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Bird biodiversity and its conservation in Central European non-forest woody vegetation – the importance of habitat, landscape mosaic and management

Summary of the Ph.D. Thesis

Supervisor: prof. Mgr. Jiří Reif, Ph.D.

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Articles involved in the thesis

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Dvořáková, L., Kuczyński, L., Rivas-Salvador, J., & Reif, J. (2022). Habitat characteristics supporting bird species richness in mid-field woodlots. *Frontiers in Environmental Science*, *10*, 816255. https://doi.org/10.3389/FENVS.2022.816255

Publication 2

Dvořáková, L., Hernová, J., Bušek, O., & Reif, J. (2023). Relationships between bird species richness and different facets of landscape heterogeneity – insights from a military area. *Journal of Vertebrate Biology*, *72*, 23012. https://doi.org/10.25225/jvb.23012

Publication 3

Dvořáková, L., Hanzelka, J., Romportl, D., & Reif, J. (2024). Habitat changes explain shifts in bird community composition in abandoned military training areas: Lessons for conservation. *Journal for Nature Conservation*, *79*, 126612. https://doi.org/10.1016/j.jnc.2024.126612

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Reif, J., Chajma, P., Dvořáková, L., Koptík, J., Marhoul, P., Čížek, O., & Kadlec, T. (2023). Biodiversity changes in abandoned military training areas: relationships to different management approaches in multiple taxa. *Frontiers in Environmental Science*, *11*, 1243568. https://doi.org/10.3389/fenvs.2023.1243568

Abstract

Non-forest woody vegetation is an integral part of the Central European landscape. It includes all possible forms of woody vegetation growing outside of forests, agricultural production, and human settlements; it thus represents a non-productive habitat crucial to the conservation of farmland biodiversity. In this dissertation, I am looking for an answer to the question of what factors affect biodiversity in non-forest woody vegetation and in what way, observing the effect mainly on birds as an indicator group sensitive to changes in the agricultural landscape. In a total of four publications, we focused on the white spots in research to date – habitat characteristics of non-forest woody vegetation, characteristics of the landscape mosaic, and applied management. We have shown that all these factors significantly affect bird biodiversity and, thus, the success of conservation measures and agricultural subsidies oriented towards non-forest woody vegetation. While woody vegetation in the form of mature and species-variegated stands of native trees will rather support forest species and, at the same time, a high total number of species, stands enriched by various earlier stages of succession will rather support farmland species. Furthermore, we show that in the landscape context habitat diversity is key for a large number of bird species, but for endangered species the fine-grained mosaic of non-forest woody vegetation is especially beneficial. We show that such a valuable fine-grained mosaic of non-forest woody vegetation can be found, for example, in military training areas thanks to the special disturbance regime arising as a secondary effect of military training. When these disturbances end, the mosaic of non-forest woody vegetation gradually disappears by transformation into urban areas, as well as by natural succession. The effect of natural succession can be reversed by suitably chosen disturbance management - based on to our results, conservation grazing (but also agricultural grazing) appears to be particularly suitable for the protection of bird biodiversity. However, comparisons of birds with other taxa reveal considerable differences in management preferences. The results of this work emphasize the fact that non-forest woody vegetation hosts a wide range of species with different ecological requirements and that the key to protecting biodiversity is, in addition to ensuring its sufficient quantity in the landscape, above all ensuring its diversity, both on a local and landscape scale.

Introduction

The term "non-forest woody vegetation" refers to woody vegetation that is located outside of urban areas and is neither forest nor agricultural land (Kolařík, 2003). Non-forest woody vegetation is an integral part of the Central European open landscape - it occurs in the form of solitary trees, vegetation along roads and waterways, hedgerows, shrublands, windbreaks, woodlots, etc. In the current intensively managed agricultural landscape, which is facing a drastic decline in biodiversity (Stoate et al., 2009), non-forest woody vegetation provides refuges for a number of organisms, including many endangered species - be it plants (Bergmeier et al., 2010), insects (Sebek et al., 2016), or vertebrates (Fuller et al., 2004). Thanks to the varied range of habitat conditions, we can find species with different habitat preferences - from grassland to forest species (Takkis et al., 2018). Many of them are closely tied to non-forest woody vegetation as it essentially represents the only alternative to their natural forest-steppe environment, now completely suppressed by humans (Wright et al., 2011).

