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Short communication

Uncropped habitats under power pylons are overlooked refuges for small mammals in agricultural landscapes

Martin Šálek[a,b,*], Radovan Václav[c], František Sedláček[d]

[a] The Czech Academy of Sciences, Institute of Vertebrate Biology, Květná 8, 603 65 Brno, Czech Republic
[b] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 1176, Suchdol, 16521 Prague, Czech Republic
[c] Institute of Zoology, Slovak Academy of Sciences, Dúbravská Cesta 9, 845 06 Bratislava, Slovakia
[d] Department of Zoology, Faculty of Science, University of South Bohemia, Branišovská 1760, 370 05 České Budějovice, Czech Republic

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ABSTRACT

Agricultural intensification has led to landscape simplification partially due to massive reduction in the area of biodiversity-rich non-cropped habitats. Power lines and their associated infrastructure occurring in homogeneous farmland have recently been suggested to provide suitable habitat resources for some animals. This is the first study to investigate the importance of high-voltage power pylons in providing habitats of uncropped patches for small mammal communities in the agricultural landscape. We found that the abundance and species richness of small mammals during the winter was significantly higher in uncropped habitat patches under power pylons compared to the surrounding farmland. We suggest that power line infrastructure in the agricultural landscape may represent a crucial, though overlooked, refuge for small mammals by providing them with persistent habitat for wintering and spring dispersal.

1. Introduction

Agricultural intensification during the last century has substantially transformed the structure and functioning of European agricultural landscapes, with lowland arable regions specialized for crop production having been most heavily influenced (Stoate et al., 2009). It is currently common that small islands of natural and semi-natural habitats are surrounded by tens to hundreds of hectares of intensively used farmland (Benton et al., 2003). Moreover, agricultural specialization in the production of a few profitable crops has led to the simplification of traditional crop rotations resulting in the further homogenization of farmland structure. Finally, the intensification of management practices, including greater pesticide and fertilizer use or agro-technical operations involving soil disturbances during tillage, are characteristic for intensive agricultural production (Stoate et al., 2009). All of these factors are responsible for a substantial reduction of landscape complexity, which is reflected by a massive decline in farmland biodiversity (Tilman et al., 2001; Butler et al., 2010; Pavliska et al., 2018; Šálek et al., 2018).

Small mammals are fundamental elements of ecosystem functioning. Although some species are considered as agricultural pests, others have beneficial roles in consuming weed seeds and invertebrate pests (e.g. Brown et al., 2007; Fischer et al., 2011a). Small mammals are also crucial prey for diverse mammalian and avian species and their distribution and numbers affect the functional and demographic response of predators (de Bruijn, 1994; Šálek et al., 2010; Pavluččík et al., 2015). At the farm scale, intensive crop production leading to landscape simplification is often associated with less abundant and diverse small mammal communities (Fischer et al., 2011b). Yet, the abundance of some generalist species may be even higher in more intensively cultivated landscapes (Gentili et al., 2014). At the landscape scale, small mammals may be more abundant in a variety of uncropped habitats compared to cropped areas, including field margins, fallow land, road verges, hedges, shrubland, and small insular forests (e.g. Heroldová et al., 2007; Broughton et al., 2014). These patches may thus represent important predictors of species persistence and colonization within farmland (Heroldová et al., 2007; Michel et al., 2007).

Medium and high voltage power lines are an anthropogenic threat to wildlife. For example for birds, power lines pose a deadly risk, through collisions with wires or pylons and electrocution, and for some bird species may constitute a major source of anthropogenic mortality (Loss et al., 2014). However, power lines and their associated infrastructure may also have a positive conservation value by providing uncropped early-succession habitats, thus benefiting e.g. endangered species of butterflies or solitary bees (Russel et al., 2005; Berg et al., 2016). A recent study by Tryjanowski et al. (2014) has shown that

* Corresponding author at: The Czech Academy of Sciences, Institute of Vertebrate Biology, Květná 8, 603 65 Brno, Czech Republic.
E-mail address: martin.sali@post.cz (M. Šálek).

