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Spatial distribution of bird communities in small forest fragments in central Europe in relation to distance to the forest edge, fragment size and type of forest

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ABSTRACT

Species-rich communities of forest birds generally occupy larger rather than smaller forest fragments. However, the role of distance to the forest edge on the spatial distribution of bird communities within forest fragments remains largely unknown. In this study, we attempted to determine whether and how forest bird species distribution was related to distance from the forest edge or clearing (whichever was closer) taking into consideration effects of fragment size and vegetation. Based on data from a four year bird survey, we explored the spatial distribution of 29 common forest bird species within 24 forest fragments (0.1–255 ha) in relation to distance to the forest edge, fragment size and forest vegetation. For this purpose we used generalized additive models (GAMs) with spline components and demonstrated the distance – frequency relationship for each bird species for whom it was relevant. Spatial distribution of the majority of common forest bird species was significantly affected by distance to the forest edge and/or fragment size and vegetation. The maximum frequency of species dependent on distance to the forest edge differed considerably along the line connecting forest edge to the centre of forest fragments. While frequency of the generalist species generally peaked somewhere close to the forest edge, frequency of sensitive forest resident species increased up to a distance of 150 m or more from the forest edge. The effect of forest fragment size was consistently accompanied with the effect of distance to the forest edge with the exception of only two generalist species. It appears that a substantial part of the effect traditionally attributed to forest fragment size may be related to distance to the forest edge. Spatial distribution of almost all of the common bird species were further modified by forest vegetation at the local scale, but only rarely by prevalent forest vegetation of the respective forest fragment. Populations of forest resident species, such as *Dryocopus martius*, may be threatened by management intervention in the forest interior that leads to the forming of "internal" forest edges (e.g. clearcutting). The results documented that forest management based on clear-cut timber harvesting may increase the negative effects of forest fragmentation on distribution of the sensitive forest bird species within forest fragments. This negative effect could be reduced by adoption of timber harvesting methods that avoid the creation of clearings (e.g. single-tree selection), preferably accompanied by exemptions of individuals or patches of old trees from logging.

1. Introduction

Habitat conversion, fragmentation and degradation caused by human activity leads to a global decline in terrestrial biodiversity (Tscharntke et al., 2012; Newbold et al., 2015). Disappearance and fragmentation of forest habitats are considered a major threat to forest bird populations (e.g. Robinson et al., 1995; Lindenmayer et al., 2002; Barlow et al., 2006), whereas effects of forest management appear to be rather species-specific and more ambiguous (Montague-Drake et al., 2009; Sweeney et al., 2010; Newbold et al., 2013).

In Europe, changes in both habitat quantity and quality have been recognized as probably the most important drivers of forest

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bird species population trends (Dolman et al., 2007; Gregory et al., 2007). In general, forest bird species find appropriate conditions in large rather than small forest fragments (van Dorp and Opdam, 1987; Robinson et al., 1995; Dolman et al., 2007), which are composed of native rather than non-native tree species (Sweeney et al., 2010). While high bird species richness is common in late-successional natural forest habitats, ecotones, and even managed stands (Reif et al., 2013; Begehold et al., 2015), many specialized and threatened species require early-successional native forest habitats (Imbeau et al., 2003; Betts et al., 2010). However, major forest areas in traditionally inhabited central European landscapes consist of small and regularly managed forest fragments surrounded by agricultural land (Pokorný, 2005; Kaplan et al., 2009). Limited forest area appears to be a principal reason for lower density and diversity of bird communities in small forest fragments that are dispersed in the landscape matrix (Askins et al., 1987; van Dorp and Opdam, 1987; Juliard et al., 2006; Devictor et al., 2008). In addition, a positive effect of forest edge on density and diversity of bird communities has not been documented in small forest fragments (Baker et al., 2002; Schlossberg and King, 2008), while in larger forest fragments it has (Terraube et al., 2016). A study conducted in the largest deciduous forest in Germany revealed that edge effect shaped bird community composition and positively affected abundances of tree and shrub breeding birds in the first 30 m of forest (Batáry et al., 2014). According to Imbeau et al. (2003), bird species that prefer forest edge habitats are in fact associated with early-successional habitats. These early-successional habitats have almost disappeared from central European landscapes over the last decades (Šálek, 2012) and in managed forests are associated almost exclusively with forest edges (Imbeau et al., 2003). Moreover, forest edge habitats are generally attractive for a wide variety of forest bird species because of higher variability of light conditions, complex vertical structure, and woody species composition providing rich foraging and nesting resources (Batáry et al., 2014; Terraube et al., 2016).