However, over the past half century, non-forest woody vegetation in the European landscape has been significantly suppressed, and with it the associated biodiversity. It has been caused by agricultural intensification and the associated removal of non-productive habitats, as well as the abandonment of marginal agricultural areas and the subsequent overgrowth of the landscape (Benton et al., 2003; Foley et al., 2011). The task of nature conservation is to find an effective way of restoring and managing non-forest woody vegetation in the landscape. This thesis contributes to this by examining the effect of the habitat characteristics of non-forest woody vegetation, the effect of the landscape mosaic, and the effect of different management types on the number of species, species diversity, and species composition of the bird community. We work with birds as an indicator of overall biodiversity, but also offer comparisons with other, ecologically different taxa.

Aims of the thesis

- To investigate what habitat characteristics affect bird biodiversity in non-forest woody vegetation (Publication 1).
- To investigate how different components of heterogeneity affect bird biodiversity in a landscape mosaic with non-forest woody vegetation (Publication 2).
- To investigate whether the landscape mosaic formed by military disturbance differs in the various components of heterogeneity compared to the normal agricultural landscape (Publication 2).
- Evaluate changes in the landscape with non-forest woody vegetation and its bird biodiversity after the disappearance of military disturbance (Publication 3).
- Evaluate the impact of different types of subsequent management on bird biodiversity in this landscape and compare the findings with the preferences of other taxa (Publication 4).

Effect of area, isolation, and shape of non-forest woody vegetation

Although the effect of the area, isolation, and shape of non-forest woody vegetation is not the subject of this thesis, I consider it important to at least briefly present it here as these are characteristics that significantly affect the bird biodiversity. From the point of view of the island theory of biogeography, non-forest woody vegetation can be considered as islands of "forest" habitat located in the inhospitable matrix of an open landscape, while the number of species in such islands is mainly determined by their size and isolation from the surrounding "forest" environment (Loman & Von Schantz, 1991; Tworek, 2002). Research to date has indeed confirmed that the number of bird species increases with the area of non-forest woody vegetation and that it can, in contrast, decrease with increasing isolation. However, in this relationship, there are significant differences between forest species and farmland species, where forest species are limited in size and isolation much more significantly than the farmland ones, which also commonly use the "matrix" in the form of an open landscape (Batáry et al., 2012; Bellamy et al., 1996; McCollin, 1993). For this reason, birds of agricultural landscapes also seek out islands with a less compact shape, i.e. with higher proportion of ecotonal habitats (Bellamy et al., 1996).

Effect of habitat characteristics of non-forest woody vegetation

(Publication 1)

While the effect of the area, shape, and isolation of non-forest woody vegetation on bird biodiversity is relatively well described, we do not know much about the significance of habitat characteristics. Therefore, the first part of our research investigated how habitat characteristics of non-forest woody vegetation affect bird biodiversity. We studied 82 small isolated woodlots of a compact shape surrounded by intensively farmed agricultural land. In each woodlot, we determined the tree height, density of the shrub and tree layers, woody plant species richness, proportion of non-native tree species, and diversity of microhabitats. At the same time, we conducted bird surveys in each one and determined the total number of bird species in each woodlot, calculated the total species diversity of birds (using the Shannon index) and, based on habitat preferences provided by Reif et al. (2010), we determined the number and diversity of forest and farmland species.

