Potential Impacts of Climate Change on the Summer Distributions of Southern Ontario's Passerine Birds

Jeff Price

Introduction

Water vapor, carbon dioxide (CO_2), methane, and other trace gases in the Earth's atmosphere act much like the glass in a greenhouse, helping to retain heat by trapping and absorbing infrared radiation. This "greenhouse effect" acts to keep the Earth's surface temperature significantly warmer than it would otherwise be, allowing life, as we know it, to exist. However, since pre-industrial times, there have been significant increases in the concentration of greenhouse gases in the atmosphere. The current levels of the two primary greenhouse gases are now greater than at any time during at least the past 420,000 years (likely much longer) and are well outside of the bounds of natural variability (IPCC 2001).

Accompanying the increases in greenhouse gases has been an increase in temperature. The 1990s were the warmest decade and the 1900s the warmest century of the last 1000 years. Of the more than 100 years for which instrumental records are available, 1998 was the warmest year on record, and 7 of the top 10 years all occurred in the 1990s. The annual global mean temperature is now 0.6°C above that recorded at the beginning of the century. Limited data from other sources indicate that the global mean temperature for the 20th century is at least as warm as any other period since approximately 1400 AD (IPCC 1996, 2001). And, "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC 2001). These activities include the burning of fossil fuels, increases in agriculture, and other land use changes (such as deforestation).

Increases in greenhouse gases (past and projected), coupled with the length of time these gases remain in the atmosphere, are expected to cause a continued increase in global temperatures. Models estimate that the **average** global temperature, relative to 1990 values, will rise by 1.4°–5.8°C by the year 2100 (IPCC 2001). Warming due to increases in greenhouse gases is expected to be even greater in some areas, especially Northern Hemisphere land areas. Models based on various scenarios for population growth, economic well being, improvements in technology, and fossil fuel use project annual average temperature increases in southern Ontario of 3°–6°C in winter and 4°–8°C in summer by 2100 (Kling et al. 2003). This could leave southern Ontario with a summer climate similar to that currently experienced in Maryland and northern Virginia in the United States.

How might these changes impact the summer distributions of southern Ontario's passerine birds? "Recent regional changes in climate, particularly increases in temperature, have already affected hydrological systems and terrestrial and marine ecosystems in many parts of the world" (IPCC 2001). For example, changes in growing season, earlier spring green-up and earlier arrival and breeding in some birds have all been documented (Root et al. 2003). If these changes have been observed with only a small rise (0.6°C) in the global average temperature, what might happen if temperatures continue to rise? In addition to rising temperatures, many climate models also project an overall increase in evaporation—leading to increases in precipitation (mostly in storms) but also to overall declines in soil moisture. Lake levels in each of the Great Lakes are projected to decline, potentially by as much as 0.23–0.47 m in Lake Superior and 0.99–2.48 m in Lake Huron (Kling et al. 2003). Shifts in the timing of precipitation and snowmelt and declines in duration of ice cover are also all possible. Even after emissions are reduced, CO_2 concentrations, temperature and sea level will all continue to rise for a period ranging from decades/centuries (CO_2 stabilization, temperature rise) to millennia (sea-level rise). Thus, climate change will likely have a continuing impact on southern Ontario's birds and their habitats for some time to come.

Projected Habitat Changes

Temperature, precipitation and soil moisture are important factors limiting the distribution of both plants and animals. As the climate changes, so will plant and animal distributions. In general, the geographic range of North American plants and animals will tend to shift poleward and/or upwards in elevation in response to temperature changes. Range shifts in plants will be dependent upon factors such as soil types, migratory pathways (e.g., no cities blocking the way), seed dispersal mechanisms and pollinator availability. Range shifts of wildlife populations will be dependent upon factors such as the availability of migration corridors, suitable habitats and the concurrent movement of forage and prey. It is very unlikely that plant and animal species will respond in the same manner to climate change. The best available evidence from paleoclimatic studies, models and observations suggests that each plant and animal species will move independently. Thus, communities as we now know them will look different in the future. Indeed, there is evidence indicating that many ecosystems have already begun to change in response to observed climatic changes (Root et al. 2003).

Models project possible major changes in the suitable climates of many vegetation communities occurring over the next 75–100 years. In the neighbouring Great Lake states, for example, these models estimate that climate suitable for maple (*Acer*) - beech (*Fagus*) - birch (*Betula*) and elm (*Ulmus*) - ash (*Fraxinus*) - cottonwood (*Populus*) forests will ultimately become more suitable for oak (*Quercus*) - hickory (*Carya*) forests (NAST 2000). It is not unreasonable to expect some of these changes to occur in southern Ontario as well. Increasing temperatures may also lead to declines in the extent of boreal forest, at least along its southern boundary.