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power lines play a positive rolefor birds inhabiting agricultural landscapes. Namely, uncropped patches under power pylons provide birds with alternative nesting and foraging habitats, and the pylons themselves serve as suitable nesting sites, song posts and hunting perches.

This is the first study investigating the importance of semi-natural uncropped habitat patches associated with power pylons for small mammals in the agricultural landscape. In particular, we investigated differences in the abundance and species richness of small mammals under power pylons and adjacent cropped farmland during winter. We hypothesised that both the abundance and species richness of small mammals should be higher in habitat patches under power pylons compared to cropped farmland. Hence, we aim to 1) explore the hidden potential of the habitats associated with power lines within intensively used farmland and 2) stimulate potentially productive research ideas.

2. Material and methods

The study area represents intensively-used arable farmland located in the region of South Bohemia in the Czech Republic (centred on: N 49°1.16325', E 14°31.99055'). The study region has a gently rolling topography (with altitudes from 380 to 490 m) and land use is composed of a mosaic of agricultural land dominated by arable fields, grasslands (intensive hayfields and pastures), small secondary coniferous or mixed forest patches, human-made fishponds and human settlements. Arable fields are mainly used for the cultivation of cereals (especially winter wheat), maize and oilseed rape, with a smaller proportion of legumes and alfalfa (for more details see Šálek et al., 2014). The majority of arable fields during winter are covered by low vegetation or are ploughed.

The selection of study plots was based on several criteria. First, we searched for locations with high-voltage (110 kV and 400 kV) power pylons using satellite maps. We searched for power pylons surrounded by crop fields and avoided selecting study plots in grasslands, fallow land, or other semi-natural vegetation, as those habitats are known to be important habitats for small mammals in the agricultural landscape (Heroldová et al., 2007; Michel et al., 2007). The geographic location of individual power pylons was projected in the GIS environment (QGIS, 2012) and subsequently we selected paired control patches in cropped fields within farmland. The control patches in farmland were located 50 m from power pylon patches, both patches having been located in the same type of crop field to avoid the confounding effects of crop composition, farming practices, or local and landscape habitat structure on the abundance and species richness of the small mammals (Fischer et al., 2011b). Moreover, the position of plot pairs (power pylon and control patches) was always situated inside a crop field (i.e. more than 50 m from the nearest habitat edge), as small mammal abundances in farmland increase with decreasing distance to habitat edges (e.g. Šálek et al., 2010).

The community structure and abundance of small mammals were surveyed using snap-trapping during the single winter season of 2018/2019 (December 2018 – mid-February 2019). The snap traps were baited with wicks soaked in fried fat and flour, which have been shown to be appropriate bait for voles, mice, and shrews (Heroldová et al., 2007). The captured individuals were used for pilot testing of the possible influence of the electromagnetic field on selected somatic parameters (e.g. Fernie and Reynolds, 2005), including the state of the genital organs, the relative weight of the internal organs including the adrenal glands, the incidence of tumours, and the endoparasite load (these results are not presented in this study). At both patches (i.e. power-pylon and farmland) within each study plot, four snap-traps were placed in a square and one in the centre of the patch, totalling five snap-traps per patch (i.e. 10 traps per study plot). Snap traps under power-pylon patches were placed in the corners of the concrete or steel bases of pylons. The area under 110 kV power pylons was on average three times smaller than the one under 400 kV pylons (110 kV - mean ± SD: 9.5 ± 25.2 m^2, n = 43 vs. 440 kV - mean ± SD: 30.5 ± 24.3 m^2, n = 60). Therefore, the trapping grid size in each farmland patch followed that of the corresponding power pylon patch. Traps were exposed for 24 h in favourable weather conditions, i.e. no snowfall or heavy rain (Šálek et al., 2010), resulting in a total of 1030 trap-nights (n = 103 study plots). Moreover, as a supplementary method to snap-trapping we used a burrow index, which has been found to be a reliable and efficient indirect method for estimating vole abundance and which provides a density estimate similar to that obtained by capture–mark–recapture trapping or snap-trapping (Liro, 1974; Jareño et al., 2014). In particular, we counted all burrow entrances within 1-m belt transects delineated on the margins of power pylon patches; the same transect length and shape was used for the corresponding farmland patches. An estimate of small mammal density was calculated as the number of burrow entrances per 1 m of transect length.

