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Birds in boreal protected areas shift northwards in the warming climate but show different rates of population decline

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ABSTRACT

Climate change has the potential to have wholesale impacts on species populations, driving them polewards and upwards, and even affecting populations occurring within protected area (PA) networks. We studied population changes in bird species in the boreal PA network of Finland based on extensive bird census data collected in the years 1981–1999 and in 2000–2017. Between these time periods, the mean annual temperature increased in Finland by 1.1 °C, and the mean weighted density of the species shifted 28.5 km (1.8 km/year) northwards in the PA network. However, the total bird population density simultaneously declined by approximately 10%. The decline was most pronounced in long-distance migrants, which showed strongest population contraction in southern boreal regions. In contrast, resident species increased between the two time slices, particularly in larger PAs. While the PA network of boreal native habitats appears to be successful in preserving resident species, climate-induced changes have also caused a decline in the populations of migrants in the PAs. Thus, life-history characteristics of species can significantly affect the success of conservation efforts in a warming climate. To enhance future survival of resident and migrant bird species moving to Finland and northwards, the PAs should be larger and the connectivity of the PA network improved in southern and central Finland. In addition, international actions are needed to enhance the survival of long-distance migrants during the migratory period and in overwintering grounds.

1. Introduction

A key aim of the protected area (PA) network is to ensure the maintenance of populations, species and communities, but there are several challenges in reaching this target (Rodrigues et al., 2004; Gaston et al., 2008). Importantly, ongoing climate change is putting accelerating pressure on species to move polewards and upwards (Parmesan, 2006; Huntley et al., 2007, 2008; Pereira et al., 2010; Garcia et al., 2014), which, in turn, is creating further demands for the PA network to efficiently preserve biota (Hannah et al., 2007; Araújo et al., 2011). In extreme cases, PA networks may cease to afford protection to those species for which they were originally established (Coetzee et al., 2009; Hole et al., 2009), but the evidence for such prospects is mixed, and a number of recent studies have actually shown that well-established effective PA network can provide important support for species movements to, and population establishment in, new areas, even under changing climatic conditions (Thomas et al., 2012; Gillingham et al., 2015). PA networks may also alleviate, at least temporarily, the negative effects of climate change on species and communities (Virkkala et al., 2014; Gaüzère et al., 2016; Santangeli et al., 2017).

In addition to changes in species distributions, their abundances are also moving polewards (Virkkala and Lehikoinen, 2014; Lehikoinen and Virkkala, 2016). The latitudinal density shift of species may affect community composition (see, e.g. Lindström et al., 2013). However, the challenge here is that density shifts are not as easily observable as species range shifts. This is because, to be discovered, they require quantitative censuses of species over wide areas. Densities of species with large distribution areas may also shift latitudinally to a considerable degree without any observable change in their range limits. Because of these methodological challenges, it is highly important to know how the population densities of species have changed in the PA network under a changing climate, and most importantly, if they exhibit hidden decreasing density trends in PAs that are not apparent in species presence-absence monitoring data or in country-wide population density monitoring data.

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Examining species density changes in the PAs of northern boreal and Arctic regions is a particularly important task. This is because the Arctic Ocean represents an effective natural barrier to species' northward range shifts (Virkkala et al., 2008). In addition, for our study area, Finland, the Baltic Sea creates a barrier for the northward movement of southern species and for recruits from more southern regions. Moreover, climate-change-driven changes in biota are projected to be most dramatic at northern latitudes because of the greater temperature increase in these regions (Jetz et al., 2007). For example, in Finland the ratio of the annual mean temperature increase to the global mean increase is projected to range from 1.6 to 1.9 depending on the greenhouse gas scenario, and the annual mean surface air temperature will increase by 2 to 5.5 °C by 2080 in comparison with the baseline period, 1981–2010, depending on the scenario (Ruosteenoja et al., 2016). Annual mean temperatures in Finland increased by 0.7 °C in the years 1901–2000, with most of the increase occurring at the end of the century (see Jylhä et al., 2004).

In northern Europe, the boreal landscape has been intensively utilized; in particular, forestry together with agriculture account for the major land use in vast areas. In Finland, both mires and old-growth forests, in particular, are focal habitats for the conservation of biodiversity, and specific protection programmes for both of these habitats have been implemented (OECD, 1997; Auvinen et al., 2010). Approximately 12% of all mires and > 7% of forest land with over half of all remaining old-growth forests have been protected. Such PAs may thus provide important sites for species conservation. However, great geographic differences exist in the cover of PAs, as, i.e. approximately 80% of the protected land is situated in northern Finland (Virkkala et al., 2000), where the protected area network thus is the largest and the most representative.

With birds, migratory habits create a further complicating factor in studying climate-change-driven effects on species. This is because in the northern, boreal latitudes, some breeding bird species overwinter in tropical areas either in Africa or in Asia, some in temperate or Mediterranean areas, while with some species part of the population is migratory and part is resident (partial migrants). Additionally, certain species are true residents. These different migratory groups may face quite different environmental variations in their life cycle. For example, spring temperatures greatly affect the arrival of migrants (Saino et al., 2011), and mild winters may enhance the survival of residents and partial migrants (Lehikoinen et al., 2016). However, relatively little is known about how the densities of birds representing different migratory habits have changed in the protected areas and whether there are notable differences between the species groups that might be reflected in the persistence of species.

