

## Assemblages of orthopterans, small mammals and birds of prey in areas after conversion from arable land to grassland

Spoločenstvá rovnokrídlovcov, drobných cicavcov a dravých vtákov v území po premene ornej pôdy na trávnatý porast

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**Abstract:** Intensive agricultural management is considered a factor contributing to biodiversity loss, and therefore, there are increasing efforts to convert areas of arable land into extensively used habitats. Our study describes the colonisation process of Orthoptera, Mantodea, and small mammals on land converted to managed permanent grassland, while also assessing the impact on birds of prey abundance. Research conducted between 2021 and 2024 indicated rapid positive responses by the studied taxa, with Site 1 recording 16 Orthoptera and Mantodea and 12 small mammal species, comparable to other natural sites in the Danube Lowlands. No differences were found in Orthoptera abundance and species richness, or small-mammal abundance; however, small-mammal species richness was higher at Site 1. The abundance and species richness of small mammals at both sites exhibited pronounced seasonal variation, peaking in autumn. We found a positive relationship between the abundance of small mammals and the abundance of birds of prey. The birds of prey assemblage was dominated by common buzzard (*Buteo buteo*), common kestrel (*Falco tinnunculus*), and western marsh harrier (*Circus aeruginosus*). Our research underscores the swift adaptability and colonisation capabilities of the studied taxa and suggests that recently converted grasslands can support relatively diverse assemblages of orthopterans, mantids, and small mammals within a few years of conversion. Consequently, these restored habitats provide a critical food supply for birds of prey, mitigating declines in prey abundance caused by intensive agricultural practices in the surrounding landscape.

**Abstrakt:** Intenzívne poľnohospodárstvo je považované za faktor prispievajúci k úbytku biodiverzity, preto sa čoraz viac úsilia vynakladá na premenu ornej pôdy na extenzívne využívané biotopy. Štúdia opisuje proces osídľovania zástupcami radov Orthoptera, Mantodea a drobných cicavcov na plochách premenených na trvalé trávne porasty v roku 2, pričom hodnotí aj vplyv týchto zmien na početnosť dravých vtákov. Výskum v rokoch 2021 až 2024 preukázal rýchlu pozitívnu odozvu skúmaných taxónov, pričom na lokalite 1 sme zaznamenali 16 druhov Orthoptera a Mantodea a 12 druhov drobných cicavcov, čo je porovnateľné s diverzitou na iných prírodných lokalitách v Podunajskej nížine. Medzi plochami neboli zistené rozdiely v abundancii a druhoveom bohatstve Orthoptera a početnosti drobných cicavcov. Druhovú bohatosť drobných cicavcov však bolo vyššie na Site 1. Početnosť a druhové bohatstvo drobných cicavcov na oboch plochách vykazovali sezónne zmeny s vrcholom počas jesene. Zaznamenali sme pozitívny vzťah medzi početnosťou drobných cicavcov a početnosťou dravých vtákov. V spoločenstve dravých vtákov dominovali myšiak lesný (*Buteo buteo*), sokol myšiár (*Falco tinnunculus*) a kaňa močiarna (*Circus aeruginosus*). Naš výskum poukazuje na rýchlu adaptabilitu a schopnosť osídľovať nové biotopy u skúmaných taxónov a naznačuje, že premenené trávnaté porasty môžu už niekoľko rokov po premene poskytovať domov pomerne rozmanitým spoločenstvám rovnokrídlovcov, kudlankovitých a drobným cicavcov. V dôsledku toho tieto obnovené biotopy poskytujú dôležitý zdroj potravy pre dravé vtáky, čím zmierňujú pokles početnosti koristi spôsobený intenzívnymi poľnohospodárskymi postupmi v okolitom prostredí.

**Key words:** post arable rewilding, colonisation, biodiversity recovery, management measures, birds of prey food supply

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## Introduction

Changes in land-use management that increase biodiversity are essential for protecting and sustaining populations of specific species and assemblages (Melstrom & Horan, 2014; Leseberg et al., 2023). Initiatives focused on rare umbrella species can benefit other populations and communities in the area, thereby enhancing overall biodiversity and ecosystem stability (Roberge & Angelstam 2004; Aldridge et al. 2024).

Most of the arable land in Central Europe (including Slovakia) is characterised by intensification (Meyer 2020), associated with intensive agrochemical use (Klimkiewicz-Pawlas et al. 2023), rapid agrotechnical interventions (Petrović et al. 2024), and large-scale monocultures in the fields (Galis 2020; Hološková et al. 2024, 2025). This affects the diversity of various animal groups and interspecific interactions in this human-affected/managed ecosystem.

Large-scale field crops are typical ecological deserts in terms of insect and other organism biodiversity in former grassland habitats (Nicholls & Altieri 2013). For this reason, there are more frequent calls to increase biodiversity by converting arable land and large monoculture fields into grassland habitats, or habitats with a more diverse plant cover (“post-arable rewilding”) in the sense of Gardiner & Casey (2022).

The transformation from agricultural to grassland habitats often leads to changes in their structure and resource availability (Luoto et al. 2003, Magioli et al. 2019). While some such transformations led to an increase in small mammal species richness and diversity post-restoration (Moro & Gadal 2007), for example, by shifting the proportions of trophic groups, such as an increase in granivores (Balčiauskas & Balčiauskienė 2022). Some transformations, such as the extensive conversion of arable land (Kozakiewicz & Kozakiewicz 2008), led to a decrease in species diversity. Other studies found no significant change in taxonomic diversity, but given management, they led to changes in functional diversity (Balestrieri et al. 2019), habitat use, and activity patterns in the studied taxa (Shore et al. 2005). The effects of such land-use transformations are complex and can vary depending on the specific environmental context.