As many tree species are long-lived and migrate slowly, it could potentially take decades to centuries for species in some vegetation communities to be replaced by others (Davis and Zabinski 1992). However, as increased temperatures and drought stress plants, they become more susceptible to fires and insect outbreaks. These disturbances could play a large role in the conversion of habitats from one type to another. There could very well be instances where existing plant communities are lost to disturbance but climatic conditions and migration rates limit the speed at which they are replaced. Thus, invasive species, grasslands and shrublands may transitionally replace some of these areas.

Projected Changes in Bird Distributions

Summer bird ranges often are assumed to be tightly linked to specific habitats. This generalization is only partially true. While certain species are usually only found in specific habitats, e.g., Kirtland's Warbler (*Dendroica kirtlandii*) breeding in jack pines, others may be more flexible in their habitat use. Species found in a particular habitat type throughout their breeding range may not be found in apparently equivalent habitat north or south of their current distribution. Birds are also limited in their distributions by their physiology and food availability. The link between physiology and the winter distributions of many species is well established (Kendeigh 1934; Root 1988a, 1988b). Research increasingly shows that physiology plays a role in limiting summer distributions as well (Dawson 1992; T. Martin, pers. comm.). Often, the choice of a specific habitat may actually be to provide a microclimate suitable for a species' physiology. While habitat selection, food availability, and competition may all play a role in influencing *local* distributions of a given bird species, looking at a species' overall distribution often yields different results. This paper presents results from a study that examined the association between summer bird distributions and climate and how these distributions may change with a changing climate.

Methods

Logistic regression was used to develop models of the association between bird distributions (from Breeding Bird Survey data) and climate. The climate variables used in this study encompassed both temperature and precipitation—the climate variables acting as surrogates for the many factors potentially limiting a species distribution (e.g., physiology, habitat, food availability). One way of determining how "accurate" these models are is to compare how well the predicted species distribution map based on climate (Figure 1b) matches a map of the actual distribution (Figure 1a) based on similar bird data (Price et al. 1995). This comparison (and various statistical tests) indicated that at least a portion of the summer distributions of many North American birds could be modeled accurately based on climate alone.

The next step was to examine how bird distributions might change in response to climate change. For this study, climate projections from the Canadian Climate Centre (CCC) were used to determine what the average climate conditions might be once CO_2 has doubled, sometime in the next 75–100 years. For example, for a given point, the difference in average summer temperature between the "current" and "future" (both model-derived) climate might be +2°C. This value is then added to the *actual* average summer temperature at that point to estimate what the climate at that point might be with a doubling of CO_2. These new climate data were then used to estimate the probability of a given BBS route having the proper climate for a species. A more complete explanation of methods used to develop the models and maps has been published elsewhere (Price 1995; Price, in press).

These results were then used to create maps of the projected possible future climatic ranges for almost all North American passerine birds (e.g., Figure 1c). What these maps actually show are areas projected to have the proper climate for a species, or *climatic range*, under conditions derived from the CCC model. While the results of the models cannot be used to look at the fine points of how a given species' distribution might change, they can provide an impression of


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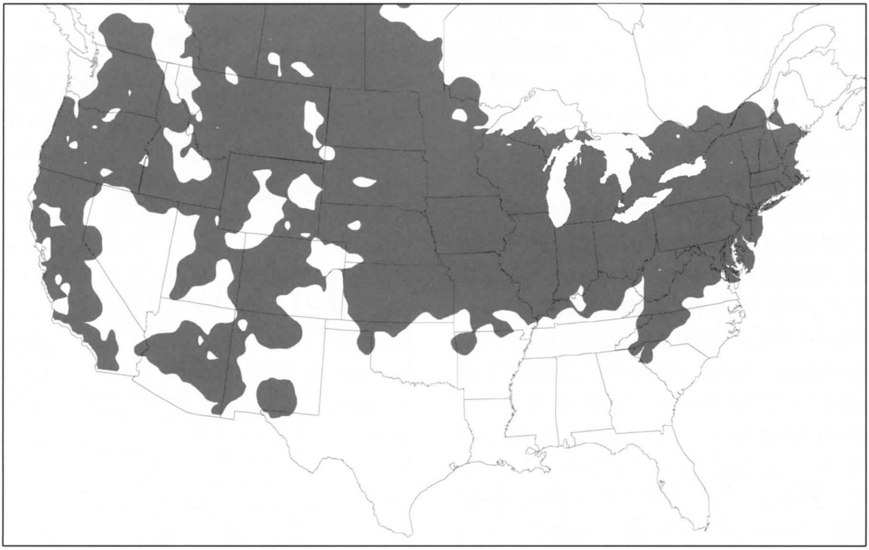

Figure 1a: Map depicting the distribution of House Wren as detected by the Breeding Bird Survey. This map is based on one found in Price et al. (1995).

