determined to 67 bird species) and 6 mammals (2 species) have been recorded. The highest mortality has been observed in *Buteo buteo* – 23% (568 individuals), *Pica pica* – 19% (469 individuals) and *Cygnus olor* – 5% (122 individuals). The cause of death has been determined for 2,316 individuals – of which 71% was killed by electrocution and 29% by collision with wires. From the interesting data from the viewpoint of fauna we have recorded some significant European species listed in the Council Directive 79/409/EEC, Annex I, such as: *Anthus pratensis, Coturnix coturnix, Crex crex, Lanius collurio, Muscicapa striata* and *Porzana parva*. The results were prepared under the project LIFE13 NAT/SK/001272 Energy in the land – power lines and conservation of priority bird species in Natura 2000 sites.

(*talk*)

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Ecology and management of the Grey wolf (*Canis lupus*) in Slovakia

Nuno Guimarães*, Francisco Álvares, Slavomír Finďo, Peter Urban

The Grey wolf (*Canis lupus*) was distributed across whole European continent some centuries ago. The continuously persecution led to species extinction in most of its European range but it is presently recolonizing old territories. Currently, 11,000 wolves are estimated to occur in Europe divided in 10 different populations. Slovak wolves are part of the Carpathian population, one of the largest wolf populations in Europe. Wolves are a native species in Slovakia and despite the low numbers reached during the 1970's they never became extinct in the country. Nowadays wolf distribution covers approximately 40 to 60% of Slovakia territory with 200 to 400 wolves estimated to occur in the country. Average pack size is between 4 to 6 individuals and pack territory size varies between 80 to 200 km². In Slovakia wolves feed mostly on wild ungulates, with diet composed by: 70% Cervidae, 22% Wild boar, 5% rodents, 1% livestock and 2% other food items. Wolves are regulated in Slovakia under the EU Habitat Directive (92/43/EEC) Annexes II and V (derogation). There is an annual quota established by the Ministry of Agriculture and Rural Development in Slovakia, that determines the number of wolves to be hunted from the 1st of November until the 15th of January. Conservation measures, following European legislation, are being engaged by Slovak government and a new wolf management plan is being implemented. The creation of protected areas near international borders, were specifically designed for full year protection of wolves, becoming an important step for wolf conservation.

(*poster*)

František J. Turček, CSc. – chief, teacher, colleague

Hubert Hilbert†

Famous world ecologist Dr.Turcek, from Institute of Landscape Biology of the Slovak Academy of Sciences created a group of young scientists in Department of Landscape Dynamic at the beginning of 1970's in the Banská Štiavnica town. He offered to us his contacts with leading scientists (ecologists, zoologists, biologists), shared and showed the humanity, friendship, and understanding. He supported creative scientific environment and showed wide publishing possibilities for young scientists. His orientation to a synergistic, holistic approach to study of ecosystems, supported by fieldwork experiments (e.g. in Liptov basin, Eastslovakian Lowland), exact statistical methods and functional aspect were a big motivation for young scientists. We can conclude, his approaches provided a background for new generations of scientists to study the Landscape ecology and Landscape ecology planning.

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Breeding abundance of the White-throated dipper (*Cinclus cinclus*) in Liptov and Orava regions

Lucia Hrčková[*]**, Michal Baláž, Tomáš Flajs**

White-throated dippers (*Cinclus cinclus*) are considered to be permanent and numerous breeding birds occurring in the foothill and montane rivers of northern and central part of Slovakia. In the Liptov and Orava region this species finds optimal topical and trophical conditions. However, accurate data of their density in these sites absent or come only from relatively small areas. We have studied the breeding density of this species in creeks and rivers of different sizes in this area and based on these results we have estimated the number of breeding pairs in whole region. During the breeding seasons 2008–2015, breeding pairs were monitored in the creeks and rivers (17,113 km) of four size categories (breeding in the nest boxes). The average density of 83 pairs reached the value 0.98 pairs per km rate (between 0.8–1.1). No difference was confirmed in the density of pairs in different categories of flows ($F = 0.56$; $P = 0.65$). That may indicate that the most important factor affecting the breeding density in study flows is the availability of suitable sites for nests. Moreover, this assumption can be also supported by the maximum (small-scale) density recorded on the selected flow sections which reached relatively high levels compared to foreign studies. According our data we have estimated overall 140–251 breeding pairs in the monitored area (1,150 km^2).