Stone (2007) observed temporal dynamics post arable rewilding, with initial declines followed by stabilisation and an increase in diversity. Conversely, Avenant (2011) observed a decline in diversity following an initial increase due to a decline in ecological integrity.

Insects are suitable indicators of changes in land-use management (Gerlach et al. 2013). They could be the first to reflect changes in plant communities, microclimate, and soil conditions (Perner & Malt 2003; Pykälä et al. 2005). Grasshoppers and crickets (Caelifera, Ensifera) are mobile insects, mostly well-flying (Gerlach et al. 2013), and among the first colonisers of plots converted from arable farmland to more diversified grasslands (Gardiner & Casey 2022). The speed and success of colonisation depend on several factors, including changes in vegetation cover, microclimate, and soil conditions (Perner & Malt 2003), as well as species richness and abundance in surrounding habitats (Gardiner 2007; Fabriciusová et al. 2011). Large plots of arable farmland are very poor in the sense of orthopteran species richness and abundance (Gardiner 2007; Cherrill 2011). Hence, changes that reduce land-use intensity and increase habitat heterogeneity may promote higher diversity of orthopterans and potentially other animal groups, although responses can vary among taxa and sites.

Small mammals are also highly sensitive to environmental changes, making them effective indicators of environmental contamination (Koroleva et al. 1999), chemical transfer through food chains (Shore & Douben 1994), and landscape degradation (Avenant 2011). Small-mammal diversity tends to increase in more natural or semi-natural habitats, such as meadows and pastures, compared to intensively cultivated areas, as these environments support higher abundances of specialist species (Gentili et al. 2014). Recolonisation by small mammals can occur rapidly in restored habitats. In reclaimed mining areas, small mammal communities stabilised within two years, with increasing species diversity over time (Hingtgen & Clark 1984). However, the overall abundance of small mammals may be higher in disturbed landscapes due to the dominance of generalist species (Gentili et al. 2014).

Orthopterans and small mammals serve as the main food source for many predatory species, especially for some insectivorous and zoophagous birds, such as birds of prey and shrikes. The role of orthopterans in the birds' diets has been documented (e.g., Krištín 1995; Chavko & Krištín 2017; Ganbold et al. 2017; Krištín et al. 2017; Berlusconi et al. 2025); as has the role of small mammals (e.g., Birrer 2009; Palatitz et al. 2011; Horváth et al. 2020; Obuch 2022). Predatory birds react to the increased food supply through numerical responses such as a rise in reproductive outputs (Norrdahl & Korpimäki 2002; Hoi et al. 2004), aggregation responses, where individuals concentrate in areas with higher prey density (Brighton et al. 2022), and functional responses characterised by an increase in consumption rate of more numerous prey species (Smout et al. 2010; Hellström et al. 2014). High prey availability of prey can positively affect the survival rate of young individuals or shorten their post-fledging dependence period (Kouba et al. 2013, Kouba et al. 2024). It can also influence the spatial hunting activity of breeding males (Kouba et al. 2017). Beemster & Vulink (2013) observed that the abundance of small mammals directly affected birds of prey diversity. The authors noted that vegetation structure influenced birds of prey density and suggested that effective grazing management can help maintain small-mammal populations, thereby supporting birds of prey diversity. Raptors are considered indicators of environmental health because they are at the top of the food chain. Changes in birds of prey populations often reflect broader ecological changes, including those affecting small mammal and insect populations. Raptors' sensitivity to habitat changes makes them suitable and valuable for monitoring ecosystem health and guiding conservation efforts (Rodríguez-Estrella et al. 1998).

In southwestern Slovakia, several sites have been converted into permanently managed grasslands after long-term use as arable land (more than 70 years). The aim of this study was to document the process of orthopteran and small-mammal colonisation following a change in land-use management and to evaluate the impact of this land-use change on birds of prey abundance. Based on the knowledge of the above-mentioned studies, we hypothesised that (i) after the conversion of uniform large-scale arable farmland to permanent grassland, the diversity of different animal taxa would increase as reported in similar studies. Furthermore, we expected that (ii) the increasing abundance and diversity of food supply at the Site 1 would lead to a higher presence and abundance of birds of prey.

## Material and Methods

### Study area

The research was conducted at two locations: Study Site 1 (hereinafter Site 1), Veľký Ostrov (N 47.96521, E 17.87626), and Study Site 2 (hereinafter Site 2), Čalovec (N 47.86523, E 17.92603). Both sites are situated in the Danube Lowlands and around 110 m a.s.l. They fall within the lowland climate zone, characterised by a warm, very dry region with mild winters and warm summers. They also experience extended periods of sunshine, with an average annual rainfall of about 500 – 550 mm (Miklós 2002). In the west and south, Site 1 is surrounded by riparian forest and the Čierna voda river, and on the north and east, it borders intensively cultivated agricultural land. Site 2 is surrounded by intensively cultivated agricultural land on all sides except for the southwest, where it borders the periodically flowing Dudvák river.

### Study design

Site 1 (10.2 hectares) was converted from long-term arable land (over 70 years) to managed permanent grassland in 2020. Prior to the conversion, wheat was cultivated on this site for three years. A mixture of several grass species was planted at a sowing rate of 35 kg/ha, consisting of 10% *Bromus inermis*, 15% *Dactylis glomerata*, 15% *Festuca arundinacea*, 20% *Festuca pratensis*, 30% *Lolium perenne*, and 10% *Phleum pratense*. Since 2021, Site 1 has been mowed once or twice a year, without further intervention.

To provide a comparative context for the colonisation patterns observed at Site 1, we included Site 2 (6.5 ha), located 11 km from Site 1, as an independent reference site that had undergone a similar conversion from arable land to managed permanent grassland one year earlier. From 2021 to 2023, sheep and cows grazed the Site 2 during spring and summer. We anticipated that the monitored parameters (abundance and species richness) at Site 1 would gradually converge with those of the reference Site 2. If the conversion alters the assemblages, there should be no difference in the parameters studied between the two study sites.