The uncropped habitats under power pylons consisted of ruderal vegetation, e.g. grasses and herbaceous plants (dominated by clonal grass *Calamagrostis epigejos* and couch grass *Elymus repens*) and shrubs (dominated by elder *Sambucus nigra*, blackthorn *Prunus spinosa,* and blackberry *Rubus* sp.). To consider the potential effect of vegetation cover on the abundance and species richness of small mammals, we visually assessed the cover (%) of ruderal and shrub vegetation under the power pylons. Similarly, uncropped power pylon patch size (m^2) was assessed as it may significantly influence small mammal assemblages, with smaller patches providing lower habitat heterogeneity and availability of food resources resulting in increased intra- or interspecific competition.

3. Statistical analysis

Since multiple parameters of small mammal abundance and community structure were assessed, we first aimed at reducing this number in order to extract the most important components of variation in our data and to avoid examining inter-correlated parameters, such as burrow density and common vole abundance. Consequently, we conducted PCA analysis, including the total number of small-mammal individuals trapped in a patch, the total number of small mammal species trapped in a patch, the total number of common voles trapped in a patch, the total number of wood mice trapped in a patch, and the density of rodent burrow entrances in a patch. We did not include data on the yellow-necked mouse, common shrew, or white-toothed shrew in the PCA, because these species were rarely trapped (cf. Table 1). All variables were scaled before PCA. The PCA revealed two principal components with eigenvalues > 1 that cumulatively explained 80.9 % of the variance and succinctly described the relationships among the five variables (Table S1). Namely, PC1 captures positive relationships between all five variables. Therefore, PC1 represents an index of small mammal abundance as well as species richness. In turn, PC2 captures the inverse relationship between wood mouse and common vole

Table 1
Abundance (A) and prevalence (P, %) of individual small-mammal species as well as the burrow index (number and range of burrows per 1 m transect) for power pylons and farmland patches at 103 study plots.

Species	Power pylons		Farmland		Total	
	A	P	A	P	A	P
Common vole	54	36.9	2	1.9	56	38.8
Yellow-necked mouse	3	1.9	0	0.0	3	1.9
Wood mouse	55	32.0	5	3.9	60	35.9
White-toothed shrew	1	1.0	0	0.0	1	1.0
Common shrew	5	4.9	0	0.0	5	4.9
	Density	Range	Density	Range	Density	Range
Burrow index	0.7	0.1-3.2	0.03	0-0.5	0.3	0-3.2

abundances and, therefore, can be viewed as an index of rodent community structure within study plots (Supplementary material 1).

We used linear mixed models (LMMs) to investigate how habitat features affect small mammal abundance and species richness (PC1) and community structure (PC2) in the agricultural landscape. Specifically, we studied two effects of habitat type at the study plots: 1) habitat patch type (i.e. power pylon vs. farmland patches) and 2) crop type. We used inverse values of PC1 scores such that the highest score values corresponded to the highest values of small mammal abundance and species richness. Plot identity (n = 103 study plots) was used as a random factor to account for the paired design of power pylon (uncropped) and farmland (cropped) patches within the same plots. Moreover, surveyor identity (MŠ and FS) and power pylon type (110 and 400 kV) also were used as random factors to account for potential variation in PC1 and PC2 between surveyors and power pylon types. The size of the uncropped area under pylons and the cover of ruderal/shrub vegetation (centred and scaled before analysis) did not significantly relate either to PC1 or PC2 for power-pylon patches (Supplementary material 2). Therefore, we did not explicitly consider these covariates in LMMs on the effects of habitat type, though the effects of the covariates were implicitly considered through the inclusion of the random intercept for power pylon type (the patches under 400 kV pylons were more than three times larger than those under 110 kV pylons; see above).

