

EFFECTS OF CLIMATE CHANGE AND FOREST FRAGMENTATION ON BREEDING
BIRD ABUNDANCE IN ONTARIO

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An Undergraduate Thesis submitted in partial fulfilment of the requirements for the degree
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ABSTRACT

Yuqi, S. 2022. Indirect effects of climate change and forest fragmentation on breeding bird abundance in Ontario. 29 pp.

From data on forest breeding bird species in the Atlas of Breeding Birds of Ontario, this thesis summarizes population changes from 1981 to 2005 and all the direct and indirect reasons that may lead to the decline of these bird species. The decline and shift in the distribution of forest breeding birds in some parts of Ontario are related to rising temperatures and forest fragmentation caused by climate change.

Key words: Atlas of Breeding Birds of Ontario, Carolinian forest, forest breeding birds, Kentucky warbler, species distribution

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INTRODUCTION AND OBJECTIVES

Climate change is a key factor threatening biodiversity. Global climate change has always been a hot issue for scientists. As climate change becomes more and more intense, biodiversity is seriously threatened. Climate change will lead to changes in some sensitive ecosystems. Climate change will affect some high-latitude and high-altitude areas. Some plants and animals in these areas are more adaptable to the cold. Due to the increases occurring in global temperatures, many species must move to higher latitudes or altitudes. But new habitats bring new stages of adaptation and more competition, which leads to the disappearance of some species from local areas or altogether (Walck et al. 2011). For example, a flower on a mountain depends on a specific insect for pollination. If the flower has already bloomed and the insect remains dormant, the flowering period will be missed.

The dislocation of the interrelationships between species is also a manifestation of the climate's influence on biodiversity to a large extent. Changes in biological, genetic diversity are also characteristics of biological diversity affected by climate change. Although some species themselves are not extinct, their distinct populations adapted to cold or a specific environment are threatened, leading to the disappearance of genetic diversity (Kappelle et al. 1999). In implementing policies to help biodiversity adapt to climate change, it is necessary to continuously strengthen the already degraded ecosystem and carry out effective restoration and reconstruction of it. We must optimize ecological community structure, gradually restore the state of vegetation, and fundamentally reduce the threat to the natural ecosystem due to climate change. Various regions also need to establish a good monitoring and management

system, carry out *in situ* conservation of species, and fundamentally enhance species' adaptability in the original distribution area. We must strengthen the breeding and protection of endangered species, expand the population of endangered species, and fundamentally improve an ecosystem's ability to adapt to changing climate.

Breeding birds are an important part of the forest ecosystem. In the course of evolution, their physiological characteristics have adapted to complex and changeable environmental conditions (Cody 1985). As indicator species, birds are very sensitive to changes in the surrounding environment (Fleishman et al. 2005). Once living conditions change, they may become endangered. There is increasing evidence that climate change has an impact on the reproductive phenology of birds (Dunn et al. 2010). Some bird populations have begun to reproduce early due to the increase in temperature brought about by climate change.

Higher temperatures may lead to an increase in the yield of young birds in early spring. However, the warmer spring temperatures caused by climate change can also allow prey species, often insects, to mature earlier. Therefore, later emerging chicks face a lower food supply than normal, and a large number of them will not survive (Li and Shi 2007). In Ontario, the boreal forest is the largest habitat for birds. In the context of climate change, the structure, function, productivity of boreal forest ecosystems, as well as the restoration and reconstruction of degraded forest ecosystems, will face severe challenges. Increasing the intensity and frequency of extreme weather events will increase the frequency and intensity of forest disasters and endanger the safety of forests (Lindner et al. 2010). Many bird species in boreal forests have shown a decline in population and changes in their distribution in the past few decades (Cadman 2007). These changes can be mainly explained by the effects of climate change or habitat changes or the combined effects of these factors (Virkkala 2016). Other forest regions in

southern Ontario may feel more acute stresses related to fragmentation because these forest regions are smaller.

OBJECTIVE and HYPOTHESIS

How will forest breeding birds react after being affected by climate change or forest fragmentation? This study aims to analyze the population distribution and population changes of forest breeding birds in Ontario from 2001 to 2005 in the context of how they might be affected by climate change and forest fragmentation. The direct impact of climate change is realized as an increase in the frequency of extreme weather and warmer temperatures, while an indirect impact is manifested as changes in forest structure that are part of forest fragmentation. By collecting the information in the Ontario Breeding Bird Atlas about forest breeding bird response to climate change, I will determine by use of a set of tables the different changes in affected bird communities and determine those that could be due to climate change and those that could be due to forest fragmentation. I predict that all forest breeding birds will show a decline in population or shift in distribution if affected directly or indirectly by climate change.