(*poster*)

Monitoring of large carnivores in Poľana area

Vladimír Hrúz[†]**, Vladimír Vician, Ivan Valach**

To obtain information on abundance of large carnivores from a particular area is the main task in order to choose its optimal management. In this order the monitoring of large carnivores is being carried out in the Poľana Mountain using various methods. Animals such as Brown bear (*Ursus arctos*), Grey wolf (*Canis lupus*) and Eurasian lynx (*Lynx lynx*), as well as Wild cat (*Felis sylvestris*) are part of this monitoring. Data gathering on large carnivores of the Poľana Mountain includes following methods: the method of counting of the residential marks in the snow, the method of monitoring of the tagged individual using radiotelemetry, the method of genetic analysis and the method of direct observation. The method of counting of the residential marks in the snow is very demanding regarding the personal availability as well as the suitable climatic conditions. The best term to use this method is during November and December. When the area is evenly covered by trails those are then walked-through two days in a row. The method of monitoring using the radiotelemetry helps to obtain data on the space-time activity of a particular individual. The method of genetic analysis is the most reliable method to determine the frequency of a given species in a particular area if done systematically. Samples are taken from the droppings, hair, etc. The direct observation method can accurately identify each individuals; the age and sex structure of the population in the territory can be thus presumed. Such observations are carried out through May and June. The species population development trend in the specific time and space can be obtained from data gained with the help of above described methods.

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The growth rate of the *Microtus oeconomus mehelyi* based on live-trapping

Veronika Hulejová Sládkovičová*, Peter Miklós, Dávid Žiak

The growth rate is one of the most important peculiarities of seasonal generations of rodents and it has not been studied in an endangered Pannonian root vole (*Microtus oeconomus mehelyi*) yet. Our CMR research on population ecology of this subspecies took place between 2012 and 2015 in spring, summer, autumn, and occasional winter samplings at localities near Čiližská Radvaň and Veľké Kosihy (Podunajská nížina Lowland). Altogether 147 recaptured individuals were categorized by sex and the season of birth (spring: 12 fem., 19 mal.; summer: 20 fem., 19 mal.; autumn: 11 fem., 9 mal.; over-wintered: 34 fem., 23 mal.). Just over-wintering individuals were sexually active from spring to autumn, so they invested to reproduction during the second year of life. They underwent very intensive growth from winter to spring of the second year (females 1.59 mm or 1.82 g and males 0.72 mm or 0.87 g per week). Females born in the spring were mature in their first summer after the intensive growth 2.27 mm and 1.41 g per week (immature males 3.05 mm or 1.28 g per week). Individuals born in summer grew about 1 mm or 0.55 g per week. The main body lengths of detected cohorts were significantly different from each other in the spring, summer, and autumn. These results show the need to consider both the sex and the seasonal variations in the morphological characters important for correct understanding of the specific problems of maturation and population dynamic. Supported by Life08/NAT/SK000239.

(*talk*)

Is the Danube river a significant barrier for dispersal of the endangered Pannonian root vole?

Veronika Hulejová Sládkovičová*, Peter Miklós, Dávid Žiak, Ivan Stolárik, András Gubányi