Although particular bird species, including common ones, differ in their association to forest habitats with respect to the forest edge-interior gradient, the spatial extent and magnitude of the differences among species are yet little explored. In an attempt to ascertain edge effects on the spatial distribution of common bird species in fragmented forests in central Europe we conducted a survey of bird occurrence covering the entirety of 24 forest fragments (0.1–255 ha) with a total area of 515 ha. Our goal was to examine and describe in detail the effect of distance to the forest edge on the spatial distribution of common bird species. Apart from the distance to the forest edge, we also considered the effects of forest fragment size and prevalent forest vegetation type at two spatial scales (site and fragment) that are also potentially important for the spatial organization of bird communities within forest fragments.

We hypothesize that effective protection of species-rich forest bird communities in the current forest mosaic European landscape requires a sufficient area of both highly variable edge habitats and low disturbance forest interior habitats. Specifically, we hypothesized that the spatial distribution of several forest bird species within forest fragments is differently related to the edge-interior gradient even if we take into account forest fragment area and forest vegetation type.

2. Methods

2.1. Study area

We examined 24 forest fragments ranging in size from 0.1 to 255 ha (total area 515 ha) located within approximately 30 km^2 of rural landscape in central Bohemia, the Czech Republic (centred at Lat 49 °53′54″N, Long 14 °07′0.9″E) (Fig. 1; Table 1). Forest fragments occupy slopes and hilltops, with elevations ranging from 268 to 497 m asl. The surrounding matrix consists primarily of medium large (up to ~50 ha) plowed fields, and a lesser area of one or two-cut meadows and villages. Mean annual temperature and precipitation averaged 9.5 °C and 518 mm, respectively (means of 10 and 50 years, respectively, recorded at the meteorological station of the Crop Research Institute in Karlštejn). The dominant type of forest vegetation (78%) is deciduous forests (Table 1). Oaks (*Quercus petraea*, *Q. pubescens*), hornbeam (*Carpinus betulus*), and in some places, particularly north aspects, beech (*Fagus sylvatica*) represent the dominant tree species, further supplemented by maples (*Acer campestre*, *A. platanoides*, and *A. pseudoplatanus*), ash (*Fraxinus excelsior*), wild service tree (*Sorbus torminalis*), and limes (*Tilia cordata* and *Tilia platyphyllos*). About 3% of deciduous forests is occupied by exotic tree species, mainly black locust (*Robinia pseudoacacia*). Coniferous forests occupy 13% of the forest fragments with pines (*Pinus nigra* and *P. sylvestris*) and spruce (*Picea abies*) as dominant species. Clearings and low shrubby areas without trees occupy 9% of the forest fragments. A shrub layer of variable density is a regular component of most of the forest vegetation with *Cornus mas*, *C. sanguinea* and *Crataegus* sp. as dominant species. Although forest vegetation is highly variable within particular forest fragments with regard to tree species composition, age and management, the differences among forest fragments in terms of the contribution of particular types of forest vegetation appear to be moderate (Table 1).

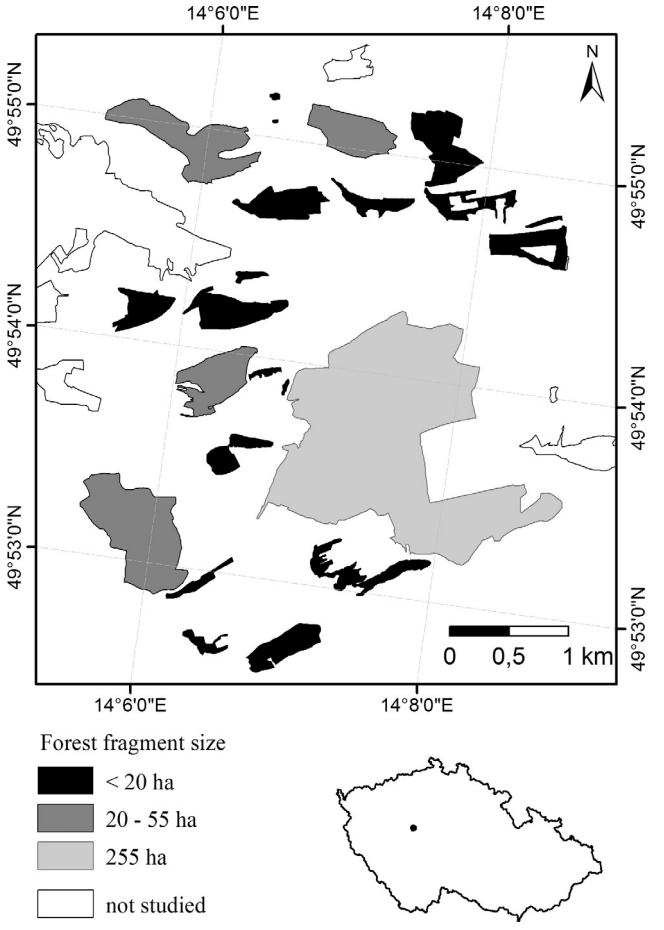

Fig. 1. Study area and its location in the Czech Republic in the coordinate system WGS. Brief description is in Table 1.