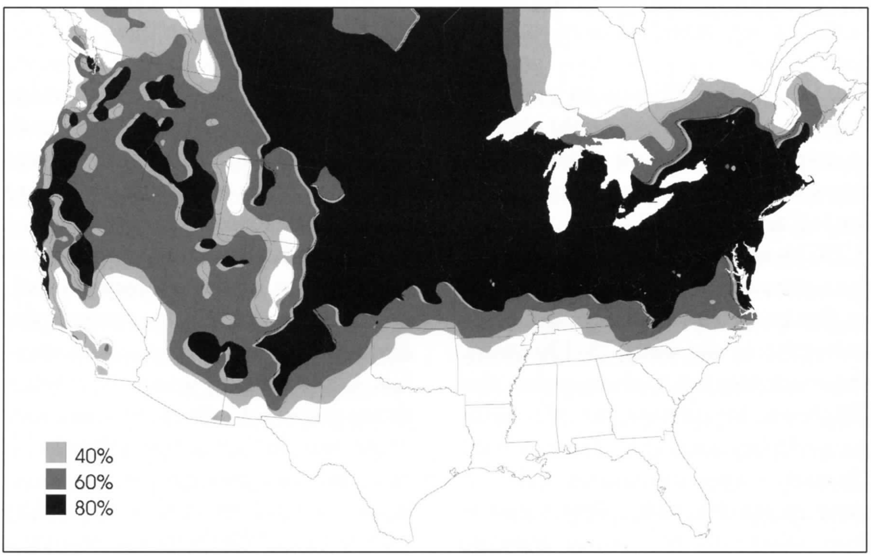

Figure 1b: Map depicting a *model* of the distribution of House Wren based solely upon the climate of 1985-1989. The scale represents the probability of the species' occurrence, with shaded areas depicting the distribution of the species (i.e., areas with suitable climate).

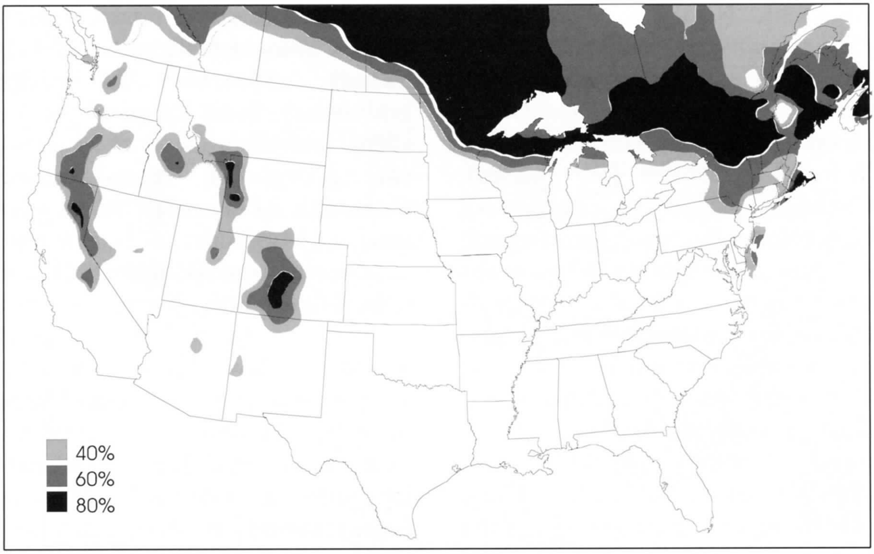

Figure 1c: Map depicting the possible distribution of House Wren under the doubled CO_2 climate conditions projected by the CCC. The scale represents the probability of the species' occurrence, with shaded areas depicting the distribution of the species (i.e., areas with suitable climate for the species).

the possible direction and potential magnitude of the change in the suitable climate for the species. These maps of projected summer climatic ranges of birds were then compared with the maps and information found in *Atlas of the Breeding Birds of Ontario* (Cadman et al. 1987) to determine how southern Ontario's avifauna might change under this climate change scenario.