### Data collection

#### Orthoptera

A qualitative-quantitative survey of Orthoptera assemblage structure (including one mantid species) was conducted intensively from 2022 to 2024. Both sites were visited twice a year in the same periods (the first, in the early summer period (first decade of July – summer) and the second, autumn period (late

September – autumn), to record the widest possible spectrum of species occurring in both seasonal aspects and exclude the possible seasonal differences between the sites. The material was sampled mainly by sweeping grassy-herbaceous vegetation on three  $100 \times 1$  m transects (min. 300 sweeps/visit/site). This method was supplemented by acoustic identification and individual manual collections along transects. The time spent on active sampling at each site was one hour per visit. For subsequent analyses, data from both visits in each year (2022–2024) were pooled. The species were identified using the identification key Kočárek et al. (2005).

### Small mammals

Small mammals were captured using the Capture-Mark-Recapture quadrat method from 2021 to 2024 (16 trapping sessions). We utilised Ugglan No. 2 live traps, arranged in  $5 \times 5$  trap quadrats (trapping plots), and left in place for 2 nights. The traps were spaced 10 meters apart and baited with a mixture of cereals and apples. At Site 1, four trapping quadrats (A, B, C, and D) were used, while two (A and B) were set up at Site 2. Trapping was conducted four times a year: spring (April), summer (August), autumn (October), and winter (February). Captured individuals were marked with an ear tag (Csáková 2025). Small mammals were identified based on identification features (Baláž et al. 2013).

### Raptors

Bird monitoring was carried out from a single observation point (N 47.96564, E 17.87955) at Site 1 in the morning once a month for 3 hours, from January 2021 to December 2024 (similar to Schröpfer 2013). For subsequent analyses, data from all 48 samples/visits were aggregated into 16 seasonal samples (four seasons per year).

### Statistical analyses

The differences in Orthoptera abundance and species richness between the two sites were tested using Pearson's chi-square test.

Only data on the first capture of small mammal individuals were included in the analysis; recaptures were not included. Abundance was modelled using a generalised linear model with a negative binomial error distribution *MASS package* (Venables & Ripley 2002), with *season*, *quadrat* and *year* as fixed effects. Species richness was represented by Chao1 asymptotic richness estimates obtained from abundance data using the *iNEXT package* (Hsieh et al. 2024) and modelled with a linear

model after log-transformation using *log1p*, including the same fixed effects. In additional models incorporating Site 2, abundance values were standardised to 100 trap nights to account for differences in trapping effort. These standardised abundance values were log-transformed and modelled as a function of site and season using a linear model. Richness estimates in the same dataset were modelled using a Poisson GLM with a log link and season and site as fixed effects. Post hoc pairwise comparisons among categorical factor levels were performed using the *emmeans package* (Lenth 2025), computed on the response scale with Tukey correction for multiple comparisons.

For the small mammal, we evaluated the dominance of species in five categories: eudominant > 10%, dominant 5–10%, subdominant 2–5%, recedent 1–2%, and subrecedent < 1% (Tischler 1949). We also evaluated the frequency of occurrence (F%) across 16 captures.

To assess the relationship between birds of prey abundance and small mammal abundance over time, we fitted a generalised linear model with a Poisson error distribution and log link function. The monthly census data sets on birds of prey abundance were aggregated into seasonal total abundance. Raptor abundance was modelled as a function of small mammal abundance and a second-order polynomial of time, represented by an ordered integer variable indexing seasons chronologically from winter 2021 to autumn 2024, to account for nonlinear temporal (seasonal) effects on birds of prey abundance. Type II Wald chi-square tests for model terms were conducted using the Anova function from the *car package*. All the analyses were performed in R (R Core Team 2025).

## Results

### Orthopterans and mantids

At both sites, we recorded 1,341 orthopteran and mantid individuals over a three-year study (665 at Site 1 and 676 at Site 2). We found a total of 21 species (16 at each site, but different ones) with the same abundance score (69) at both sites (Table 1). We found no difference in either abundance ( $\chi^2 = 0.97$ ,  $df = 2$ ,  $p = 0.62$ ) or species richness ( $\chi^2 = 0.65$ ,  $df = 2$ ,  $p = 0.72$ ) between the two sites. Five different species were found at each site (Table 1). Among them, *Tesselana veysseli* at Site 1 and *Platycleis affinis* and *Euchorthippus pulvinatus* at Site 2 were classified as rare species. Furthermore, we found a slight increase in species richness and abundance between the first two monitoring years, i.e., the second and third year after rewilding (Fig. 1).

**Tab. 1.** Orthoptera assemblages recorded at Site 1 and Site 2 during 2022–2024 (grey highlighted - species recorded in the near surroundings, not included in analyses).

