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What drives current population trends in forest birds – forest quantity, quality or climate? A large-scale analysis from northern Europe

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ABSTRACT

Changes in forestry practices and on-going climate change may both have large impacts on forest bird populations. However, large-scale analyses of the effects of temporal changes in forest structure on forest bird numbers are largely lacking. We compared temporal trends from two Swedish nationwide long-term monitoring schemes, the Swedish Bird Survey (1998–2015) and the Swedish National Forestry Inventory (1983–2014), giving representative values for both forest and bird changes over an area of 35 million ha. Since 1998 the total area of middle-aged and mature forest increased by 6.4%. In parallel, several forest structures potentially beneficial to birds (dead wood, retention trees on clear cuts, multi-layer forests, old forest and broadleaved forest) increased somewhat in abundance, most likely as a result of legislation changes and increasing areas under forest certification schemes. Summer temperatures also increased, with warm summers dominating since 2002. In 1998–2015, the population sizes of 58 forest bird species on average increased, as did the number of species observed per route, with no general difference between forest specialists (16 species) and generalists (42 species). However, from around 2005, the positive trends in bird numbers and many forest structures have levelled out. An analysis of species population trends in relation to a measure of climate sensitivity (Species Temperature Index, STI) suggested that forest birds, just like Swedish birds in general, have indeed been affected by a warming climate. But given their STI, forest birds on average had more positive trends than non-forest birds, suggesting that other factors than climate have affected them positively. Strong candidate factors are the documented changes in forest quality and quantity. Whereas our data and analyses are correlational, and no firm conclusions on causality therefore can be drawn, it is reasonable to assume that the recent increases in forest quantity, forest quality, and summer temperatures, all have contributed to the general increase in forest bird numbers in Sweden. But the relative contribution of these driving forces remains to be determined. When it comes to the potentially positive effects of improving forest quality in terms of increases in old forest, stratification, retention trees and dead wood, it is noteworthy that many of the positive trends in forest structures since the mid-1990s seem to have ceased recently.

1. Introduction

Contemporary forestry practices are generally considered harmful to both forest biodiversity (Halme et al., 2013; Johansson et al., 2013; Wade et al., 2013) and ecosystem services (Gamfeldt et al., 2013). In Europe and North America, where most forests have already been managed intensively for decades to centuries, forest generalist bird species have had relatively stable populations the last few decades (Gregory et al., 2007 [updated trends on http://www.ebcc.info/]; Virkkala and Rajasärkkä, 2012; Reif, 2013; Massimino et al., 2015). One contributing factor to the relatively good situation for forest generalists, as compared to the generally declining farmland birds (Butler et al., 2010), is that the amount of forest in many countries has increased (Reif, 2013). In contrast, especially in northern Europe, many forest specialists with demands for older, heterogeneous forests with large amounts of dead wood have fared poorly (Helle and Järvinen, 1986; Virkkala, 1991; Fraixedas et al., 2015). Despite the general decline of forest specialists, there is evidence that some populations have been stable or increased in recent time, for example within areas of protected forest where suitable forest structures have been conserved (Virkkala, 1991; Virkkala and Rajasärkkä, 2012). Not only bird numbers but also bird species richness has been shown to

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be higher in structurally more diverse forests (Poulsen, 2002; Forslund, 2003; Söderström, 2009; Rosenvald et al., 2011). This indeed suggests a strong effect of forest habitat quality on population size and species richness and suggests that if the conditions of forests could improve, it would be beneficial to many forest specialist birds.

About 57% of Sweden's land area is productive forest (23 million ha; land suitable for forestry with a production rate of at least 1 m^3 ha^{-1} $year^{-1}$), and forestry is highly rationalized and intense (Anon, 2015). Pine *Pinus sylvestris* and spruce *Picea abies* forest are the most common forest types in Sweden, making up around 82% of Sweden's productive forest. There is only 7% broadleaved forest (65% or more broadleaved trees and less than 45% temperate broadleaved trees), of which 1% is temperate broadleaved forest (65% or more broadleaved of which 45% or more are native temperate species such as beech *Fagus sylvatica*, oak *Quercus robur/petraea*, ash *Fraxinus exelsior* and hornbeam *Carpinus betulus*). In total only 3.6% of the productive forest is formally protected in national parks and reserves and around 12.8% of the forest area are in voluntary set asides (Claesson et al., 2015). Accordingly, forestry practices most likely have a large effect on forest biodiversity in Sweden.