We found that total bird species diversity and species diversity of only forest birds increased with tree height and with woody plant species richness; in contrast, they were negatively affected by the dominance of the non-native Black Locust (*Robinia pseudoacacia*) in woodlots. The species diversity of farmland birds depended positively only on the microhabitat diversity of woodlots. The results for the number of species and species diversity were consistent in all cases.

Our results show that habitat characteristics affect not only the total number of bird species in non-forest woody vegetation, but also the composition of the bird community. The effort to maximize overall diversity, which is a frequent conservation practice and the goal of agricultural subsidies, rather supports commonly distributed forest species. However, the priority for conservation in non-forest

woody vegetation should clearly be the farmland species found here, as they are closely linked to this habitat and include a number of endangered and specialized species. Our results show that, if we want to support bird biodiversity in non-forest woody vegetation, it is necessary to think not within the framework of one element, but within the entire landscape and ensure a variety of different non-forest vegetation stands with different habitat characteristics, including earlier successional stages.

Effect of heterogeneity of landscape mosaic with non-forest woody vegetation *(Publication 2)*

Biodiversity generally increases with higher landscape heterogeneity. However, the role of the individual components of heterogeneity – habitat composition and configuration – has not yet been satisfactorily unravelled (Reynolds et al., 2018). Therefore, in this work, we examined how both components of landscape heterogeneity affect the number of species and the number of endangered bird species in a landscape with non-forest woody vegetation. As explanatory variables, we measured two factors of the landscape mosaic: habitat diversity expressed by the Shannon index (indicating compositional heterogeneity) and the number of woody vegetation patches (indicating configurational heterogeneity; Bennett et al., 2006). The explained variables were the total number of all bird species and the number of threatened bird species detected in the research areas (Act No.114/1992 Coll. on Nature Conservation and Landscape Protection, 1992, https://www.zakonyprolidi.cz/cs/1992-114; Šťastný & Bejček, 2003).

We found that only habitat diversity had a significant effect on the total number of bird species - positive at first, but negative after crossing a certain diversity threshold. The number of endangered bird species was higher in the study plots with a higher number of woody vegetation patches. This relationship was linear, however, when the number of patches was logarithmized.

Our results show that if we want to support endangered bird species in the agricultural landscape, the best solution is not to establish the largest possible compact stand of non-productive woody vegetation (see the effect of area above); on the contrary, what is required is as many small patches as possible scattered in the landscape, including solitary trees and shrubs. In the context of other research, it may be appropriate to establish a so-called archipelago, i.e. several patches in close proximity to each other (Loman & Von Schantz, 1991). Judging by the shape of the relationship modelled by us, it will be of the greatest benefit to establish non-forest woody vegetation where there is still an absolute minimum of it.

On the other hand, as shown by the negative trend in the number of species at excessively high values of habitat diversity, this principle cannot be applied to other types of habitats such as forests, meadows, wetlands, or water bodies. Although high heterogeneity is also generally desirable in these habitats (Tews et al., 2004), when diversification exceeds a certain limit, the negative effect of the limited habitat area and the related limited dispersion prevail (the "area-heterogeneity trade-off"; Allouche et al., 2012).

Landscape mosaic shaped by military disturbance *(Publication 2)*

Recently, it has been shown that a large part of the biodiversity of (not only) Central Europe is hidden in military training areas (Bušek & Reif, 2017; Harabiš & Dolný, 2018; Warren & Büttner, 2008). According to the theory of Warren et al. (2007), this is due to the heterogeneity of the disturbance regime that takes place here, which creates a highly heterogeneous landscape. In this part of the thesis, we decided to verify this theory and find out whether the heterogeneity of the landscape mosaic (specifically the number of woody vegetation patches and overall habitat diversity) differs between a military training area and an ordinary agricultural landscape.