All analyses were conducted with the R software (R Core Team, 2018), using the *prcomp* function in the *stats* package 3.5.2 and the *lme* function in the *nlme* package 3.1–139 (Pinheiro et al., 2019).

4. Results

In total, 125 small mammal individuals were captured, with the species including the wood mouse *Apodemus sylvaticus*, common vole *Microtus arvalis*, yellow-necked mouse *A. flavicollis*, common shrew *Sorex araneus,* and white-toothed shrew *Crocidura suaveolens*. The most frequently captured species were wood mouse and common vole, comprising 48 % and 44.8 % of all captured individuals, which were recorded at 35.9 % and 38.8 % of the study plots, respectively (Table 1). We detected 1112 burrows of small mammals and their densities ranged from 0 to 3.2 burrows per 1 m transect (Table 1).

The abundance and species richness of small mammals, in terms of PC1, was significantly higher under power pylons compared to the adjacent farmland ($F_{1,102}$ = 138.01, P < 0.0001; Table 2). In contrast, the abundance and species richness of small mammals within study plots did not differ with respect to crop type occurring in farmland patches surrounding the power pylon habitat patches ($F_{5,94}$ = 0.41, P = 0.843).

Table 2
Linear mixed model on the relationship between small-mammal abundance and species richness, in terms of PC1, and two habitat attributes – habitat type (power pylon vs farmland) and crop type in farmland surrounding uncropped habitat patches. Uncropped habitat patch was used as the reference level for habitat type and alfalfa was used as the reference level for crop type. Random effect of study plot ID was nested in pylon type and in surveyor ID; SD are shown for random factors.

Parameter	Estimate	SE	df	*t*	*P*	SD
Random terms						
Surveyor ID						≈0
Pylon type						≈0
Study plot ID						≈0
Fixed terms						
Intercept	0.79	0.43	102	1.82	0.071	
Habitat (farmland)	−2.19	0.19	102	−11.75	< 0.001	
Crop (set aside)	0.74	1.04	94	0.71	0.478	
Crop (oilseed rape)	0.56	0.47	94	0.98	0.331	
Crop (ploughed)	0.36	0.47	94	0.77	0.442	
Crop (stubble)	1.09	1.04	94	1.05	0.295	
Crop (winter wheat)	0.27	0.44	94	0.61	0.540	

Table 3
Linear mixed model on the relationship between small mammal community structure, in terms of PC2, and two habitat attributes – habitat type (power pylon vs farmland) and crop type in farmland surrounding uncropped habitat patches. Uncropped habitat patch was used as the reference level for habitat type and alfalfa was used as the reference level for crop type. Random effect study plot ID was nested in pylon type and in surveyor ID; SD are shown for random factors.

Parameter	Estimate	SE	df	*t*	*P*	SD
Random terms						
Surveyor ID						0.40
Pylon type						0.23
Study plot ID						≈0
Fixed terms						
Intercept	0.60	0.45	102	1.33	0.187	
Habitat (farmland)	−0.33	0.13	102	−2.49	0.015	
Crop (set aside)	−1.33	0.74	94	−1.79	0.076	
Crop (oilseed rape)	−0.98	0.41	94	−2.34	0.019	
Crop (ploughed)	−0.81	0.35	94	−2.30	0.023	
Crop (stubble)	−0.91	0.74	94	−1.23	0.222	
Crop (winter wheat)	−0.39	0.32	94	−1.21	0.228	

The community structure of small mammals, in terms of PC2, was found to differ between power pylon and adjacent farmland habitat patches (Table 3). Specifically, considering two dominant rodent species, power pylon habitat patches were characterised by a relatively higher abundance of common vole, while farmland patches showed a relatively higher abundance of wood mouse ($F_{1,102}$ = 6.19, P = 0.015). Crop type within the study plots also played a role in the community structure of small mammals ($F_{5,94}$ = 2.71, P = 0.025). Specifically, while study plots within alfalfa crops showed relatively higher common vole abundances, study plots within set-aside fields showed relatively higher wood mouse abundances (Table 3).