Pannonian root vole (*Microtus oeconomus mehelyi*) inhabits isolated habitats around Neusiedlersee, Balaton, and in the Danube inland delta area. Stabilisation of the Danube main river bed in 19th century has apparently divided the distribution area of root vole into the left and right bank populations. To find out genetic structure of root vole populations on both river banks we collected samples from five localities in 2011–2015. The locality near Lipót (n = 24) is located on the right bank of the Danube, four others are located on its left bank near Vojka nad Dunajom (n = 12), Kráľovská Lúka (n = 7), and Bakanské rameno (n = 4). Locality Čičov (n = 26) is the southernmost, situated down the inland delta. The population genetic structure was detected using program Structure. There is significant genetic differentiation between three clusters identified by Structure (Fst = 0.05, P = 0.007). The first cluster is formed by samples from locality Vojka nad Dunajom. The second cluster is formed mostly by individuals from the locality Čičov. Finally, the third group consists of individuals from the middle part of the Danube inland delta area, and the most of Hungarian samples. The Danube has never been or till the recent past was not a significant barrier for dispersal of root vole individuals. The assignment test and the low values of Fst suggest possibility of dispersal between populations probably supported by natural corridors of wet habitats along the river branches and also probably by the passive transport across the river. Supported by Life08/NAT/SK000239.

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Scientometric analysis of the first Slovak ecologist

Benjamín Jarčuška*, Peter Kaňuch, Marcel Uhrin

František Jozef Turček (FJT; 1915–1977) was self-made man without completed secondary-school education but who defended dissertation thesis. Thanks to his 13 books and more than ca. 530 published articles written also in English and German, he was the first Slovak ecologist and the best known Slovak zoologist acknowledged abroad. Using a scientometric analysis by retrieving data from our private database, and from public databases as Science Citation Index (SCI), Web of Science Core Collection (WoS) and Google Scholar, we assessed features as the paper type, language of the article, taxon and subject area of the article, temporal variation of before-mentioned features, citations and geographic distribution of authors cited FJT's articles. Most than half of his papers has character of basic research, popular science papers comprised ca. 25% of his lifetime-output. Although the last type of papers was common for him in the first half of his carrier, review papers raised among his outputs in the second half of his productive life. Slovak language dominated in his writings during early carrier in forestry practice, however, German and English language was the most common in papers arising during his appointment at Forestry Research Institute and Slovak Academy of Sciences, respectively. Birds and mammals were taxa that appeared most often during whole career in his papers dealing with topics of ecology, ornithology, forestry, game science, feeding ecology, mammalogy etc. According to WoS (1985–2015), he has obtained almost 200 citations on seven of his most cited papers. In overall, we found ca. 600 citations of FJT's articles in SCI (1945–1991) and WoS (1992–2015) databases. His papers were cited by authors from all the continents except the Antarctica.

(*talk*)

František Jozef Turček – conservationist

Ľudovít Kocian†

If we consider F. J. Turček as the first Slovak ecologist, then we can also say he was the first one who pointed out the need for nature protection based on ecological principles. In his first publications (1940s–1950s) he mentioned the negative influence of wetland habitat regulation for various waterfowl species. He also criticized the outdated division of animals to harmful and helpful, and pointed out that biocenosis is a conservation unit that should be studied and protected. Mainly, he dealt with the importance of animals in forests or other ecosystems, and with the need for whole community protection. He was active as a voluntary conservationist, as the author of some nature reserves projects and as the member of conservation journal editorial boards ("Ochrana fauny", "ČS ochrana prírody", "Zborník prác o Tatranskom národnom parku"). In 1953 the first members were appointed former supreme authority for matters of Tatra National Park - Advisory Boards. One of them was Turček, working here up to 1970. He participated on the elaboration of basic directive for management of this park ("Územný priemet funkcii z hľadiska ochrany prírody v širšej tatranskej oblasti – fauna"), in 1973. He was the member of the scientific board of Slovak Institute of Monument Care and Nature Conservation. Also important were his documents for the study of influences of building Gabčíkovo river barrage system. There he formulated proposals to protect endangered species, their relocation from the permanently flooded area and also to protect the barrage system from digging species of animals.