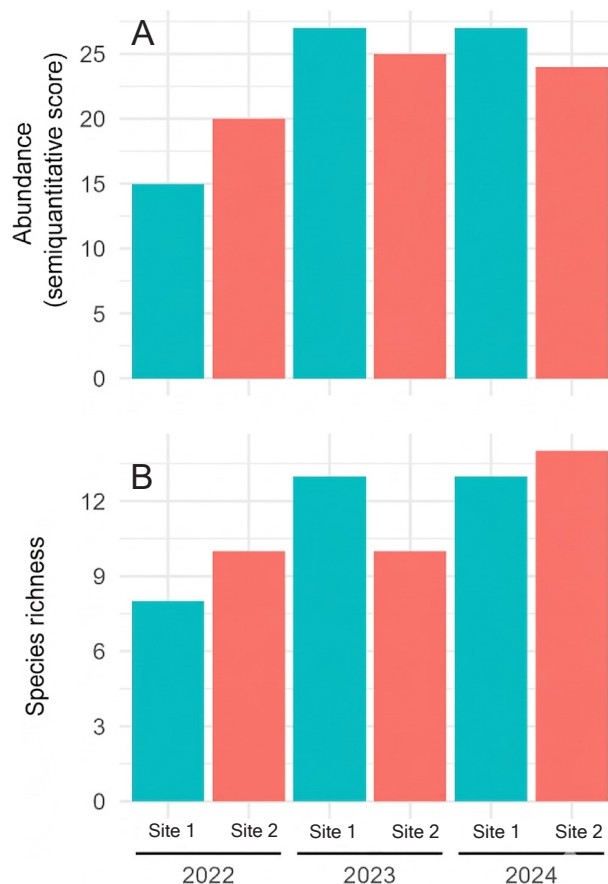
**Tab. 1.** Spoločensvá Orthoptera na lokalitách 1 a 2 v priebehu rokov 2022 až 2024 (sivo zvýraznené - druh zaznamenaný iba v ekotonálnych a susedných prírodných parcelách, nezahnutý do analýz).

| Year                                | 2022   |        | 2023   |        | 2024   |        | $\Sigma$ |        |
|-------------------------------------|--------|--------|--------|--------|--------|--------|----------|--------|
| Species / Site                      | Site 1 | Site 2 | Site 1 | Site 2 | Site 1 | Site 2 | Site 1   | Site 2 |
| <i>Conocephalus dorsalis</i>        |        |        |        |        |        |        |          |        |
| <i>Conocephalus fuscus</i>          |        |        | 2      |        | 3      |        | 5        | 0      |
| <i>Leptophyes albovittata</i>       | 2      | 3      | 1      | 3      | 1      | 2      | 4        | 8      |
| <i>Bicolorana bicolor</i>           |        | 1      |        |        |        | 2      | 0        | 3      |
| <i>Roeseliana roeselii</i>          |        |        | 1      | 2      | 2      | 2      | 3        | 4      |
| <i>Phaneroptera nana</i>            |        |        |        |        |        |        |          |        |
| <i>Ruspolia nitidula</i>            |        | 3      | 3      | 2      | 2      | 1      | 5        | 6      |
| <i>Platycleis grisea</i>            |        |        | 2      | 3      | 1      | 1      | 3        | 4      |
| <i>Tesselana veyseli</i>            |        |        | 2      |        | 1      |        | 3        | 0      |
| <i>Platycleis affinis</i>           |        |        |        | 1      |        | 1      | 0        | 2      |
| <i>Tettigonia viridissima</i>       | 1      |        | 1      |        |        |        | 2        | 0      |
| <i>Melanogryllus desertus</i>       | 3      | 1      | 2      | 1      |        | 1      | 5        | 3      |
| <i>Modiocoryllus frontalis</i>      |        |        |        |        |        |        |          |        |
| <i>Oecanthus pellucens</i>          |        | 2      |        |        |        | 1      | 0        | 3      |
| <i>Pteronemobius heydenii</i>       |        |        |        |        |        |        |          |        |
| <i>Xya variegata</i>                |        |        |        |        |        |        |          |        |
| <i>Tetrix bolivari</i>              |        |        |        |        |        |        |          |        |
| <i>Tetrix subulata</i>              |        |        |        |        |        |        |          |        |
| <i>Calliptamus italicus</i>         | 2      | 3      | 3      | 3      | 2      | 3      | 7        | 9      |
| <i>Chorthippus biguttulus</i>       |        |        |        | 3      |        | 1      | 0        | 4      |
| <i>Chorthippus brunneus</i>         | 2      | 1      | 3      | 3      | 2      |        | 7        | 4      |
| <i>Chorthippus dorsatus</i>         |        |        |        |        | 3      |        | 3        | 0      |
| <i>Chorthippus mollis</i>           |        |        | 2      |        |        |        | 2        | 0      |
| <i>Chorthippus oschei/albomarg.</i> | 1      | 1      |        |        | 3      | 3      | 4        | 4      |
| <i>Pseudochorthippus parallelus</i> | 2      | 2      | 2      |        | 2      |        | 6        | 2      |
| <i>Euchorthippus declivus</i>       | 2      | 3      | 3      | 4      | 3      | 3      | 8        | 10     |
| <i>Euchorthippus pulvinatus</i>     |        |        |        |        |        | 1      | 0        | 1      |
| <i>Oedipoda caerulea</i>            |        |        |        |        |        |        |          |        |
| <i>Mantis religiosa</i>             |        |        |        |        | 2      | 2      | 2        | 2      |
| <b>Abundance (semiquantitative)</b> | 15     | 20     | 27     | 25     | 27     | 24     | 69       | 69     |
| <b>Species richness</b>             | 8      | 10     | 13     | 10     | 13     | 14     | 16       | 16     |