The forest landscape in Sweden has been influenced by human activities for centuries and has varied a lot over time (Östlund et al., 1997; Lundmark et al., 2013). Clear-cutting became the most commonly used method after the Second World War when forestry intensified (Lundmark et al., 2013). Mostly coniferous tree species were planted and undergrowth and broadleaved species were removed to make forestry activities easier. This process created more single-layered, single-species forests (Östlund et al., 1997). In the second half of the 20th century, aesthetic landscape values and biodiversity became an increasingly important consideration in the public debate and in forest management (Simonsson et al., 2015). With the revision of the Swedish Forestry Act in 1993, it was for the first time stated that the conservation of flora and fauna should be equally important to wood production (Bush, 2010). This legal revision included, for example, that temperate broadleaved cannot be replaced with other stand types, damages to valuable biotopes and red-listed species in forest should be avoided or minimized, trees with high conservation values should be prioritised to be retained during clear cutting operations, and protection zones should be established when needed. At the same time some of the detailed regulations relating to cleaning, thinning and final felling, were relaxed (Appelstrand, 2007).

In the last 15–20 years, voluntary forest certification (FSC and PEFC) has added another layer of measures to the legal requirements added in 1993, aimed at improving conditions for biodiversity by setting quantifiable standards (Johansson et al., 2013). These include a minimum number of retention trees (mature trees left at clear-cuts), the creation of high stumps, and increasing the amount of broadleaved trees within the productive forests. Currently, approximately 50% of Sweden's productive forest is certified (FSC, 2013; PEFC, 2014).

Given the changes of the Forest Act and the increased areas of forest being certified, an important question is if this has been beneficial to forest biodiversity. Whereas many studies have analysed the importance of forest structure on bird abundance and community structure, only few have analysed large-scale temporal trends in forest characters and bird abundance in parallel (Helle and Järvinen, 1986; Burgess et al., 2015). This is in contrast to farmland birds, where the large-scale effects of changes in farming practices on bird trends have received considerable attention (e.g. Donald et al., 2001; Wretenberg et al., 2006; Butler et al., 2010). We investigate how recent population trends in Swedish forest birds correlate to changes in forest variables in Sweden. This is done using data from two nationwide long-term and systematic monitoring schemes, the Swedish Bird Survey and the Swedish National Forest Inventory.

Birds are not influenced by land-use changes only. In parallel to warmer summers the last decades, Swedish breeding birds have on average shifted their distribution northwards (Davey et al., 2013; Tayleur et al., 2015), and warm-dwelling species have on average had more positive population trends than cold-dwelling species (Lindström et al., 2013; Tayleur et al., 2016). However, there are large differences in species-specific responses, where the changes recorded in some species are opposite to the expected if they were affected by climate change alone (Tayleur et al., 2015, 2016). We therefore also discuss the potential effects of recent changes in summer temperatures on forest bird populations.

2. Materials and methods

Forest and bird data were compared at both a national and regional level, although the individual sites sampled for forest structure and bird numbers are not spatially overlapping. Nevertheless, the strict sampling protocols of both schemes ensure that representative data are collected both for forest characteristics and birds within a given region, and thus form a sound basis for a direct comparison between temporal trends in forest structures and bird abundance. Below follows a short description of the forest and bird variables we analysed (more information can be found in Appendix A).

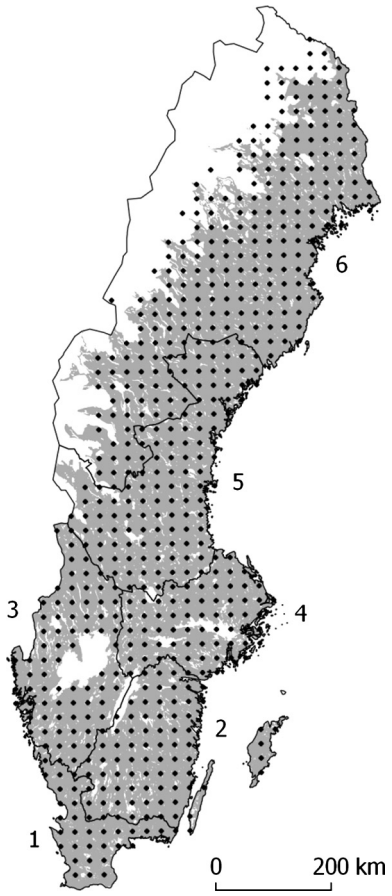

Fig. 1. Map of Sweden and the six defined regions (see Appendix A). The area from which the Swedish National Forest Inventory data originate is shown in grey. The white area in the northwest largely consists of subalpine birch forest (non-productive) and treeless tundra. The smaller white areas in the rest of the country are mainly lakes, but also nature reserves and national parks. Black dots indicate the fixed routes of the Swedish Bird Survey that were included in this study.