(*talk*)

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What are ecological guilds? Dilemma of guild concepts

Martin Korňan*

Guilds are understood are basic structural units of ecological communities and ecosystems. The concept of ecological guilds was widely accepted in the fields of plant and animal ecology. Richard Root in 1967 first defined the term "guild" as a group of species that utilize same type of environmental resources in similar way. This concept groups species regardless their taxonomic relationships. James MacMahon et al. in 1981 recommended excluding "similar way" from the definition due to limitation of the concept mainly to assemblages. John Fauth et al. in 1996 proposed to distinguish between terms "guild" and "ensemble". Bastow Wilson in 1999 proposed the concept of intrinsic guilds that are based on distributional patterns of species and competitive exclusion principle. Based on this concept, guild members should not tend to co-occur together to minimize interspecific competition. Wilson argued that intrinsic guild concept is the most objective due to the statistical definition by null model analysis without any a priori defined criteria by a researcher. I argue that the concept of ecological guilds should be based and come from the Hutchinsonian theory of ecological guilds. This theory defines niche as a multidimensional space, whose dimensions or axis represents factors limiting existence of species. These axes can be understood as resource dimensions, yet not as foraging strategy or strategy of resource utilization. Coming from this notion, I proposed novel definition of ecological guild as a group of species that has significant niche overlap in the multidimensional niche space of a community.

(*talk*)

Estimation of population size of Eurasian otter in Strážovské vrchy

Diana Krajmerová†, Ladislav Paule, Karol Pepich

Non-invasive samples from the region of Strážovské vrchy covering 2,318 km^2 with about 1,027 km of watercourses were collected during the three winter months in 2013/2014. Eight microsatellite markers were used for individual identification of samples. From 220 analysed samples 77 multilocus genotypes were obtained. Among 77 genotypes 37 different individuals of otter were identified with 17 males and 14 females, in six individuals sex was not identified. Genotyping success on the level 35% is comparable with other studies of otter. Program Capwire estimated the most probable number of otters to 48 that corresponds also to the calculation according to Chessel that assessed average number of otters 47 with maximum 58. The average migration rate within the studied period was about 10 km (2.7–20.7 km). With population size 48 otters population density is about two individuals per 100 km^2 and 4.7 otters per 100 km of watercourses which can be considered within limits of average population density in Slovakia (2–10 per 100 km). It is difficult to evaluate these results from ecological point of view as there is no monitoring of suitability and quality of biotopes for otter.

(*poster*)

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Breeding bird assemblages of montane natural forest after 65 years: case study from Poľana Mts (C Slovakia)

Anton Krištín[*]

Natural forests in mountain ridges are habitats, where direct human disturbance is kept at the minimum. They could serve as reference sites to study the impact of large-scale anthropogenic changes (e.g. deforestation) on woodland birds. Structure of breeding birds was studied by mapping method in Poľana mountain forest (100 ha square, ca. 60% mixed beech forest, 40% natural spruce forest, 1,000–1,340 m asl, Central Slovakia) and species spectrum and density were compared for three periods, 1951 (27 ha), 1988 and 2015 (both 40 ha). Number of bird species was higher (63, 66) in the first two periods, but there was registered significant decrease in 2015 (58 species). Similar pattern was found in abundance: 1,655 and 1,696 ind./100 ha) versus 1,478 ind./100 ha in 2015. Significant differences were found in group dominance (SD5, SD20), when the rate of the first five most abundant species positively correlated with time in studied three periods (34.8, 44.1, and 50%), what can be result of forest habitats degradation. The main differences in species spectrum were registered in *Tetrao urogallus, Phoenicurus phoenicurus* (population failure), and on other hand in *Lanius collurio, Phylloscopus trochilus, Sylvia borin, Regulus ignicapillus* (increase). The forest harvesting in beech forest (1992–2004) seems to be the most serious negative impact on bird assemblages. On other hand, forest succession and natural spruce forest decline increased the quantity of species living in open and shrubby vegetation. Different methods and different state of knowledge can play some role in explanation of differences between 1951 and 2015, too.

