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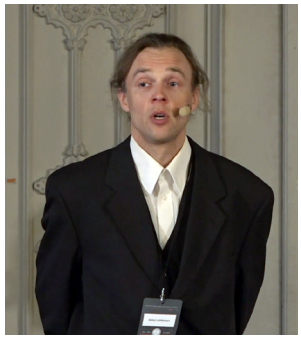
What do birds tell us about recent changes in the environment?



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The loss of biodiversity has become an increasingly important topic of societal discussions. However, measuring biodiversity loss is not easy compared to for instance documenting the other environmental crisis, the climate change. Therefore, different tools are needed to measure whether biodiversity has changed, and how it reflects known habitat changes and possible conservation actions. Birds have been used in many countries as indicators of environmental status. There are several reasons for this. There is a large number of bird enthusiasts around the world who collect data on species. This has led to the accumulation of a considerable amount of long-term data on birds, and the amount of data is increasing every year. Because birds are at the top of the food chain, which means that their numbers are likely to reflect changes at lower trophic levels. Birds are also ubiquitous in a variety of environments and every human knows something about birds, which greatly facilitates the popularisation of science and communication of the impacts of habitat change.

Climate change shifts distribution of birds

Birds have been used in numerous studies of environmental change, including climate change. The effects of climate change on animal species can be broadly divided into changes in species phenology, abundance and morphology. For example, long-term observation series on bird migration times in both Europe and North America show that spring migration begins earlier as springs warm up (Lehikoinen et al. 2019b). In contrast, the timing of autumn migration shows varying responses to climate change. Some species even advance their autumn migration as spring migration begins earlier (Lehikoinen et al. 2010). In some species, such as in waterfowl, migration is delayed, which may lead to a shift in wintering distributions of species (Lehikoinen & Jaatinen 2012, Lehikoinen et al. 2013).

The increase in wintering waterfowl abundance in coastal areas is one of the fastest phenomena caused by climate change in Finland (Lehikoinen et al. 2013, Fraixedas et al. 2015, Meller et al. 2016, Pavón-Jordán et al. 2019). Warming in early winter and decreasing ice cover have led to a tenfold increase in abundances of species such as common goldeneye *Bucephala clangula* and tufted duck *Aythya fuligula*. As recently as the 1980s, there were at most a few dozen wintering tufted ducks in the south-western archipelago, whereas now the numbers are already several tens of thousands (Lehikoinen et al. 2013). The increasing abundance of waterbirds in northern Europe is also reflected in declining abundances of some species at the southern edge of their range.

For example, wintering numbers of goldeneyes have declined significantly in Ireland, Switzerland and Germany (Lehikoinen et al. 2013).

In addition to waterbirds, abundances of landbirds have also shifted northwards as climatic conditions have shifted. Based on line transect counts of more than 100 species, the abundances have shifted northwards on average about 1.5 km per year in Finland since the 1970s (Virkkala & Lehikoinen 2014, Lehikoinen & Virkkala 2016). This means that southern species on average are becoming more abundant and spreading over an ever wider area in Finland. Northern species, on the other hand, are becoming scarcer and are moving further north. In general, however, the rate of species shifts is slower than the rate at which climatic conditions have changed and there is significant variation between species in their speed and direction of shifts. Some species are also moving south against climate predictions, such as the raven Corvus corax and the starling Sturnus vulgaris (Virkkala & Lehikoinen 2014, Lehikoinen & Virkkala 2016, Välimäki et al. 2016).

Changes in habitat quality

Climate change is not the only factor affecting bird populations. Human land use and changes to it, such as logging, also affect bird abundance. In Finland, the amount of logging has increased since the 1980s (Statistics from the Natural Resources Institute Finland 2022). This has led to a decrease in older forests and an increase in younger stands, which are becoming more dominant in the forest landscape. In southern Finland in particular, the proportion of forests aged 81–120 years has decreased, while the proportion of forests younger than 40 years has increased. In northern Finland, the proportion of forests over 120 years old has decreased and the proportion of forests between 41 and 80 years old has increased (Korhonen et al. 2020).

Recent population changes in forest birds are linked to species' habitat selection. The more the forest bird species preferred older forests, the more negative were their population trends in South Finland between 1984 and 2013 (Fraixedas et al. 2015a). Based on the population trends of species occurring in the same habitat, so-called habitat indicators can be developed. Such habitat-specific bird indicators have been implemented for a number of habitats, including forests, farmland, peatlands, wetlands and fells, and are presented on the luonnontila.fi website maintained by the Finnish Environment Institute (see Figs. 1–3).