### Small mammals

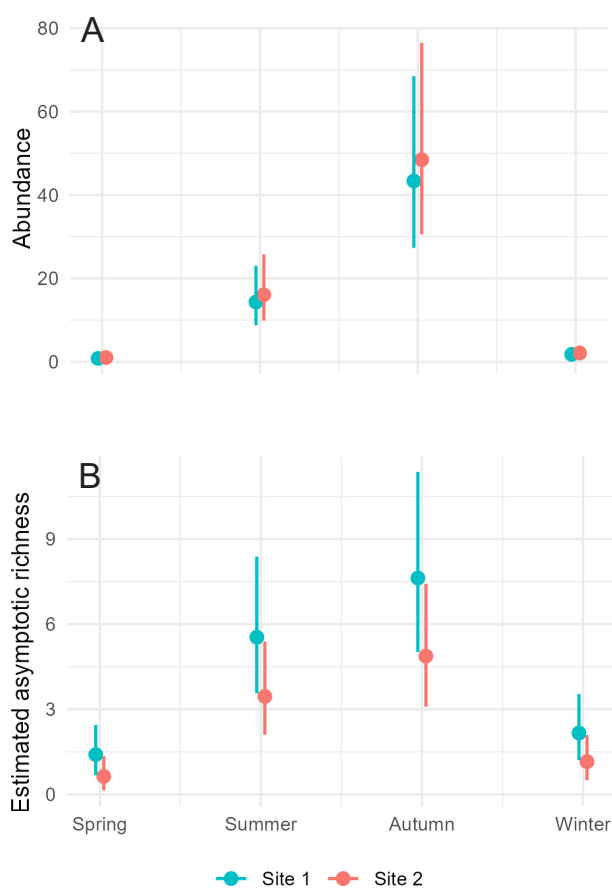
At Site 1, we captured 445 small mammals over a four-year study. We identified three eudominant species (>10%): the striped field mouse (*Apodemus agrarius*), the white-toothed shrew (*Crocidura suaveolens*), and the common vole (*Microtus arvalis*). The dominant species was the pygmy field mouse (*Apodemus uralensis*) (5–10%), while the other species were subdominant (5–2%) or recessive (2–1%). The frequency of occurrence was notably high, at 81% for the striped field mouse, 62% for the white-toothed shrew, and 56% for the common vole. For other species, the frequency of occurrence was less than 50% (Table 2). At Site 2, a total of 245 small mammals were captured.

We identified five eudominant species. One species was classified as subdominant, while the remaining four were recedent and subrecedent. The frequency of occurrence was highest for the white-toothed shrew (62.5%), followed by the wood mouse (*Apodemus sylvaticus*) and the pygmy field mouse (both at 50%). For all other species, the frequency of occurrence was 43.8% or less (Table 3). We did not observe any effect of year on small mammal abundance at Site (GLM:  $\chi^2_3 = 7.441$ ,  $p = 0.059$ ). Their abundance at Site 1 exhibited significant variation across seasons (GLM:  $\chi^2_3 = 230.123$ ,  $p < 0.0001$ ) (Fig. 2A) and among trapping plots (quadrats) (GLM:  $\chi^2_3 = 24.833$ ,  $p < 0.0001$ , Supplementary material Fig. S1).



**Fig. 1.** Orthopteran abundance (A) and species richness at Site 1 (blue columns) and Site 2 (red), after conversion to the grassland.

**Obr. 1.** Početnosť a druhové bohatstvo rovnokridlovcov na lokalite 1 (modré stĺpce) a lokalite 2 (červené stĺpce) po premene na trvalý trávnatý porast.



**Fig. 2.** Seasonal changes in the abundance (A) and species richness (B) of small mammals with an autumn peak at Sites 1 and 2; mean  $\pm$  95% CI (confidence interval).

**Obr. 2.** Sezónne zmeny v abundancii (A) a druhovom bohatstve (B) drobných cicavcov s jesenným vrcholom na lokalite 1 a 2; priemer  $\pm$  95 % CI (interval spoľahlivosti).

The abundance of small mammals gradually increased from spring, peaked in autumn, and then declined throughout winter, with significant differences between the compared seasons, except between spring and winter. Additionally, we found significant differences in abundance among the trapping plots, specifically between quadrats B/A, B/D, and C/D (Supplementary material Table S1). We also observed a significant effect of season on the abundance of small mammals at Site 2 (LM:  $F_{3,27} = 57.8$ ,  $p < 0.0001$ ), peaking in autumn and then declining in winter and spring (Supplementary material Table S3). We did not observe a significant difference in small mammal abundance between Site 1 and Site 2 (LM:  $F_{1,27} = 0.308$ ,  $p = 0.58$ ). We recorded a total of 12

species of small mammals at Site 1 and 10 species at Site 2. The species richness of small mammals varied significantly across seasons at both Site 1 (GLM:  $\chi^2_3 = 14.81$ ,  $p < 0.002$ ) and Site 2 (GLM:  $\chi^2_3 = 28.4$ ,  $p < 0.001$ ) (Fig. 2B). This variation mirrored the trends observed in small mammals' abundance, with significant differences between spring/summer, spring/ autumn, winter/summer, and winter/ autumn at both sites (Table S4). We did not observe any effect of trapping quadrat at Site 1 (LM:  $F_{3,54} = 2.62$ ,  $p = 0.06$ ) or year (LM:  $F_{3,54} = 0.87$ ,  $p = 0.461$ ). Species richness comparisons across both sites revealed a significant effect of season (GLM:  $\chi^2_3 = 35.754$ ,  $p < 0.0001$ ) and site (GLM:  $\chi^2_1 = 5.478$ ,  $p = 0.019$ ), with higher species richness at Site 1 than at Site 2 (Fig. 2B).