LITERATURE REVIEW

FOREST BIRDS

Forest is defined as an area covered by continuous tall trees, so a forest bird can be defined as occupying a habitat restricted to this area, depending on this area, or a species whose distribution center is in this area (Keast 1990). The Canadian boreal forest is habitat for

186 species of land birds in 35 families, many of these in the northern regions of Canada. Another 41 or more species appear there incidentally, or are rare, if the boreal forest is at the edge of their normal distribution range (Blancher 2016). Forest birds are an important part of the forest ecosystem. In the process of evolution, their physiological characteristics gradually adapted to the intricate and changeable environmental conditions, and they are always or gradually dependent on dense forests (Cody 1985).

The integrity of the habitat, vegetation, soil, climatic conditions, land type, wetland, etc., to which various birds are adapted determines the possibility of their survival in these living environments and determines their habits, life history, and biological characteristics. The composition and structure of the forest will affect the population distribution of forest birds in different degrees and seasons. The vegetation, the diameter of trees, the height and density of the canopy and understory, and the abundance of standing and fallen dead trees are all important factors in describing forest structure and composition (MacArthur 1964). Most boreal forest birds migrate back to their birthplace in spring to prepare for the short breeding season in summer (Rainio et al. 2006). They find suitable habitats in the boreal forest to settle, start breeding and prepare to hatch young birds. In autumn, these forest birds will leave the northern forest and migrate south for the winter. Once the living conditions change, such as sudden changes in climate, loss of food, loss of habitat, etc., it will directly affect the survival of bird populations and put them on the verge of extinction.

BIRD CONSERVATION POLICY

The "Stand and site guide" is one of a series of forest management guidelines used by forest managers when planning and implementing forest management operations (OMNR 2010). By formulating forest operation plans, forest managers provide guidance on protect hundreds of vertebrate species and tens of thousands of invertebrates within the Boreal and Great Lakes-St. Lawrence forest regions of Ontario. The policy is to protect forest biodiversity by meeting the needs of wildlife and to maintain healthy and sustainable forests in Ontario. Any forest management operations in Ontario's operating areas need to maintain the suitability of bird habitats and avoid disturbing nesting birds during critical breeding periods. The policy exists to ensure that the biodiversity of birds will not be reduced due to forest operations.

The Migratory Birds Convention Act is Canada's most important bird-protection law, and the Act protects most birds in Ontario. The law states that hunting, collecting, and trapping are prohibited unless a license is issued by the Canadian Wildlife Service or one of its agents. Otherwise, a fine or imprisonment, or both will be imposed. The Migratory Birds Convention Act, Endangered Species Act (Ontario), Fish and Wildlife Conservation Act (Ontario), and other laws and related policies work together to protect Ontario's bird biodiversity (Pittaway 2006).

THE IMPACT OF CLIMATE CHANGE ON ONTARIO'S FOREST STRUCTURE

Climate change is defined as a change caused by human activities directly or indirectly changing the composition of the global atmosphere after a considerable period of observation

(United Nations 1992). Therefore, the United Nations Framework Convention on Climate Change distinguishes between "climate change" that changes the composition of the atmosphere due to human activities and "climate change" attributed to natural causes. Climate change may increase the frequency of extreme weather, such as droughts, floods, and extreme temperatures, which affect the survival of organisms (Hardy 2003).

When the climate changes, some species will lose because they cannot adapt (Capinha et al. 2013). In contrast, some new species will invade and change the structure and composition of the original forest ecosystem (Lindner et al. 2010). In addition, warm and dry conditions create forest conditions particularly susceptible to fire, drought, and insect interference, while warm and humid conditions increase wind and pathogen interference. At the same time, climate change will cause specific changes in the distribution of precipitation (Seidl et al. 2017).

Forest structure in a narrow sense refers to the number of forest plant species in a forest community, and in a broad sense, it includes other components in the ecosystem (Smith 1993). In natural forests, the complexity of the community structure is closely related to the number of plant species that make up the community. The more abundant a species is, the higher its utilization of environmental resources, and thus the higher the biological production and stability (Seidler 2017).

There are four main forest regions in Ontario: Hudson Bay Lowlands, boreal forest, and the Great Lakes-St. Lawrence forest and deciduous forest in southern Ontario (Parker et al. 2000). In boreal forests, the frequency and severity of natural disturbances change with the intensification of climate change, causing the rising temperature and fires with more significant than average frequency to occur (Thompson et al. 1998). This change leads to an

increase in the relative abundance of young forests dominated by pioneer deciduous species in the future boreal forest. At the same time, the proportion of conifers is expected to decrease significantly (Cadieux et al. 2020). Eventually, the area covered by the boreal forest will be reduced (Thompson et al. 1998). The Hudson Bay Lowlands is mainly distributed in the colder northern regions. Plant growth is usually restricted in its tundra environment, and climate may be the most important factor restricting plant growth (Kent et al. 2018). With climate change, the distribution and range of many species are expanding to northern latitudes previously unsuitable for them to live in. They will become more and more adapted to high latitude areas with less precipitation and shorter growing seasons. The trees in other forest regions are mainly hardwoods (Drever et al. 2006). In the case of frequent dry seasons caused by climate change, high temperatures, and low precipitation in the growing season, the resistance of these hardwoods is reduced. To reduce the negative impact of more frequent droughts on the forest, the forest composition will gradually evolve into conifers as the dominant trees (Arthur and Dech 2016). Species that can withstand the impact of climate change on forest communities will eventually form the forest stand composition and structure (Goldblum and Rigg 2005).