Results

Species whose future climatic summer ranges might exclude southern Ontario (i.e., possibly extirpated as summer residents) – Olive-sided Flycatcher (*Contopus cooperi*), Yellow-bellied Flycatcher (*Empidonax flaviventris*), Alder Flycatcher (*E. alnorum*), Blue-headed Vireo (*Vireo solitarius*), Philadelphia Vireo (*V. philadelphicus*), Bank Swallow (*Riparia riparia*), Cliff Swallow (*Petrochelidon pyrrhonota*), Boreal Chickadee (*Poecile hudsonica*), Red-breasted Nuthatch (*Sitta canadensis*), Winter Wren (*Troglodytes troglodytes*), Blue-winged Warbler (*Vermivora pinus*), Tennessee Warbler (*V. peregrina*), Nashville Warbler (*V. ruficapilla*), Magnolia Warbler (*Dendroica magnolia*), Cape May Warbler (*D. tigrina*), Yellow-rumped Warbler (*D. coronata*), Black-throated Green Warbler (*D. virens*), Blackburnian Warbler (*D. fusca*), Bay-breasted Warbler (*D.

castanea), Northern Waterthrush (*Seiurus noveboracensis*), Connecticut Warbler (*Oporornis agilis*), Mourning Warbler (*O. philadelphia*), Hooded Warbler (*Wilsonia citrina*), Wilson's Warbler (*W. pusilla*), Canada Warbler (*W. canadensis*), Clay-colored Sparrow (*Spizella pallida*), Savannah Sparrow (*Passerculus sandwichensis*), Lincoln's Sparrow (*Melospiza lincolnii*), White-throated Sparrow (*Zonotrichia albicollis*), Dark-eyed Junco (*Junco hyemalis*), Rusty Blackbird (*Euphagus carolinus*), Brewer's Blackbird (*E. cyanocephalus*), Purple Finch (*Carpodacus purpureus*), Pine Siskin (*Carduelis pinus*) and Evening Grosbeak (*Coccothraustes vespertinus*).

Species whose future climatic summer ranges in southern Ontario might contract – Willow Flycatcher (*Empidonax traillii*), Least Flycatcher (*E. minimus*), Warbling Vireo (*Vireo gilvus*), Tree Swallow (*Tachycineta bicolor*), Black-capped Chickadee (*Poecile atricapillus*), White-breasted Nuthatch (*Sitta carolinensis*), House Wren (*Troglodytes aedon*), Gray Catbird (*Dumetella carolinensis*), Golden-winged Warbler (*Vermivora chrysoptera*), Northern Parula (*Parula americana*), Yellow Warbler (*Dendroica petechia*), Chestnut-sided Warbler (*D. pensylvanica*), Black-throated Blue Warbler (*D. caerulescens*), Black-and-white Warbler (*Mniotilta varia*), American Redstart (*Setophaga ruticilla*), Ovenbird (*Seiurus aurocapilla*), Scarlet Tanager (*Piranga olivacea*), Vesper Sparrow (*Pooecetes gramineus*), Song Sparrow (*Melospiza melodia*), Swamp Sparrow (*M. georgiana*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), Bobolink (*Dolichonyx oryzivorus*) and Baltimore Oriole (*Icterus galbula*).

Species whose future climatic summer ranges in southern Ontario might expand – Acadian Flycatcher (*Empidonax virescens*), Loggerhead Shrike (*Lanius ludovicianus*), White-eyed Vireo (*Vireo griseus*), Yellow-throated Vireo (*V. flavifrons*), Horned Lark (*Eremophila alpestris*), Purple Martin (*Progne subis*), Tufted Titmouse (*Baeolophus bicolor*), Carolina Wren (*Thryothorus ludovicianus*), Eastern Bluebird (*Sialia sialis*), Northern Mockingbird (*Mimus polyglottos*), Pine Warbler (*Dendroica pinus*), Prairie Warbler (*D. discolor*), Cerulean Warbler (*D. cerulea*), Louisiana Waterthrush (*Seiurus motacilla*), Kentucky Warbler (*Oporornis formosus*), Yellow-breasted Chat (*Icteria virens*), Eastern Towhee (*Pipilo erythrophthalmus*), Field Sparrow (*Spizella pusilla*), Grasshopper Sparrow (*Ammodramus savannarum*), Northern Cardinal (*Cardinalis cardinalis*), Dickcissel (*Spiza americana*), Eastern Meadowlark (*Sturnella magna*) and Orchard Oriole (*Icterus spurius*).