(*talk*)

Current data on bat occurrence in the Muránska planina National Park – the results of survey within the "ŠF Pilotné PS" project

Denisa Lőbbová[†], Martin Ceľuch, Milan Hrivňak, Dominika Csepányiová, Ján Rys, Marcel Uhrin, Romana Uhrinová, Gabriela Benčuríkova, Mária Jarošíkova, Matúš Hudák

In 2015 (June–September), there was carried out a bat research using mist-nets and bat detectors in various forest habitats in the Muránska planina National Park. The aim of the research was to identify a higher quality forest areas used by bats to reproduce. Altogether 24 bat species were recorded. Reproduction was detected in nine species: *Barbastella barbastellus* (only 3 sites with lactating females or juveniles occurrence), *Myotis myotis* (females foraging in the surrounding of the known attic colonies), *Myotis emarginatus* (only 1 locality with lactating female), *Myotis mystacinus/ brandtii* (most recorded species, also colony with 24 lactating females captured), *Nyctalus leisleri* (3 sites with lactating females, identified tree roost site with about 15 lactating females), *Miniopterus schreibersii* (1 lactating female captured, probably came from the Bradlo roost site), *Plecotus auritus* (2 sites with lactating females) and *Rhinolophus hipposideros* (used mostly the forest building attics). Most interesting are new ultrasound recordings of *Nyctalus lasiopterus* in the area. Repeatedly this species was detected at two sites (Za havraník, Trsteník) in July. Burda and Trsteník mountain passes seem to be migrating corridors used by bats in the National Park. We suggest additional surveys to confirm occurrence of *Myotis alcathoe, Pipistrellus pygmaeus, Pipistrellus kuhlii* and *Rhinolophus euryale* in this protected region.

(*talk*)

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Diet of Barn owl (*Tyto alba*) in Slovakia

Ján Obuch[*], **Štefan Danko, Michal Noga**

We have assembled data on the diet of Barn owl on the basis of determination of osteological pellet residues during the last 50 years. We have analysed the material from 251 localities in 16 local units. The summary from Slovakia is represented by 119,231 pieces of prey from 47 mammal species (95.7%), 58 bird species (3.9%) with only a little representation of amphibians and reptiles (0.2%) and invertebrates (0.2%). As far as Barn owl is concerned, getting food is limited to synanthropic environment and surrounding agricultural land and the centre of its spreading is now focused mainly to southern parts of Slovakia. In this kind of environment, the main prey is Common vole (*Microtus arvalis*, 59.6%). Supplementary prey is represented by mouse rodents: *Mus musculus* (5.6%), *Micromys minutus* (2.2%), *Apodemus microps* (2.2%), *A. flavicollis* (2.0%), *A. sylvaticus* (1.6%), *A. agrarius* (1.5%), shrew insectivores: *Sorex araneus* (6.2%), *S. minutus* (2.4%), *Crocidura leucodon* (4.8%), *C. suaveolens* (2.8%) and House sparrow *Passer domesticus* (2.9%). In the higher located Turčianska kotlina, the *M. arvalis* (74.3%) is more dominant and in place of lesser shrew, the water shrews: *Neomys anomalus* (2.8%) and *N. fodiens* (1.3%) are more abundant. Some Barn owls have focused their hunt to bats, for example in the church of Ratková, Chiroptera represented 35.2% of the prey. In the sub-recent time period not more than 50 years ago, barn owls were more abundant also in the higher locations of Slovakia as evidenced by collections of pellets of Weisz from 16 localities in Ondavská vrchovina in the years from 1945 until 1963, but also by a list of data from 19th and 20th century. In four samples of diet from sub-recent time period, there was a higher diversity in representation of Barn owl prey caused by lower dominance of *M. arvalis* and by higher abundance of mouse rodents of *Mus* and *Apodemus* genus. The oldest sample is from the church in Žilina - Rudiny dated from 16th century. Together with the sub-recent samples we can evaluate 134,832 pieces of *Tyto alba* prey in Slovakia.

(*talk*)

The nutritional requirements of moose (*Alces alces*) determined under experimental conditions

Matúš Rajský[†], **Zuzana Mlyneková, Zuzana Formelová, Mária Chrenková, Miroslav Vodňanský, Stanislav Bystriansky**