We found that there are significantly more patches of non-forest woody vegetation in the military training area than in the agricultural landscape. This is certainly due to the difference in the disturbance regime that shapes the non-forest woody vegetation. While in the agricultural landscape we mainly find continuous linear greenery along roads, watercourses, or the edges of fields or large, clearly demarcated woodlots, in the military training area we find non-forest woody vegetation randomly scattered, in various stages of disturbance and regrowth, often on relatively large areas. The resulting mosaic of non-forest woody vegetation is thus of a much finer grain. In contrast, the habitat diversity of the landscapes inside and outside the military training area did not differ. Apparently, military disturbance does not create more habitat types than human activities in agricultural landscapes, at least not at the spatial scale relevant to birds.

Changes in landscape mosaic after the disappearance of military disturbance *(Publication 3)*

Since many military training areas in Central Europe were gradually abandoned from the 1990s, we further focused on what changes in the landscape and its bird biodiversity took place after the disappearance of military disturbance. Our study set consisted of 30 abandoned military training areas with a mostly open landscape located throughout the Czech Republic. In these areas, together with our predecessors (Reif et al., 2013), we carried out both habitat composition monitoring and bird monitoring in 2009 and in 2020–21.

Our results show that within a decade, in abandoned military training areas with a predominantly open landscape character, grasses and sparse shrubs decreased, while dense shrubs, forest, build-up areas, and areas of bare ground expanded. Similarly, the change in bird species abundance was significant between the two periods. Among the species with the greatest decrease in abundance were Whinchat (*Saxicola rubetra*), Grasshopper Warbler (*Locustella naevia*), and European Greenfinch (*Chloris chloris*). In contrast, we recorded the greatest increase in Woodlark (*Lullula arborea*), Hawfinch (*Coccothraustes coccothraustes*), and European Robin (*Erithacus rubecula*). Changes in abundance were affected by species habitat preference (species using open habitats declined) and also by the degree of protection (species with a high degree of protection rather strengthened).

The results show that the mosaic of non-forest woody vegetation and open habitats, maintained for decades by military disturbance, is slowly but surely disappearing from our landscape. In some places, it has already been replaced by built-up areas, deposits of waste material, construction sites, and other urban projects captured in our data as places with bare ground. Elsewhere, due to the absence of disturbance, it has become overgrown with dense shrubs and forests. This unfortunate trend is mitigated by those areas where nature conservation actively preserves the original form of habitats. Our results also suggest that this conservation management successfully supports many highly threatened bird species, but is insufficient to support a wider range of farmland species.

Effect of various management types in a landscape with non-forest woody vegetation *(Publication 4)*

In order to preserve the greatest possible share of bird biodiversity in abandoned military training areas, it is necessary to make management in protected areas more efficient and, at the same time, look for ways to match biodiversity conservation with other types of use. Therefore, we devoted the last part of the research to a comprehensive evaluation of the impact of different types of management on the landscape with non-forest woody vegetation in abandoned military training areas as well as its bird biodiversity. By collaborating with other research teams, we were able to compare the results for birds with other taxonomic groups (vascular plants, grasshoppers, butterflies) to interpret the results in the wider context of biodiversity across taxa and to assess whether birds function as a reliable indicator for overall biodiversity in management evaluations.

We conducted research on 42 abandoned military training areas in the Czech Republic. For these areas, we found the use of different types of management from 2009 to 2021, distinguishing the following categories: tree cutting, agricultural mowing, conservation mowing, agricultural grazing, conservation grazing (including rewilding), and motor vehicle movement. At the same time, we conducted a bird survey at the sites in the period 2020–21 and compared it with the results of a survey in 2009. We divided the detected species into six ecological groups according to their habitat preferences, and we used the abundance of birds in these groups as an explanatory variable.