**Tab. 2.** Small mammals captured at Site 1 during 2021–2024.

**Tab. 2.** Drobné cicavce odchytené na lokalite 1 v priebehu rokov 2021 - 2024.

| Year                        | 2021   |        |        |        | 2022   |        |        |        | 2023   |        |        |        | 2024   |        |        |        | Σ   |      |    |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----|------|----|
| Species / Season            | winter | spring | summer | autumn | winter | spring | summer | autumn | winter | spring | summer | autumn | winter | spring | summer | autumn | n   | %    | F  |
| <i>Apodemus agrarius</i>    | 1      | 3      | 10     | 11     | 1      | -      | 5      | 16     | -      | 1      | 29     | 32     | -      | 1      | 7      | 22     | 139 | 31.2 | 81 |
| <i>Apodemus flavicollis</i> | -      | -      | 1      | 4      | -      | -      | -      | -      | -      | -      | -      | 1      | -      | -      | -      | 5      | 11  | 2.3  | 25 |
| <i>Apodemus sylvaticus</i>  | -      | -      | 2      | -      | 1      | -      | 7      | 2      | -      | -      | 1      | 5      | -      | 1      | -      | -      | 19  | 4.3  | 44 |
| <i>Apodemus uralensis</i>   | -      | -      | 11     | 8      | 2      | -      | 2      | 1      | -      | 1      | -      | -      | -      | -      | -      | -      | 25  | 5.6  | 38 |
| <i>Mus spicilegus</i>       | -      | 1      | 1      | 1      | -      | -      | -      | 2      | -      | -      | -      | 2      | -      | -      | -      | 1      | 8   | 1.8  | 37 |
| <i>Mus minutus</i>          | -      | -      | -      | -      | -      | -      | -      | 1      | -      | -      | -      | -      | -      | -      | -      | -      | 1   | 0.2  | 6  |
| <i>Myodes glareolus</i>     | -      | 1      | 2      | -      | -      | -      | 1      | -      | 1      | -      | -      | -      | -      | -      | -      | -      | 5   | 1.1  | 25 |
| <i>Microtus arvalis</i>     | -      | -      | 14     | 26     | -      | -      | 1      | 20     | -      | -      | 1      | 15     | 1      | 1      | -      | 10     | 89  | 20   | 56 |
| <i>Sorex araneus</i>        | -      | -      | -      | -      | 1      | -      | 1      | 1      | -      | -      | 2      | -      | -      | -      | -      | 2      | 7   | 1.6  | 31 |
| <i>Sorex minutus</i>        | -      | -      | -      | -      | -      | -      | -      | -      | -      | 1      | -      | -      | -      | -      | -      | -      | 1   | 0.2  | 13 |
| <i>Crocidura suaveolens</i> | -      | -      | 11     | 18     | -      | -      | 4      | 38     | -      | -      | 5      | 29     | 2      | 2      | 4      | 22     | 135 | 30.3 | 62 |
| <i>Crocidura leucodon</i>   | -      | 2      | 2      | -      | -      | -      | -      | 1      | -      | -      | -      | -      | -      | -      | -      | -      | 5   | 1.1  | 19 |
| Σ                           | 1      | 7      | 54     | 68     | 5      | 0      | 21     | 82     | 1      | 3      | 38     | 84     | 3      | 5      | 11     | 62     | 445 | 100  |    |
| Species richness            | 1      | 4      | 9      | 6      | 4      | 0      | 7      | 9      | 1      | 3      | 5      | 6      | 2      | 4      | 2      | 6      | 12  |      |    |

n – number of individuals, F – frequency of species occurrence (%) in 16 sampling events from 2021 to 2024

**Tab. 3.** Small mammals captured at Site 2 during 2021–2024.

**Tab. 3.** Drobné cicavce odchytené na lokalite 2 v priebehu rokov 2021 - 2024.

| Year                        | 2021   |        |        |        | 2022   |        |        |        | 2023   |        |        |        | 2024   |        |        |        | Σ   |      |      |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----|------|------|
| Species / Season            | winter | spring | summer | autumn | winter | spring | summer | autumn | winter | spring | summer | autumn | winter | spring | summer | autumn | n   | %    | F    |
| <i>Apodemus agrarius</i>    | -      | -      | -      | 9      | -      | -      | 2      | 4      | -      | -      | 5      | 5      | -      | -      | 4      | 8      | 37  | 15.1 | 43.8 |
| <i>Apodemus sylvaticus</i>  | 1      | 3      | -      | 2      | 3      | -      | 3      | 17     | -      | -      | -      | 4      | -      | -      | -      | 6      | 39  | 15.9 | 50   |
| <i>Apodemus uralensis</i>   | 2      | -      | 1      | 6      | -      | -      | 2      | 1      | -      | -      | -      | 19     | 2      | -      | -      | -      | 33  | 13.5 | 50   |
| <i>Mus spicilegus</i>       | -      | -      | 2      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | 2   | 0.8  | 6.3  |
| <i>Mus minutus</i>          | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | -      | 4      | 4   | 1.6  | 6.3  |
| <i>Myodes glareolus</i>     | -      | -      | -      | -      | -      | -      | -      | 1      | -      | -      | -      | -      | -      | -      | -      | -      | 1   | 0.4  | 6.3  |
| <i>Microtus arvalis</i>     | -      | -      | 3      | 1      | -      | -      | 8      | 10     | -      | -      | 4      | 30     | 1      | -      | -      | -      | 57  | 23.3 | 43.8 |
| <i>Sorex araneus</i>        | -      | -      | -      | 1      | -      | -      | -      | 1      | -      | -      | 4      | -      | -      | -      | -      | -      | 6   | 2.5  | 18.8 |
| <i>Crocidura suaveolens</i> | -      | -      | 3      | 1      | -      | -      | 3      | 2      | 1      | -      | 6      | 29     | 3      | -      | 7      | 10     | 65  | 26.5 | 62.5 |
| <i>Crocidura leucodon</i>   | -      | -      | -      | -      | -      | -      | -      | 1      | -      | -      | -      | -      | -      | -      | -      | -      | 1   | 0.4  | 6.3  |
| Σ                           | 3      | 3      | 9      | 20     | 3      | 0      | 18     | 37     | 1      | 0      | 19     | 87     | 6      | 0      | 11     | 28     | 245 | 100  |      |
| Species richness            | 2      | 1      | 4      | 6      | 1      | 0      | 5      | 8      | 1      | 0      | 4      | 5      | 3      | 0      | 2      | 4      | 10  |      |      |

n – number of individuals, F – frequency of species occurrence (%) in 16 sampling events from 2021 to 2024

## Raptors

We recorded 41 individuals of eight birds of prey species at Site 1. The eudominant species included the common buzzard with frequency rate 69% and the common kestrel with frequency rate 25% (Table 4). The dominant species was the western marsh harrier (with frequency rate 25%). The remaining recorded birds of prey species were

categorised as subdominant (with dominance from 5 to 2%), with a low frequency 6%. Our results indicated a positive effect of small mammal abundance on that of birds of prey at Site 1 (GLM:  $\chi^2_1 = 4.64$ ,  $p = 0.031$ ) (Fig. 3).