Another important ecological region in Ontario is the Lake Superior ecosystem. The Lake Superior Basin includes northern hardwood forests and boreal forests (Huff and Thomas 2014). Forest habitats in this region have shifted northward as a result of climate change. Forest species throughout the Lake Superior region are expected to become extirpated at a higher rate, eventually replacing species from further south forests. The tree species of the boreal forest are expected to migrate to northern Ontario and leave the Lake

Superior area. Migration rates, pests and diseases, and wildfires will all impact forest health and composition in the region.

Forests exhibit complex transient responses to rapid climate changes (Lines et al. 2010). The establishment and growth rate of trees are changed by climate change. Although all species live under the same climate conditions, their respective adaptations to climate change are different. Therefore, some species will withdraw when the climate changes because they cannot adapt, and some new species will invade. In this ecosystem, the structure and composition of the original forest ecosystem are changed. Therefore, in the case of climate change, the balance of the ecosystem will be broken, some species will migrate or become extinct, and the ecological function of the forest will be significantly affected.

ONTARIO BIRD CONSERVATION PARTNERS

There are five major bird protection agencies in Ontario, namely Birds Canada, Environment and Climate Change Canada, Ontario Field Ornithologists, Ministry of Northern Development, Mines, Natural Resources and Forestry and Ontario Nature.

Birds Canada, originally known as Bird Studies Canada, is a non-profit charitable organization (Birds Canada). It was spontaneously established by caring members and volunteer citizen scientists. Members pay close attention to the health of bird populations by addressing problems in bird habitats, acknowledging the relationship between birds and humans, and addressing the general needs of species. The organization monitors the status and threats of bird populations through a network of thousands of people, and improves habitat management by analyzing the survival status of birds in Ontario. Birds Canada has developed

the "Forest Birds at Risk" program. Birds Canada works with farmers, conservation groups, and government alliances to protect bird-friendly areas for endangered bird species such as in grasslands, forests and wetland habitats in southern Ontario. The organization's biologists monitor and make recommendations on grazing practices in agricultural areas, and strive to restore the natural environment suitable for the survival of birds.

Environment and Climate Change Canada includes a wildlife research division called the Canadian Wildlife Service in the Canadian federal government (Government of Canada). The Canadian Wildlife Service is mainly responsible for the management of migratory birds, national important habitats and other species at risk, by analyzing the status of birds in Canada and formulating relevant laws and policies. The Ontario Field Ornithologists (OFO) is a provincial organization dedicated to Ontario-based bird research. This group disseminates information about Ontario birds by printing and publishing and selling and distributing literary works, and promotes the appreciation and attention of Canadian citizens to Ontario birds. The organization encourages field research on Ontario birds, so that all people interested in birds can experience the charm of birds up close. It strives to stimulate people's awareness of the protection of wild birds.

The Ministry of Northern Development, Mines, Natural Resources, and Forestry-Government of Ontario (OMNDMNR) is responsible for the sustainable management of fish and wildlife resources in Ontario. This agency helps manage the habitat of all birds in the province by developing and applying geographic information. The department helps organize and then creates every few years a bird breeding map in Ontario, which can quickly reflect any changes in the population and distribution of birds due to climate change.

Ontario Nature is a non-profit charity organization. Since its establishment in 1931, it has been protecting wild species and wild spaces through education, conservation, and public participation. Now the organization is calling everyone's attention to the negative impact of climate change on nature. Solutions such as Protected Places Campaign, Nature Reserves Program, Wetlands Campaign, Endangered Species Program have been implemented by Ontario Nature.

These five partners who help protect Ontario birds are now facing the reality that birds are very sensitive to changes in climate and environment, and that they are a sensitive indicator of environmental health (Weaver 1995). However, while protecting bird habitats under the influence of climate change, we must also deal with other threats faced by birds.

MATERIALS AND METHODS

I collected and summarized a number of species of breeding birds of the forest and described trends between two editions of the Atlas of Breeding Birds of Ontario (1981-1985 & 2001-2005 editions).