The birds of semi-open habitats, i.e. species closely tied to non-forest woody vegetation, were affected positively by only one management type, namely conservation grazing. At the same time, the birds of the forest habitats, which also form part of the non-forest woody vegetation biodiversity, reacted favourably to it. If we look at the responses of other taxa, only two groups of grasshoppers responded to conservation grazing – one positively, the other negatively, which makes this management, when compared to others, very suitable and widely applicable. In addition to conservation grazing, agricultural grazing was also beneficial for forest birds. It is positive news that even agricultural use can be a way (albeit not optimal) to maintain non-forest woody vegetation and, at the same time, at least partially support birds in the landscape. On the other hand, however, this management had a negative

impact on most grasshoppers. Our results also showed that tree cutting can be used to suppress the gradual overgrowth of non-forest woody vegetation. In the long term, this does not affect birds, as well as other taxa, and it even had a positive effect on some plants and grasshoppers.

Conclusions

Our research has shown that the habitat characteristics, landscape mosaic characteristics, and management of non-forest woody vegetation have a significant effect on the biodiversity of birds; no single optimal way of restoration and maintenance can be recommended, as the preferences of various species differ strongly. The key to biodiversity conservation is therefore to think not within the framework of one element of non-forest woody vegetation, but within the framework of the entire landscape and to ensure heterogeneity on different spatial scales.

On a local scale, the total number of species and diversity of birds, as well as the number and diversity of forest species, can be supported through more mature stands, a higher diversity of woody plants, and prevention of the dominance of invasive tree species. Farmland birds can be supported by ensuring a high diversity of (micro)habitats, especially earlier successional stages such as areas of bare ground, grasses, wetlands, or sparse shrubs. On a landscape scale, a high number of woody vegetation patches, in other words a fine-grained mosaic of greenery, is particularly key to the number of endangered species. We have shown that such a valuable fine-grained mosaic of non-forest woody vegetation can be found, for example, in military training areas thanks to the special disturbance regime arising as a secondary effect of military training. After the disappearance of military training, habitat composition shifts to a greater proportion of urban habitats and forests and dense shrubs, at the expense of open habitats and "fine-grained" non-forest woody vegetation. In the same time, there is a shift in species composition of the bird community from grassland to forest species. Evaluation of the impact of various management types showed that, in order to maintain the scattered nature of non-forest woody vegetation, conservation grazing is the most suitable, but agricultural mowing or cutting of trees can also be used from the bird point of view (Article 4). However, bird preferences did not match those of other taxonomic groups. A comparison of the contribution of different approaches within conservation grazing (especially fence grazing and rewilding) could be the subject of further research.

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List of scientific publications and conference contributions

Scientific publications:

- Rajmonová, L., & Reif, J. (2018). Význam rozptýlené zeleně pro ptáky v zemědělské krajině. *Sylvia*, *54*, 3–24.
- Dvořáková, L., Kuczyński, L., Rivas-Salvador, J., & Reif, J. (2022). Habitat characteristics supporting bird species richness in mid-field woodlots. *Frontiers in Environmental Science*, *10*, 816255. https://doi.org/10.3389/FENVS.2022.816255
- Dvořáková, L., Hernová, J., Bušek, O., & Reif, J. (2023). Relationships between bird species richness and different facets of landscape heterogeneity - insights from a military area. *Journal of Vertebrate Biology*, *72*, 23012. https://doi.org/10.25225/jvb.23012
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- Reif, J., Chajma, P., Dvořáková, L., Koptík, J., Marhoul, P., Čížek, O., & Kadlec, T. (2023). Biodiversity changes in abandoned military training areas: relationships to different management approaches in multiple taxa. *Frontiers in Environmental Science*, *11*, 1243568. https://doi.org/10.3389/fenvs.2023.1243568

Conference contributions:

- 6th European Congress of Conservation Biology "Biodiversity crisis in a changing world", Prague, Czech Republic, 2022

  Poster presentation: How should an ideal woodlot look like?

- National ornithological conference ČSO, Mikulov, Czech Republic, 2022

  Oral presentation: Vojenské prostory jako ostrovy ptačí biodiverzity: zanikají nám před očima?

- Conference Nature conservation in abandoned military areas, Brno, Czech Republic, 2021

  Poster presentation: Výzkum účinnosti různých způsobů ochrany přírody ve vojenských prostorech