Moose is an autochthonous species in Slovakia. The aim of this work is to determine the basic nutritional requirements of moose. The content of nutrients were analysed in branches (annual shoots) of trees and other plant species. The knowledge concerning nutritive value of natural food should be one of the basic criterions for determining nutritional requirements. The crude protein content (g kg^{-1} dry mater) was for example in *Salix alba* 156, *Rubus caesius* 206, *Robinia pseudoacacia* 219 and *Sambucus nigra* 313 in the growing season, while in the biomass of meadow in forests was this content significantly lower (95). The preferences were tested in the experiment where the animals had ad libitum access to different trees. The preferences were expressed in three levels: high *Salix* sp., *Populus tremula, Acer* sp., medium *Betula pendula, Prunus avium, Swida sanguinea, Fraxinus excelsior, Tilia cordata, Quercus* sp., *Pinus sylvestris* and low *Populus nigra, Populus alba, Ligustrum vulgare, Pinus nigra*. Consumption of *Sambucus nigra* was zero. Moose belongs to selective nutritional type and naturally consumes food with a high nutritional value. Scientists warned against errors in nutrition because moose is the most sensitive species of the deer family Cervidae. Feeding ration

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for an individuals aged 1.5 years (weight 300 kg) in our experiment was as follows: lucerne hay 4.0 kg, maize silage 5.0 kg, feed mixture of own recipe (with increased content of crude protein and fat) 2 kg. Daily intake of dry matter per individual was 7.5 kg. Water intake was different in summer (38 litres) and autumn and winter (20 litres). In comparison with red deer (*Cervus elaphus*) it was significantly higher.

(*talk*)

Population trend in Western capercaillie (*Tetrao urogallus*) in the West Carpathians in 1981–2014

Miroslav Saniga[*]

From 1981–2014, population dynamics of *Tetrao urogallus* was studied on forty-three leks in the West Carpathians (Slovakia). Nest and chick losses were also studied. Results demonstrate a marked decrease in numbers of cocks and hens. The average number of birds per lek was 6.3 cocks and 6.0 hens when the monitoring started in 1981. It declined to 1.4 cocks ($r = 0.83$, $P = 0.001$) and 1.6 hens ($r = 0.67$, $P = 0.001$) per lek in 2014. Comparing the number of cocks on forty-three leks with the proportion of old-growth forest (over 80 years old with suitable spatial structure) within 1 km radius of a lek, a statistically highly significant correlation between the amount of old-growth forest and the number of cocks attending a lek was found ($r = 0.73$, $P < 0.01$). The average number of chicks accompanying a hen significantly decreased during the study period ($r = 0.77$, $P < 0.001$). Female chicks were consistently outnumbering male chicks. Several factors have contributed to the dramatic recent decline in capercaillie population in the mountains of the West Carpathians. Habitat deterioration has probably played a main role. This study was financially supported by the Grant VEGA No. 1/0035/13 ‘Reactions of the animals on the changing forest structure’.

(*poster*)

Forgetting František Jozef Turček ?!

Jozef Sládek[†]

The core of this report is text of concise biography of F. J. Turček (1915–1977) originally written from the basis of extensive biogeography (Sládek, 1992) for the encyclopaedic work “Pioneers in science and technology in Slovakia”. The first two parts of this encyclopaedia prepared by the Institute of History of the Slovak Academy of Sciences edited by PhDr. Tibenský were published in 1980’s. They introduced personalities working before the establishment of the first Czechoslovak republic (1918). The third part published in 1999 (Tibenský and Pöss, 1999) contained personalities working in the time period from 1918 until 1945. The fourth part should introduce personalities working from 1945 until present times. The fourth part was not published until now due to death of the main editor PhDr. Tibenský. Except presenting the original text, I tried to evaluate message of F. J. Turček in the field of ornithology. Coming from factography obtained from three representative sources summarizing the development of ornithology in Slovakia in the past decades (Václav, 2008; Jarčuška et al., 2014; Trnka and Grim, 2014), I came to the conclusion that the report title “Forgetting F. J. Turček” should be understood not only as a question, but also as a reproach.