In our study, we compared population changes of birds from the years 1981–1999 to 2000–2017 in the PA network in Finland extending 1100 km across the boreal zone (Fig. 1). Between these time slices, a clear warming of the climate had already occurred. Our study is based on large-scale bird inventories (almost 20,000 transect km) carried out in 254 PAs with a total area of almost 28,000 km^2. We examined the following questions: (1) How do the temporal population changes differ in the PA network between the different migratory groups and how well does the PA network maintain populations in a warming climate? (2) Are there different patterns in population changes along the latitudinal gradient? (3) Are there patterns of latitudinal density shifts of species in the PA network, and are they different between different species groups?

2. Material and methods

2.1. Protected areas

Finland stretches 1100 km across the boreal biome of northern Europe (Fig. 1). The PA network in Finland is largely concentrated in the north and is mostly covered with coniferous (dominated by Scots

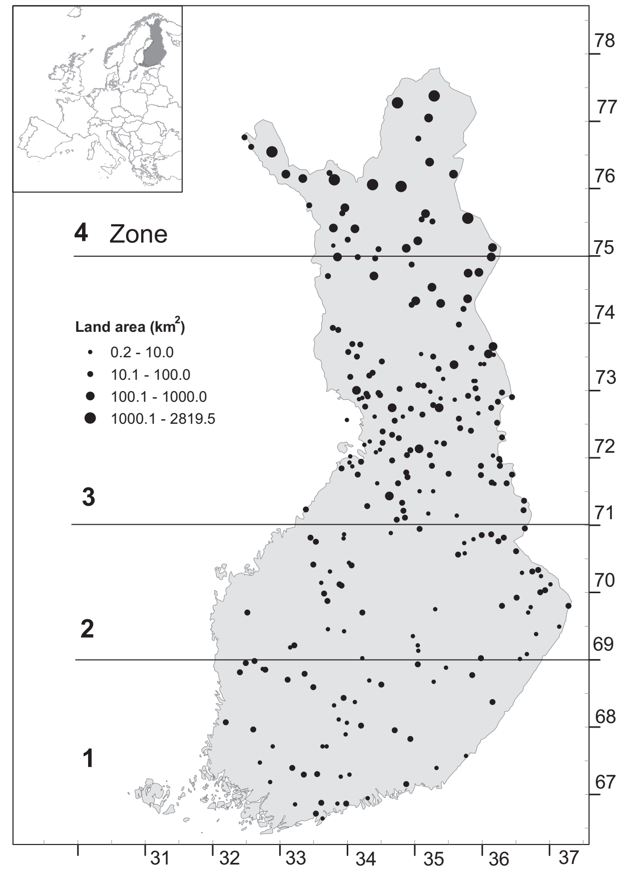

Fig. 1. Location of protected areas studied. Zones 1–4 from south to north are presented. Grid numbers are from the Uniform Coordinate Systems (uniform grids) used in Finland.

pine *Pinus sylvestris* or Norway spruce *Picea abies*), mixed and deciduous (dominated mainly by birch *Betula* spp) forests, open mires (treeless peatlands), marshlands, and Arctic mountain heaths.

Birds were counted both in 1981–1999 and in 2000–2017 in 254 PAs. In these PAs the total land area was 27,851.6 km^2, constituting approximately 70% of total land area of all PAs in Finland (Fig. 1, Fig. A.1). The median size of studied PAs was 20.7 km^2, with a size range between 0.2 and 2819.5 km^2. Five areas were smaller than 1.0 km^2 and four areas larger than 2000 km^2, and all of the largest PAs are situated in northernmost Finland (Fig. 1). In order to examine the potential large-scale geographic differences in the bird population density changes, we divided the country into four regions (zones) from south to north (see Fig. 1), and the median sizes and number of studied PAs in these zones (1–4) were as follows, respectively: 10.1 km^2 (N = 44), 12.1 km^2 (N = 54), 19.5 km^2 (N = 110) and 132.9 km^2 (N = 46).

Logging or drainage of mires is prohibited in the protected areas, so forestry is not allowed in these areas. Forests (including wooded mires) cover 56% of the land in the studied reserves, with the rest being open, treeless mires and mountain areas. In the southern half of Finland, forests cover 70% of the land area in the PAs, while in the northern half they cover 54% of the land area in the PAs. More than two thirds of the protected forest stands are over 100 years old (Virkkala et al., 2000).

2.2. Bird censuses

Land birds in protected areas were counted by using the Finnish line transect census method (Järvinen and Väisänen, 1976), which is suitable for counting birds over large areas (Väisänen et al., 1998; Virkkala and Lehikoinen, 2014). The line transect method applies a one-visit census in which birds are counted during breeding season along a