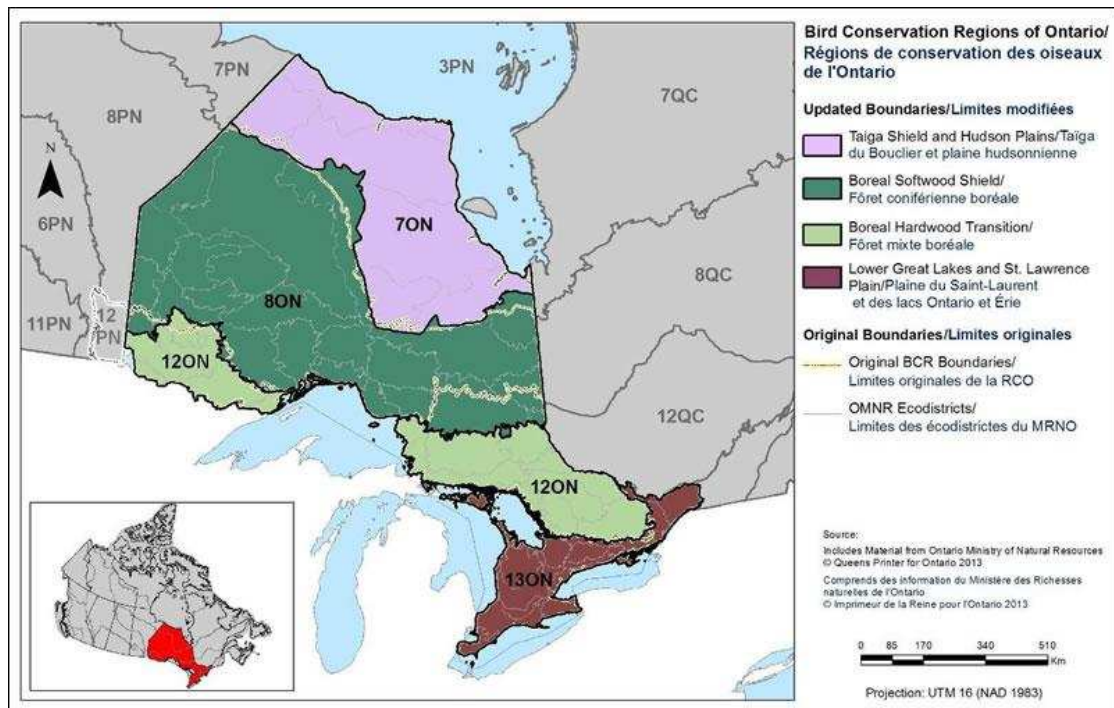


Figure 1. Map of boundaries of Ontario's Bird Conservation Regions. The four BCR sub-regions (7ON, 8ON, 12ON, and 13ON) in Ontario are displayed in different colors (Government of Canada).

A first table was created to describe Ontario's forest breeding bird species with significant declines and increases from 1981 to 2005. Significant changes were considered when a population declined by more than 20% or increased by more than 50%. A second table was created to show Ontario's forest breeding bird species with changes to their distribution during Breeding Bird Surveys over the same period. All forest breeding bird species with a significant population increase or decrease (greater than 50%) in only one of five Ontario forest regions

(Hudson Bay Lowlands, Carolinian, Lake Simcoe-Rideau, Southern Shield, and Northern Shield)
over which Birds Canada monitors changes (Figure 1) were tabulated.

RESULTS AND DISCUSSION

Eleven forest breeding birds experienced a significant decline (Table 1). Habitat loss and climate change constitute two significant threats to the diversity of forest breeding birds (Betts et al. 2018). Since 1970, bird populations in the U.S. and Canada have plummeted, and climate change has also contributed to the decline. The National Audubon Society found that two-thirds of North American birds are at risk of extinction due to global warming. The nineteen forest birds in Table 1 that increased between 1981 and 2005 were defined by Audubon as stable species that did not respond as strongly to climate change or habitat change as those with high vulnerability. As generalists, they adapt well to new habitats and populations can recover quickly.

For populations that showed a significant decline by region, the decrease was due to habitat loss (Table 2). The species belonged to the more sensitive species (Audubon n.d.) to environmental and climate change, and they responded significantly to changes in the physical environment. Nowadays, habitat is the most critical factor in the decline of Ontario's bird populations. Among the forest breeding bird species with significant population declines in Ontario, most declines are due to habitat loss (Table 1). The main reasons include changes in forest structure, increasing areas of farmland to forests, and expanding urbanization. According to the Ontario Breeding Bird Atlas, most species are affected by human activity, with a small percentage declining due to the forest's natural regeneration or maturation.

Table 1. Ontario's forest breeding bird species with significant declines and increases in Ontario during Breeding Bird Surveys over the period 1981-2005.