(*talk*)

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How does life go on in the nest-boxes? A compensatory arrangement in the Moravská brána Region

Aleš Svoboda[*], Jan Švorc, Jiří Marek, Jiří Francek, Roman Rozínek

In 2009, 498 nest-boxes were distributed as a compensation of breeding site lost by highway construction in Moravská brána Region (Lipník n. B.–Hranice na Moravě–Bělotín). During 2010–2015, spring and autumn controls of nest-boxes were performed. We focussed on the occupancy by birds, mammals and hymenopterous insects (superfamily Vespoidea). We found completed bird nests in 65.5% (49.8–75.0) of all nest-boxes on average. In total, we recorded eight cavity-nesting species (*Phoenicurus phoenicurus*, *Ficedula albicollis*, *Passer montanus*, *Sitta europaea*, *Periparus ater*, *Cyanistes caeruleus*, *Parus major*, *Lophophanes cristatus*). On the other hand, we found mammal nests in 35.5% (17.0–48.4) of all nest-boxes on average. We recorded four mammal species at least (*Glis glis*, *Dryomys nitedula*, *Apodemus* sp., *Muscardinus avellanarius*). Finally, we found nests of hymenopterous insects in 6.7% (3.1–11.1) of all nest-boxes on average. Importantly, we notice increasing number of occupancy of nest-boxes by endangered vertebrates or even invertebrates which play a crucial role in forest ecosystems functions. Based on our findings, we conclude that compensatory arrangement comprising nest-boxes distribution in Moravská brána Region had a positive effect on target organisms.

(*poster*)

Results of the monitoring of the Common noctule (*Nyctalus noctula*) hibernating in the road bridge

Veronika Školová, Michal Baláž[†], Martin Cel'uch

The Common noctule (*Nyctalus noctula*) is a synanthropic bat species using different parts or buildings for roosting and/or hibernating. Hibernation site of the Common noctule was monitored during the end of the winter period of 2015 (25th February to 15th April) in the urban part of Ružomberok (northern Slovakia). The hibernation place was situated in the concrete gap under the heavily used road bridge. The overall number of hibernating individuals, number of aggregated and solitaire individuals and the size of the aggregation and their numbers were registered within the eight controls with weekly periodicity. Air temperature in the gap and out of the gap was recorded automatically during the whole time period. Altogether 286–580 hibernating individuals of the Common noctule were registered in particular controls. It is the biggest known roosting aggregation of this bat species in this type of habitat in Slovakia. Strong positive correlation was found between the temperature and the overall number of hibernating individuals. Moreover, the size of aggregations and their numbers also seem to be strongly positive influenced by the temperature. However, almost twice as big number of bats in the end of the monitored period compared with the numbers recorded in February can be explained by the occurrence of bats not hibernating in this site. Most probably these individuals were registered here during changing of different roost places in the end of hibernation period.

(*poster*)

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The fourth culture, informed decision-making and F. J. Turček

Ján Topercer[*]

Charles Percy Snow in 1959 observed that the intellectual life of western society is increasingly being split into two polar groups. They include literary intellectuals and scientists – and a gulf of mutual incomprehension between them. Taking a second look in 1963, he already saw a third culture coming, which would be on speaking terms with scientists and soften some communication difficulties. John Brockman in 1991/1995 redefined the third culture as an undertaking of scientists and other empiricist thinkers that tend to avoid the middleman, communicate directly with the public "taking the place of the traditional intellectual in rendering visible the deeper meanings of our lives" and closing the communication gap. Yet besides the communication gap there is also an implementation or knowing-doing gap, even more important than the gap between ignorance and knowing. I argue it is deepest in regulatory and environmental sciences (climatology, ecology, conservation biology etc.) from where the fourth culture emerges. It fosters knowledge implementation, not only publication-citation loops; promotes the informed/evidence-based decision-making using all relevant legislative tools and taking the whole best available evidence into account; has no conflict of interest, particularly economic (e.g. with big corporations) and no bounds to any religion or ideology. "Any" means any – not only totalitarianism, conservatism and socialism, but also liberalism (including neoliberalism, multiculturalism etc), a "Zeitgeist" in western society that requires as competent scientific corrective as other ideologies. I portray František Jozef Turček as one of the forerunners who championed both the third and fourth culture science in Europe.