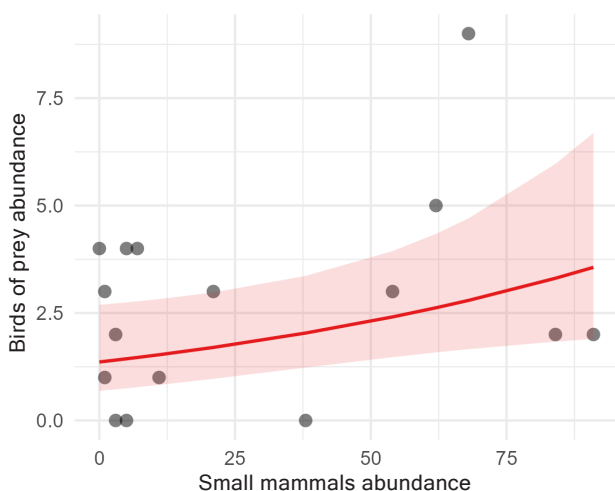
Additionally, the great grey shrike, a predatory passerine, was identified as another eudominant species (with frequency rate 44%).

**Tab. 4.** Birds of prey and great grey shrikes recorded at Site 1 during 2021 and 2024.

**Tab. 4.** Dravé vtáky a strakoš veľký zaznamenané na lokalite 1 v priebehu rokov 2021 až 2024.

| Year                        | 2021   |        |        |        | 2022   |        |        |        | 2023   |        |        |        | 2024   |        |        |        | Σ  |      |      |
|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|------|------|
| Species/ season             | spring | summer | autumn | winter | spring | summer | autumn | winter | Spring | summer | autumn | winter | spring | summer | autumn | winter | n  | %    | F    |
| <i>Accipiter nisus</i>      |        |        |        |        |        | 1      |        |        |        |        |        |        |        |        |        |        | 1  | 2.4  | 6.3  |
| <i>Buteo buteo</i>          | 3      | 1      | 2      | 2      |        | 1      | 1      |        |        |        | 1      | 1      | 1      |        | 1      | 1      | 15 | 36.6 | 68.8 |
| <i>Falco cherrug</i> †      |        |        |        | 1      |        |        |        |        |        |        |        |        |        |        |        |        | 1  | 2.4  | 6.3  |
| <i>Falco tinnunculus</i>    | 2      |        | 2      | 1      | 2      |        |        |        |        |        |        |        |        |        |        |        | 7  | 17.1 | 25   |
| <i>Circus aeruginosus</i> † |        | 1      | 1      |        |        | 1      |        |        |        |        |        |        | 1      |        |        |        | 4  | 9.8  | 25   |
| <i>Asio flammeus</i>        |        |        |        | 1      |        |        |        |        |        |        |        |        |        |        |        |        | 1  | 2.4  | 6.3  |
| <i>Asio otus</i>            |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | 1      | 1  | 2.4  | 6.3  |
| <i>Strix aluco</i>          |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | 1      | 1  | 2.4  | 6.3  |
| <i>Lanius excubitor</i> *   |        |        | 1      |        | 1      | 1      | 2      | 2      |        |        |        |        |        |        | 1      | 2      | 10 | 24.4 | 43.8 |
| Σ                           | 5      | 2      | 6      | 5      | 3      | 4      | 3      | 2      | 0      | 0      | 1      | 1      | 2      | 0      | 2      | 5      | 41 | 100  |      |
| Species richness            | 2      | 2      | 4      | 4      | 2      | 4      | 2      | 1      | 0      | 0      | 1      | 1      | 2      | 0      | 2      | 4      | 9  |      |      |

n – number of individuals, F – frequency of species occurrence (%) in 16 sampling events from 2021 to 2024; †species included in Annex I of Birds Directive, Natura 2000; \*the species was included due to its rarity and consumption of voles and large orthopterans.



**Fig. 3.** Positive effect of increased small mammal abundance on abundance of birds of prey at Site 1, red line – trend curve; light red frame – 95% CI (confidence interval).

**Obr. 3** Pozitívny vplyv rastu abundancie drobných cicavcov na abundanciu dravých vtákov na lokalite 1, červená čiara – trendová krivka; bledočervený rám – 95 % CI (interval spoľahlivosti).

## Discussion

Response to land-use management change  
The design of our study did not allow us to capture the complete effect of the transition from arable land to managed permanent grassland. The absence of an initial

stage of the studied assemblages on agricultural land before the transformation to grassland is a significant constraint of our research. Published data from similar natural conditions on arable land (not transformed) indicate that diversity is very low, consisting of only a few species of Orthoptera (Cherrill 2011; Arnóczkyné Jakab & Nagy 2022; Gardiner & Casey 2022) and small mammals (Heroldová et al. 2007; Zejda et al. 2025). At both transformed sites, we found 16 Orthoptera and Mantodea species and 12 small mammal species, which is comparable to other natural, relatively diverse sites within the Danube lowland area (Dudich et al. 1985; Fedor 1999; Krištín 2004; Krištín et al. 2004; Poláčiková 2010). Considering these findings, our results suggest that orthopterans and small mammals can respond rapidly to changes in land use and colonise newly created suitable habitats. The relatively high species richness recorded at the converted sites indicates that reduced land-use intensity may support the recovery of selected taxonomic groups in the study area. Similar patterns of rapid colonisation and relatively high diversity in restored or newly established grasslands have also been reported in other studies on Orthoptera (Arnóczkyné Jakab & Nagy 2022) or small mammals (Delattre et al. 1996).