Declines and likely causes	%	Increases	%
Loss of habitat			
Red-headed Woodpecker	-64%	Worm-eating Warbler	>200%
Gray-cheeked Thrush	-51%	Wild Turkey	>200%
Whip-poor-will	-51%	Tufted Titmouse	>200%
Northern Goshawk	-40%	Red-bellied Woodpecker	>200%
Cerulean Warbler	-30%	Orchard Oriole	>200%
Louisiana Waterthrush	-25%	Northern Hawk Owl	>200%
Baltimore Oriole	-20%	Hooded Warbler	>200%
Pine Siskin	-20%	Black-billed Magpie	>200%
Spruce budworm declines		Northern Parula	186%
Evening Grosbeak	-30%	Northern Saw-whet Owl	156%
Unknown		Pine Warbler	151%
Kentucky Warbler	-99%	Merlin	134%
Chuck-will's-widow	-69%	Golden Eagle	127%
		Boreal Owl	118%
		Brown Creeper	98%
		Acadian Flycatcher	86%
		Blue-headed Vireo	85%
		Barred Owl	69%
		Black-throated Blue Warbler	63%
		White-winged Crossbill	61%
		Summer Tanager	59%
		Nashville Warbler	50%

The Kentucky Warbler population in Ontario fell by 99% in 2005 compared to 1981 (Table 1). This bird has been rarely found in the Ontario area. There were only ten records of this species in Canada before 1945 , but the Kentucky warbler has experienced a significant, range-bound decline since 1966. The Kentucky Warbler is a bird species that is difficult to spot and typically nests in a very dense shrub-like understory, spending most of its time on or near the ground (McShea et al. 1995). Although the male's call is deafening, the pattern and syllables are easily confused with the calls of chickadees. So the Kentucky warbler is easily overlooked by many researchers (All About Birds n.d.).

Even though males of the species have the potential to attract mates, the breeding records of Kentucky warblers in Ontario and even Canada are never confirmed and remain in a state of waiting for confirmation (Cheskey 2003). Most records in Ontario represent unmated stray males or immigrants dispersed from breeding sites in the United States as habitat loss heralds the gradual disappearance of species. The Atlas of the Breeding Birds of Ontario shows that the Kentucky warbler's range is in the eastern forests close to the United States, and only species in this region are at risk of extinction due to deforestation. One of the biggest threats to Kentucky warblers is habitat loss and degradation, especially degradation caused by the white-tailed deer, which rely on forest understory as a food source and suppress local populations by reducing the shrub layers available for nesting (McShea et al. 1995).

Another issue is that the Kentucky Warbler is particularly susceptible to nest parasitism by brown-headed cowbirds. The act of female brown-headed cowbirds laying their eggs in other birds' nests and then having the young cowbirds reared by other birds deprives Kentucky warblers of nesting success (Goertz 1977). Long-term monitoring and research, habitat protection

and restoration, and control of cattle and cowbirds are recommended for the Kentucky warbler's recovery throughout North America.

Only the Northern Shield and the Carolinian experienced significant regional population increases or decreases. Most of the bird species that showed significant declines in Ontario's overall population also had decreases in all five forested areas of the province (Table 2). The populations of more than half of the bird species increased by varying degrees across the five regions. Five breeding bird species with regional population changes in Northern Shield are all on the rise, and even four of them have seen population increases of more than 200%. On the other hand, among the breeding bird species with regional population changes in the Carolinian, only the Summer Tanager had a 59% population increase. The other three had varying degrees of decline. If there is a regional decline, this phenomenon is more likely to occur in the Carolinian Forest. Due to the development of society, most grasslands, dunes, swamps, and southern types of deciduous forests have been turned into cities and farmland. The current Carolinian Forest is less than 15% of its former size (Jalava et al. n.d.). Habitat fragmentation leads to genetic isolation, and it may be difficult or impossible for breeding birds to move between these fragmented habitats to gain access to genetic renewal and reproduction (Wood 2016).

The Carolinian Forest is in the far south of Ontario's five regions, while the Northern Shield is in the north, covered by boreal forest that is warming quickly. It is speculated that a warmer climate will push southern species northward and invade northern ecosystems (Elmhagen et al. 2015). A 2009 Audubon report found that the habitats of many birds are moving north. The boreal forests provide some refuge from climate change as essential habitats for North American birds (Spurrier 2021). Moreover, not only the Canadian government, the Ontario government, and Canadian non-governmental organizations, but also Indigenous communities will use their

traditional knowledge to protect the northern forest and bird nesting areas. So birds migrating there can survive and adapt to new habitats. With a considerable northward shift, they will shift their distribution due to changes in the physical environment of the habitat.

Table 2. Ontario's forest breeding bird species with changes to their distribution during Breeding Bird Surveys over the period 1981-2005.