(*talk*)

The management plan for the Eurasian beaver (Castor fiber) in the Czech Republic

Jitka Uhlíková[†]

The Eurasian beaver is a threatened species, its abundance, however, has been increasing since the end of the 1980s. Spreading of this conflict species arose need of preparation of the Management Plan, which was adopted by the Ministry of Environment in 2013. It is a set of protective, management, legislative and educational measures providing the management of this species. The main objective of the plan is ensuring existence of viable populations of the Eurasian beaver in the Czech Republic together with reducing the amount of damages caused by beavers. The conceptual framework is dividing the Czech Republic into three zones (A, B, C). In zones, there is a different approach to management of populations according to the risk of serious damages. Risk of serious damages at highest level is in the zone C, in the south of the country. Beaver settlement is undesirable here and these rodents should be hunted. In the zone A, contrary to the zone C, there is an interest on protection and growth of present populations. The zone B is a transitional zone that, among other, has to provide connectivity among zone A parts. The following measures should lead to the fulfilment of objective indirectly: optimalization of damages compensation, testing of conflict solution technical measures, improving public relations, monitoring of the zone A, mapping the current occurrence, research. The time-frame of efficiency of the management plan is 10 years, but individual measures will be checked and evaluated during its course. More information about the management plan is available on website www.zachranneprogramy.cz.

(*talk*)

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Are birds and mammals problem for the Košice airport service?

Marcel Uhrin[*], **Stanislav Danko**

Wildlife strikes with planes on airfields represent serious problem on air traffic. We analysed risk of wildlife strikes on the Košice airport based on data from different methodological approaches: (1) quantitative bird census on quadrates (2011), (2) maximally day numbers of birds on airport field (2008–2011), (3) registry of collisions of animals with aircrafts (2008–2011). In total, 118 bird species were registered on the airport among them 51 bird species breeding there. In period 2008–2011, 68 cases of wildlife strikes and 45 records of dead animals on the airport field were registered. Most accidents (58.8%) were caused by kestrels (*Falco tinnunculus*) following by common buzzard (*Buteo buteo*). According heuristic risk analysis, four animal species (*Falco tinnunculus, Buteo buteo, Phasianus colchicus, Lepus europaeus*) should be considered as species which require particular management actions.

(*poster*)

Mammals under the wheels, or road ecology in practice

Peter Urban[†], **Miloslav Badík, Jerguš Tesák, Gabriela Ligasová**

The role of road ecology is concerned with understanding how roads affect ecological processes, often with the goal to develop strategies of mitigating negative environmental impacts of roads, including killing of wild animals by vehicles. Animal mortality on roads in Slovakia is directly connected with an increase of the transport frequency, insufficient biocorridor identification and the consequent application of wrong measures, or their total absence. The aim of the present work was to determine numbers, places and dates of mammal collisions on selected road sections in Muránska planina National Park (central Slovakia), including its buffer zone and identification the role of migration objects on the roads and habitat structure along the roads. The model area is surrounded by three roads, with the total length of 68 km. The 4.2 km long road section Zbojská–Tisovec I/72 was partially reconstructed in the years 2013–2015. Despite incorporation of some migration objects the road permeability (concerning movement of animals) has been reduced. On this road we registered 13 mammal carcasses in the year 2013 and 10 in 2014. The permeability status of the other two roads is relatively good, but the absence of mitigation measures results in the collisions between vehicles and animals. On the road I/66 Brezno–Červená Skala we registered 23 mammal carcasses in the year 2012, 33 in 2013 and 23 in 2014. On the road II/531 Tisovec–Červená Skala we registered 6 carcasses in the year 2012, 1 in 2013 and 3 in 2014.

(*talk*)

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Work in a periodical

Sharov, A.A., Liebhold, A.M., Ravlin, F.W., 1995. Prediction of gypsy moth (Lepidoptera: Lymantriidae) mating success from pheromone trap counts. *Environmental Entomology*, 24: 1239−1244.

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Web source

Woodward, J.L.W., 1999. *Effect of fungicide treatment to control shot-hole disease of cherry laurel*. Centre for Applied Nursery Research [cit. 2011-10-12]. http://www.canr.org/98013.pdf

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