The most frequent and abundant species at both converted sites were *Leptophyes albiovittata*, *Ruspolia nitidula*, *Melanogryllus desertus*, *Calliptamus italicus*, and *Euchorthippus declivus*. All of them are characteristic thermophilous species inhabiting lowland areas within

Central and Southeastern Europe. The species *M. desertus* is a steppic species, occurring mostly in traditionally managed agricultural land; other species are more generalists. Another eight orthopteran species, which may colonise the converted sites, were found nearby in surrounding habitats (Table 1).

The dominant small mammal species at Site 1 was the striped field mouse. This food and habitat generalist (Holišová 1967; Horváth et al. 2012) represents a new element of the community that has been expanding in southwestern Slovakia since 2010 (Tulis et al. 2025). Another dominant species, the white-toothed shrew, favours steppe and forest habitats and is trophically connected with the supply of invertebrates (Baláz et al. 2013). The common vole, a species characteristic of agricultural areas, was among the three most dominant species (20%). Its abundance did not exhibit any interannual fluctuations.

Orthopterans and small mammals are crucial components of the diet of all recorded birds of prey species in Slovakia (Karaska et al. 2002; Obuch 2011; Chavko et al. 2014, 2019). Our main finding is that a rise in birds of prey numbers was associated with an increase in small mammal populations at Site 1. The numerical or aggregate responses of birds of prey to increased food supply are well known (Norrdahl & Korpimäki 2002; Hoi et al. 2004; Brighton et al. 2022). In temperate ecosystems, the abundance of small mammal populations usually peaks in late summer and early autumn (Hansson & Henttonen 1985; Tkadlec & Zejda 1998), which is fully consistent with our results. This finding is relevant to the utilisation of agricultural ecosystems. Except for perennial fodder crops (which account for  $\approx 4.8\%$  of agricultural land) and permanent grassland ( $\approx 35\text{--}36\%$ ), most crops in Slovakia are harvested during the summer and early autumn (Report on agriculture and food production in the Slovak Republic for 2022, 2023). The agroecosystem in the post-production or post-harvest phase provides a poor food supply each autumn. This phase of the year or the life cycle of birds of prey is particularly challenging for yearlings and non-migratory birds of prey. The survival success of fledglings and their mortality rate essentially depend on the availability of food supply (Kouba et al. 2023, 2024). Generalist birds of prey can switch to alternative prey when their primary food sources become scarce. Specialists are typically nomadic and can move to areas with more abundant prey (Andersson 1980). However, simultaneous declines in multiple prey species can lead to food limitation, affecting not only breeding but also non-breeding populations (Rutz & Bijlsma

2006). Overall, the overwintering rate of birds of prey also depends on food supply (Salas et al. 2024). Habitat management thus plays a crucial role in supporting birds of prey populations during food scarcity. Creating and maintaining diverse habitats with a variety of prey options can help buffer birds of prey against food shortages (Álvarez et al. 2024). From this perspective, Site 1, which supports year-round permanent grassland with maximum abundance in autumn, has the potential to provide a food refuge for birds of prey and other terrestrial predators. Furthermore, the location may also serve as a spatial source (refuge) free of chemical interventions for a diverse array of other taxa, as has been documented in fungi, flora, invertebrates, and vertebrates (Eriksson 2021, Werling et al. 2014, Apfelbaum et al. 2025).

### **Comparison between sites**

We did not find statistically significant differences in Orthoptera species richness and abundance (1<sup>st</sup> year at Site 1 vs. 2<sup>nd</sup> year at Site 2 after conversion), or in small-mammal abundance, between Site 1 and Site 2 (2<sup>nd</sup> vs. 3<sup>rd</sup> years) after conversion from arable land to permanent grassland). This result suggests that, despite differences in site size, management and surrounding landscape context, both converted sites supported similar levels of Orthoptera abundance, Orthoptera species richness, and small-mammal abundance.

Species richness of small mammals differed between the two sites. While the trend was similar at both sites, richness was consistently higher at Site 1. This difference could be due to differences in site management after conversion. While Site 1 was mowed once or twice a year, Site 2 had been grazed seasonally by sheep and cows since 2021. Farm animals exhibit selective feeding, which alters vegetation (Rahmanian et al. 2019) and may affect the ecosystem's species composition (Török et al. 2024). Grazing alters vegetation structure and composition, reducing species diversity and population sizes of small mammals (Horncastle et al. 2019; Li et al. 2019). Since we did not observe differences in species richness among the four monitored quadrats at Site 1 (Supplementary material Table S2), we do not assume that the differences are caused by more diverse neighbouring habitats.

To conclude, our research underscores the swift adaptability and colonisation capabilities of orthopterans and small mammals in response to the transformation of long-term intensively used arable land into managed permanent grassland. The land use change enhanced the diversity of the studied assemblages and provided a stable food supply for birds of prey, whose abundance

was positively correlated with that of small mammals. These findings are in line with our expectations (predictions *i*, *ii*). Given our results, we suggest that insect/orthopteran monitoring could be a powerful approach for tracking short-term ecological changes. However, for a comprehensive assessment, it should be coupled with long-term vertebrate monitoring (e.g., small mammals and birds). Given the limitations of our study, we emphasise the reliable registration of the initial state to comprehensively measure the impact of land-use or management changes on the original habitat.

### Competing interests

FT and RS are members of the editorial board of the Raptor Journal but were not involved in any editorial processes related to this submission. All other authors declare no competing interests.

### Use of AI tools

The authors declare that no AI tools were used in any way during the creation of this manuscript.

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### Supplementary material

The Supplementary material for this article can be found online at: <https://sciencedirect.com/journal/SRJ>