Species	%	Region of Change
Black-billed Magpie	>200%	Northern Shield
Bohemian Waxwing	>200%	Northern Shield
Worm-eating Warbler	>200%	Northern Shield
Yellow-throated Vireo	>200%	Northern Shield
Summer Tanager	59%	Carolinian
Red Crossbill	56%	Northern Shield
Nashville Warbler	-50%	Carolinian
Northern Parula	-100%	Carolinian
White-winged Crossbill	-100%	Carolinian

Current climate change models predict that global temperatures will continue to rise as climate change intensifies (IPCC n.d.). Ecosystems in the Carolinian Forest of Ontario will fundamentally change with climate change in the coming years. On the other hand, many plant and animal populations initially inhabited in the United States will move north to the more climatic Carolinian (Williamson et al. 2009). These invasive species may bring new types of

bacteria, disrupt established food webs, and accelerate locally threatened or endangered species extinction rates (Toronto City Planning and Parks, Forestry and Recreation with the Toronto and Region Conservation Authority 2019). The effects of increasingly severe climate change in the future will be amplified in these fragmented habitats. Without landscape connectivity, species may not be able to migrate to more habitable environments or traverse the landscape in search of alternative food sources (Honnay 2002). This issue has also led to a significant decline in the population and diversity of wildlife species in Carolinian under the dual effects of human activities and climate change.

CONCLUSION

Ontario's forest breeding bird species will experience population decline or distribution change if directly or indirectly affected by climate change. The Atlas of Breeding Birds of Ontario shows many reasons for the difference in bird distribution and population decline, including urban expansion, deforestation, and foraging problems. Some of the forest breeding bird species in Ontario experienced significant population declines between 1981 and 2005, and others have shifted their distribution northwards. The reasons are higher local temperatures and forest fragmentation, which are the most significant impacts of climate change on forest bird habitats.

LITERATURE CITED

- All About Birds. n.d. Brown-headed Cowbird. Retrieved from https://www.allaboutbirds.org/guide/Brown-headed_Cowbird/overview
- All About Birds. n.d. Kentucky Warbler. Retrieved from https://www.allaboutbirds.org/guide/Kentucky_Warbler
- American Bird Conservancy. n.d. KENTUCKY WARBLER. Retrieved from <https://abcbirds.org/bird/kentucky-warbler/>
- American Bird Conservancy. n.d. MAJOR THREATS TO BIRDS. Retrieved from <https://abcbirds.org/wp-content/uploads/2019/09/Threats-to-Birds.pdf>
- Arthur, C. M., and Dech, J. P. 2016. Species composition determines resistance to drought in dry forests of the Great Lakes–St. Lawrence forest region of central Ontario. *Journal of Vegetation Science*, 27(5), 914-925.
- Audubon. n.d. Survival by Degrees: 389 Bird Species on the Brink.. Retrieved from <https://www.audubon.org/climate/survivalbydegrees/state/ca/on>
- Betts, M. G., Phalan, B., Frey, S. J., Rousseau, J. S., & Yang, Z. 2018. Old-growth forests buffer climate-sensitive bird populations from warming. *Diversity & Distributions*, 24(3/4), 439–447. <https://doi.org/10.1111/ddi.12688>
- Bird conservation strategy for Region 12: Ontario and Manitoba boreal hardwood transition. 2017, June 15. Government of Canada. Retrieved from <https://www.canada.ca/en/environment-climate-change/services/migratory-bird-conservation/publications/strategy-region-12-ontario-manitoba.html>

- Birds Canada. n.d. Canadian Conservation Partner of BirdLife International. www.birdscanad.org. Accessed November 4, 2021.
- Birds Canada. n.d. Canadian Conservation Partner of BirdLife International. Accessed November 16, 2021. Retrieved from: <https://www.birdscanada.org/birdmon/onatlas/atlas effortmap.jsp>
- Blancher, P. J. 2016. Importance of Canada's boreal forest to landbirds. Canadian Boreal Initiative.
- Boreal Songbird Initiative. n.d. NORTH AMERICA'S BIRD NURSERY. Retrieved from <https://www.borealbirds.org/threats-boreal-birds>
- Brook, R., Pollock, L., Abraham, K., and Brown, G. 2021. Bird trends from long-term observation data at sites in the Hudson Bay Lowlands. *Avian Conservation and Ecology*, 16(1).
- Cadieux, P., Boulanger, Y., Cyr, D., Taylor, A. R., Price, D. T., Sólymos, P., and Tremblay, J. A. 2020. Projected effects of climate change on boreal bird community accentuated by anthropogenic disturbances in western boreal forest, Canada. *Diversity and Distributions*, 26(6), 668-682.
- Cadman, M. D. (2007). Atlas of the breeding birds of Ontario, 2001-2005 . Ontario Nature.
- Capinha, C., Larson, E. R., Tricarico, E., Olden, J. D., and Gherardi, F. 2013. Effects of climate change, invasive species, and disease on the distribution of native European crayfishes. *Conservation Biology*, 27(4), 731-740.
- Centre for Land and Water Stewardship of University of Guelph. 1994. The Uniqueness of Carolinian Canada. Retrieved from https://caroliniancanada.ca/legacy/FactSheets_CCUniqueness.htm