For forest birds, both wintering and breeding bird indicators have been implemented. These show partly different trends. The breeding season indicator, which consists of the population trends of 25 bird species, has been largely stable since the 1980s. In contrast, the winter indicator for 12 species has declined significantly for decades (Fig. 1). For many species, the exact mechanisms of why changes in forest quality affect their populations are poorly understood, but the decline in wintering species in particular suggests that forest quality plays a greater role in winter survival. One better known mechanism has been demonstrated in the strongly declining, Endangered (EN) willow tit *Poecile montanus*. In this species, the more old-growth forest there is in the winter territory, the higher is the survival rate and the lower the stress levels of the individuals (Cirule et al. 2017). Winter bird counts have also estimated that winter bird densities are roughly eight times higher in forests compared to clearcuts and stands of saplings (Fraixedas et al. 2015b). Forest

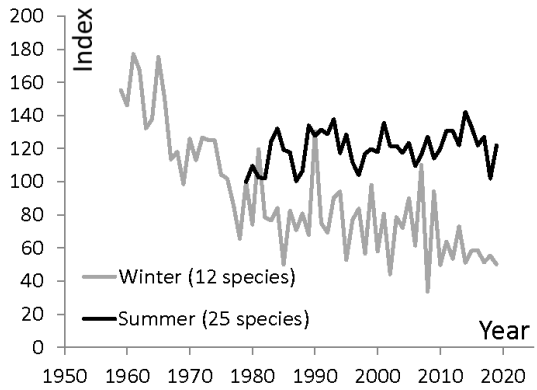

Figure 1. Finnish forest bird indicator for breeding (black) and wintering (grey, 12 species) birds. The breeding indicator is based on population trends of 25 species from line transect and point counts since 1979. The winter indicator is based on winter bird survey trends of 12 species since 1959. Both indicators have the value 100 in 1979.

quality is likely to have a greater impact on birds that are specifically wintering in forests than on many forest generalists during the breeding season (Virkkala et al. 2020). Climate change is also likely to partially compensate for the negative population effects of forest management, as many breeding forest bird indicator species are southern species, whose populations are expanding (Virkkala 2004).

The farmland bird indicator, which consists of the population trends of 14 species breeding in farmland habitats, has been declining for decades (Fig. 2), which is a pan-European phenomenon (Laaksonen & Lehikoinen 2013). However, not all such species show reduced numbers, and some species, such as jackdaw *Corvus monedula*, have increased in abundance in recent years. Among farmland species, those that breed in farmland edges or farmyards (7 species) are doing better than species which breed in the fields (7 species). There are however exceptions, such as barn swallow *Hirundo rustica* and house martin *Delichon urbicum*. These typical farmyard species have declined and are now classified as Threatened (Lehikoinen et al. 2019a).

In addition to farmland species, peatland bird species are also generally doing poorly in Finland. The combined population trends of 15 peatland bird species show a decline of almost 50% since the early 1980s (Fig. 3; Fraixedas et al. 2015). The situation of peatland species has been particularly affected by the drainage of peatlands in an attempt to increase forest growth for forestry purposes. Indeed, many peatland species have their highest densities in open, wet and undrained peatlands (Fraixedas et al. 2015). The status of the peatland bird population is significantly better in Estonia and the corresponding Estonian national bird indicator of nine peatland species is stable (Fraixedas et al. 2017). In Estonia, the majority of open peatlands are protected. In Finland only less than 15% of peatlands are protected and protection is heavily concentrated to northernmost Finland (Fraixeadas et al. 2017). Drainage of peatlands has been intense from southern Finland to southern Lapland, with a total length of about 1.4 million km of ditches.

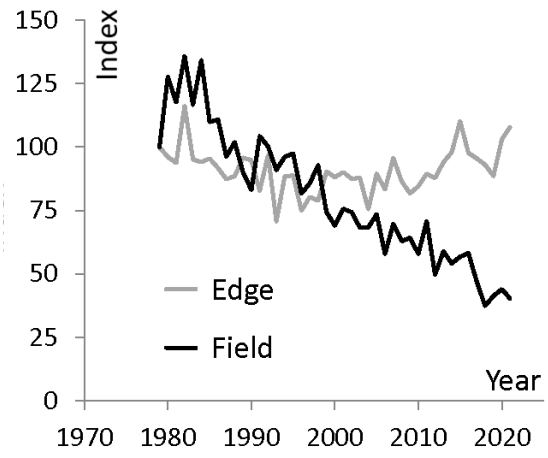

Figure 2. Finnish farmland bird for field (black) and edge (grey) species. Both indicators include 7 species and they are based on line transects and point counts situated in farmland habitats since 1979.