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Species whose future climatic summer ranges might eventually include southern Ontario – Say's Phoebe (*Sayornis saya*), Scissor-tailed Flycatcher (*Tyrannus forficatus*), Bell's Vireo (*Vireo bellii*), Carolina Chickadee (*Poecile carolinensis*), Bewick's Wren (*Thryomanes bewickii*), Blue Grosbeak (*Guiraca caerulea*) and Great-tailed Grackle (*Quiscalus mexicanus*).

Discussion

These lists are not all-inclusive, since results obtained from models of some species were not adequate to assess how their climatic ranges might change. Nor do the lists include those species whose climatic ranges in southern Ontario may undergo little change. Finally, these lists are based on output from a single commonly used climate model. Using output from different climate models may yield somewhat different results. In addition, the geographic scale of these models, like those of the underlying climate change model, is relatively coarse. As such, the models are unable to take into account localized topographic changes and the possible existence of suitable microclimates (e.g., along rivers or on north-facing mountain slopes). Therefore, some of the species whose *climatic* ranges are projected as shifting out of southern Ontario may be able to persist in refugia if suitable microclimates are available.

It is helpful to consider how species' ranges may change to know what sorts of changes to look for in the future. As the average temperature (climate) increases, weather will still occur—some years being cooler and others warmer than otherwise expected. So, colonization will most likely occur in fits and starts before a species can truly be considered to be established as part of southern Ontario's breeding avifauna. In some cases, a species may start appearing as a vagrant, off and on, for several years before breeding is attempted. In other cases, a species may start breeding in an area, then become extirpated, and then resume breeding—possibly in greater numbers than before.

How quickly these distributional changes might occur is unknown; the rate of change will largely depend on whether limits to a given species' distribution are more closely linked with physiology (i.e., climate), vegetation, or some other factor. The rate of change will also likely be tied to the rate of change of the climate itself. If the climate changes relatively slowly, then species may be able to adapt to the new climate. However, many changes could occur (and are occurring) relatively quickly. One pilot study found that the average latitude of occurrence of some species of Neotropical migrants has already shifted significantly farther north in the last 20 years, by an average distance of almost 60 miles (100 km) (Price and Root 2001; Price, unpublished data). In another study, the arrival date of 20 species of migratory birds in Michigan was found to be 21 days earlier in 1994 than in 1965 (Price and Root 2000; Root, unpublished data). Many other species have been found to be arriving and breeding earlier, not only in North America but also in Europe and elsewhere (Root et al. 2003).

Conclusion

Projected future rapid climate change is of major concern, especially when viewed in concert with other population stresses (e.g., habitat conversion, pollution, invasive species). Research and conservation attention needs to be focused not only on each stressor by itself, but also on the synergies of multiple stressors acting together. These synergistic stresses are likely to prove to be the greatest challenge to bird conservation in the 21st century. Because anticipation of change improves the capacity to manage, it is important to understand as much as possible about the responses of birds to a changing climate.

Society may ultimately need to adapt not only to range changes but also to the loss of ecological services normally provided by birds. For example, it may be necessary to develop adaptations to losses of natural pest control, pollination and seed dispersal. While replacing providers of these services may sometimes be possible, the alternatives may be costly. Finding a replacement for other services, such as contributions to nutrient cycling and ecosystem stability/biodiversity are much harder to imagine. In many cases, any attempt at replacement may represent a net loss (e.g., losses of the values of wildlife associated with recreation, subsistence hunting, cultural and religious ceremonies).

In summary, a high probability exists that climate change could lead to changes in bird distributions. Some of these changes could occur (and may be occurring) relatively quickly. While these changes may have some ecological and, possibly, economic effects, the magnitude of these effects is unknown. Ultimately, the greatest impact on wildlife and vegetation may not come from climate change itself, but rather from the rate of change. Given enough time, many species likely would be able to adapt to climatic shifts, as they have done in the past. However, the current projected rate of warming is thought to be greater than has occurred at any time in the last 10,000 years (IPCC 1996). This rate of change could ultimately lead to many changes in southern Ontario's avifauna.

Birders can help scientists look for and document changes in bird ranges and populations. Besides participating in regular events like the Breeding Bird Survey or Christmas Bird Count, information is also needed on nesting, arrival and departure. If you, or your club, have 10 or more years of data, please contact me at the address listed below.

Acknowledgments

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