- Cheskey, E. 2003. Twelve Mile Creek Headwaters Important Bird Area. Retrieved from <https://www.ibacanada.org/documents/conservationplans/ontwelvemilecreekheadwater.pdf>
- Chow, D. 2020. A climate-sensitive bird hints at global warming's lasting impact. Retrieved from <https://www.nbcnews.com/science/science-news/tiny-songbirds-big-consequences-why-ornithologists-see-climate-change-looming-n1140716>
- Climate Change. n.d. Ontario Natural. Retrieved from <https://ontarionature.org/>. Accessed November 4, 2021.
- Cody, M. L. (Ed.). 1985. Habitat selection in birds. Academic press.
- COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT. n.d. Kentucky Warbler. Retrieved from <https://oepos.ca.uky.edu/content/kentucky-warbler>
- Cowie, A. 2011. Biodiversity in Ontario's greenbelt. Biodiversity in Ontario's greenbelt. Retrieved from https://ontarionature.org/wp-content/uploads/2017/10/REPORT-GB_Habitat-Dec2011.pdf
- Drever, C. R., Messier, C., Bergeron, Y., and Doyon, F. 2006. Fire and canopy species composition in the Great Lakes-St. Lawrence forest of Témiscamingue, Québec. *Forest Ecology and Management*, 231(1-3), 27-37.
- Dunn, P. O., Winkler, D. W., and Møller, A. P. 2010. Effects of Climate Change on Birds. Chapter 10 Effects of climate change on timing of breeding and reproductive success in birds
- Elmhagen, B., Kindberg, J., Hellström, P., and Angerbjörn, A. 2015. A boreal invasion in response to climate change? Range shifts and community effects in the borderland between forest and tundra. *Ambio*, 44(1), 39-50.
- Fleishman, E., Thomson, J. R., Mac Nally, R., Murphy, D. D., and Fay, J. P. 2005. Using indicator species to predict species richness of multiple taxonomic groups. *Conservation Biology*, 19(4), 1125-1137.

- Goertz, J. W. 1977. Additional records of Brown-headed Cowbird nest parasitism in Louisiana. *The Auk*, 94(2), 386-389.
- Goldblum, D., and Rigg, L. S. 2005. Tree growth response to climate change at the deciduous boreal forest ecotone, Ontario, Canada. *Canadian Journal of Forest Research*, 35(11), 2709-2718.
- Government of Canada. 2014. Conserve Ontario's Carolinian Forests: preserve songbird species at risk, chapter 1. Retrieved from <https://www.canada.ca/en/environment-climate-change/services/migratory-bird-conservation/publications/ontario-carolinian-forests-preserve-songbird/chapter-1.html>
- Hardy, J. T. 2003. *Climate change: causes, effects, and solutions*. John Wiley and Sons.
- Hinterland Who's Who. n.d. Help Habitat Hot Spots. Retrieved from <https://www.hww.ca/en/things-you-can-do/action-and-awareness/community/help-habitat-hot-spots.html>
- Honnay, O., Verheyen, K., Butaye, J., Jacquemyn, H., Bossuyt, B., & Hermy, M. 2002. Possible effects of habitat fragmentation and climate change on the range of forest plant species. *Ecology Letters*, 5(4), 525–530. <https://doi.org/10.1046/j.1461-0248.2002.00346.x>
- Huff, A., and Thomas, A. 2014. *Lake Superior Climate Change Impacts and Adaptation*. Superior Work Group of the Lake Superior Lakewide Action and Management Plan.
- Intergovernmental Panel on Climate Change. 2021. Climate change widespread, rapid, and intensifying. Retrieved from <https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/>
- Jalava, V. J., Sorrill, J. P., Henson, J. and Brodri, K. n.d. The big picture project: developing a natural heritage vision for Canada's southernmost ecological region. Retrieved from https://caroliniancanada.ca/legacy/ConservationPrograms_BigPictureMethodology2.htm

- Kappelle, M., Van Vuuren, M. M., and Baas, P. 1999. Effects of climate change on biodiversity: a review and identification of key research issues. *Biodiversity and Conservation*, 8(10), 1383-1397.
- Keast, A. 1990. *Biogeography and Ecology of Forest Bird Communities*. SPB Academic Publishing. <https://kugler.pub/publisher/spb-academic-publishing/>
- Kent, A., Drezner, T. D., and Bello, R. 2018. Climate warming and the arrival of potentially invasive species into boreal forest and tundra in the Hudson Bay Lowlands, Canada. *Polar Biology*, 41(10), 2007-2022.
- Kreitinger, K and Schuurman, W. G. 2018. Kentucky Warbler (*Geothlypis formosa*) Species Guidance. Retrieved from <https://dnr.wi.gov/files/PDF/pubs/er/ER0694.pdf>
- LI, D. Q., and SHI, J. B. 2007. A Review of Impacts of Climate Change on Birds: Implications of Long-term Studies. *Dōngwùxué Yánjiū*, 27(6).
- Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., and Marchetti, M. 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *Forest Ecology and Management*, 259(4), 698-709.
- Lines, E. R., Coomes, D. A., and Purves, D. W. 2010. Influences of forest structure, climate and species composition on tree mortality across the eastern US. *PloS one*, 5(10), e13212.
- MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. *American Naturalist*, 98(903), 387-397.
- Government of Canada. 2021. Migratory Birds. Retrieved from <https://www.canada.ca/en/services/environment/wildlife-plants-species/migratory-birds.html>
- McShea, W. J., McDonald, M. V., Morton, E. S., Meier, R., & Rappole, J. H. (1995). Long-Term Trends in Habitat Selection by Kentucky Warblers. *The Auk*, 112(2), 375–381. <https://doi.org/10.2307/4088724>