5. Discussion

This study is to our knowledge the first to show that uncropped habitat patches under power pylons act as an important habitat for small mammals in agricultural landscapes. Traditionally, power lines are widely recognized as a crucial threat to wildlife, mainly due to the risks of mortality from collision and electrocution in birds (Bevanger, 1998). However, in recent decades, researchers and conservationists have reported examples of positive effects of power line infrastructure for some organisms and their assemblages, including rare and threatened species of invertebrates (Russel et al., 2005; Berg et al., 2016) or birds (Tryjanowski et al., 2014). The positive effects in all these cases were attributed to the occurrence of semi-natural (ruderal) habitat patches associated with power lines, though some birds in addition use power pylons as song posts, hunting perches or nesting sites.

The preference of small mammals for uncropped farmland habitats under high-voltage power pylons is likely a combined effect of suitable conditions for resting and foraging, especially during the winter, when sufficient foraging resources are of particular importance. Specifically, uncropped habitats under power pylons mostly consisted of ruderal vegetation and/or shrubs that offer a rich supply of seeds and berries, thus providing limiting food resources for herbivorous small mammals during winter. In intensively managed crop fields within farmland, communities of small mammals are heavily disturbed by agricultural operations, which can imply both direct (mortality during agricultural operations) and indirect (reduction of foraging resources, risk of poisoning by pesticides, or destruction of burrow systems) negative effects. In contrast, the patches of uncropped habitats under power pylons provide relatively persistent habitats for small mammals and may, therefore, serve as their winter refugia. Both of the dominant species, wood mouse and common vole, are commonly associated with cropped habitats within farmland, though their distribution during the winter is concentrated in a variety of uncropped habitats, especially including semi-natural vegetation (Tattersall et al., 2001; Broughton et al., 2014; Jacob et al., 2014). Therefore, uncropped habitats under power pylons appear to provide small mammals with suitable habitats and may act as source habitat for dispersion in the early spring (Ouin et al., 2000). Moreover, power lines leading through an unhostile farmland matrix may also represent important stepping zones for dispersal of small mammals, but this idea needs to be addressed in further research. Despite the fact that crop type did not affect abundance and species richness of small mammals, it is important to note that study plots within alfalfa fields showed a relatively higher abundance of common vole, whereas study plots within fallow fields showed a relatively higher abundance of wood mice (c.f. Heroldová et al., 2007).

In conclusion, our study provides the first evidence of the potential importance of uncropped habitats under power pylons for small mammals suggesting an intriguing area for further research. These insular habitats associated with power-line infrastructure may represent overlooked refugia for small mammals of farmland ecosystems as they constitute suitable and persistent habitats for wintering and spring dispersal. Apart from the positive effects on small mammal communities, the refugia under power pylons may serve as important foraging habitats for avian and mammalian predators due to the combination of increased abundance of small mammals and due to, with regard to avian predators, higher availability of elevated hunting perches (Shrubb, 1982). Considering hundreds of thousands of power pylons in Europe, directed management of these habitats may increase the biological potential of intensive agricultural landscapes and contribute to the conservation of farmland biodiversity. Future work is needed to concomitantly address the potentially negative effects of electromagnetic fields from power lines on the biology and behaviour of organisms exploiting this habitat type (Fernie and Reynolds, 2005). Finally, in order to address the potential conflict with farmers, it should be established how persistent uncropped habitats, including those associated with power pylons, affect the spatial and temporal distribution of small mammals and their predators in farmland. In this way, it would be possible to inform stakeholders about the relative roles of uncropped habitats in promoting the biological control of pest species in the surrounding cropland (c.f. Morandin and Winston, 2006).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.agee.2019.106777.

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