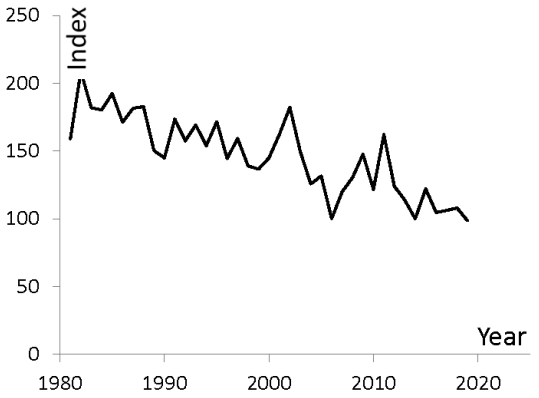

Figure 3. Finnish peatland bird indicator covers population trends of 15 species. The indicator is based on line transect and point count surveys in peatland habitats since 1979.

Not only does drainage affect the quality of peatlands, but ditches also transport nutrients and carbon to a wide area downstream of the catchment. Only recently has it become better understood that the emissions to water bodies from forest drainage are equivalent in magnitude to nutrient inputs from agriculture (Nieminen et al. 2017). The overall length of ditches around lakes can increase eutrophication, water browning and turbidity (Holopainen & Lehikoinen 2021). These changes in water chemistry affect the abundance and occurrence of many plants, invertebrates and fish. For example, submerged aquatic plants suffer from reduced water visibility, darkening water colour impairs aquatic invertebrates, and eu-

trophication increases the abundance of cyprinids (Moss et al. 2011, Arzel et al. 2020, Olin et al. 2002). All of these are linked to waterbird abundance, as submerged aquatic plants and benthic invertebrates are important food species for many waterbirds (Pöysä et al. 2013, Lehikoinen et al. 2016, Kareksela et al. 2021). Waterbirds may also suffer from food competition with cyprinids (Pöysä et al. 2013, Lehikoinen et al. 2016, Väänänen et al. 2012). According to national waterbird monitoring, waterbird populations have declined since the 1990s, especially in eutrophicated wetlands, while the situation is not as bad in oligotrophic water bodies (Lehikoinen et al. 2016). This suggests that changes in water quality in already eutrophicated waters have become unfavourable through hypertrophication, brownification and turbidity (Pöysä et al. 2013, Lehikoinen et al. 2016, Pavón-Jordán et al. 2017). Climate change will increase winter precipitation, which may also increase nutrient flow from the catchment area into water bodies in the future. Wetland species may also be more vulnerable to predation by two invasive predators, raccoon dog *Nyctereutes procyonoides* and American mink *Mustela vison*. It is currently unknown which of these two factors, water quality or predators, is more important in causing declines in wetland bird populations (Pöysä et al. 2013, Lehikoinen et al. 2016).

Future of the bird populations

Habitat-specific bird indicators summarise the population trends of species occurring in a similar environment, which can be used as a measure of environmental status. The decline of common species is worrying, as it indicates large-scale changes in nature. Habitat degradation is probably one of the main reasons for the decline of bird populations in Finland in a number of different habitats. Fortunately, in recent years, research has also accumulated information on different ways to restore habitats and thus improve the situation (e.g. Lehikoinen et al. 2017, Kareksela et al. 2021). Similarly, protected areas are now known to play an increasingly important role in mitigating the negative population impacts of climate change (Virkkala et al. 2014, Lehikoinen et al. 2019c, 2021). In the coming years, there should therefore be an increasing focus on identifying which restoration measures are most effective in different circumstances, and how to promote restoration and conservation on a broader scale to halt the biodiversity loss. Species monitoring will be key to assessing the impact of restoration measures, and there will be a greater need for habitat-specific indicators in the future. Species monitoring and indicators should therefore be further developed for other taxa than birds, thus improving our understanding of biodiversity trends.

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