- Ministry of Northern Development, Mines, Natural Resources and Forestry. 2016. Government of Ontario. Retrieved from <https://www.ontario.ca/page/ministry-northern-development-mines-natural-resources-forestry> Accessed November 4, 2021.
- Oberhofer, M. n.d. Kentucky Warbler. Retrieved from https://identify.whatbird.com/obj/289/_/Kentucky_Warbler.aspx
- OMNR. 2010. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales – Background and Rationale for Direction. Toronto: Queen’s Printer for Ontario. 575 pp.
- OMNR. 2010. Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales. Toronto: Queen’s Printer for Ontario. 211 pp.
- Ontario Field Ornithologists. n.d. Retrieved from <http://www.ofo.ca/>. Accessed November 4, 2021.
- Parker, W. C., Colombo, S. J., Cherry, M. L., Greifenhagen, S., Papadopol, C., Flannigan, M. D., and Scarr, T. 2000. Third millennium forestry: what climate change might mean to forests and forest management in Ontario. *Forestry Chronicle*, 76(3), 445-463.
- Pimm, S. L., & Askins, R. A. 1995. Forest losses predict bird extinctions in eastern North America. *Proceedings of the National Academy of Sciences*, 92(20), 9343-9347.
- Pittaway, R. 2006. Bird Protection Laws. *OFO NEWS* 12: 3
- Rainio, K., Laaksonen, T., Ahola, M., Vähätalo, A. V., and Lehikoinen, E. 2006. Climatic responses in spring migration of boreal and arctic birds in relation to wintering area and taxonomy. *Journal of Avian Biology*, 37(5), 507-515.
- Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., and Reyer, C. P. 2017. Forest disturbances under climate change. *Nature Climate Change*, 7(6), 395-402.

- Seidler, R. 2017. Patterns of Biodiversity Change in Anthropogenically Altered Forests. 10.1016/B978-0-12-809633-8.02186-5.
- Smith, T. J. 1993. Forest structure. *Tropical Mangrove Ecosystems*. pp.101-136. Chapter 5 Forest Structure. Publish by American Geophysical Union <https://www.agu.org/>
- Spurrier, L. 2021. 5 Reasons the Boreal Forest Is Important to Migratory Birds. Retrieved from <https://www.pewtrusts.org/zh/research-and-analysis/articles/2021/05/07/5-reasons-the-boreal-forest-is-important-to-migratory-birds>
- Thompson, I. D., Flannigan, M. D., Wotton, B. M., and Suffling, R. 1998. The effects of climate change on landscape diversity: an example in Ontario forests. *Environmental Monitoring and Assessment*, 49(2), 213-233.
- Toronto City Planning and Parks, Forestry and Recreation with the Toronto and Region Conservation Authority. 2019. WILD, CONNECTED AND DIVERSE: A BIODIVERSITY STRATEGY FOR TORONTO. Retrieved from <https://www.toronto.ca/legdocs/mmis/2019/ie/bgrd/backgroundfile-136906.pdf>
- Virkkala, R. 2016. Long-term decline of southern boreal forest birds: consequence of habitat alteration or climate change? *Biodiversity and Conservation*, 25(1), 151-167.
- Walck, J. L., Hidayati, S. N., Dixon, K. W., Thompson, K. E. N., and Poschlod, P. 2011. Climate change and plant regeneration from seed. *Global Change Biology*, 17(6), 2145-2161.
- Weaver, J. C. 1995. Indicator species and scale of observation. *Conservation Biology*, 9(4), 939-942.
- Williamson, T. B., Colombo, S. J., Duinker, P. N., Gray, P. A., Hennessey, R. J., Houle, D., and Spittlehouse, D. L. 2009. Climate change and Canada's forests: from impacts to adaptation. Retrieved from <https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/29616.pdf>
- Wood, C. 2016. On Nature's Death Row: Ontario's Vanished 'Carolinian' Forest. Retrieved from <https://theyee.ca/News/2016/02/04/Ontario-Carolinian-Forest/>