Potential Impacts of Climate Change on Neotropical Migrants: Management Implications[1]

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Abstract

The world is warming. Over the last 100 years, the global average temperature has increased by approximately 0.7°C. The United Nations Intergovernmental Panel on Climate Change projects a further increase in global mean temperatures of between 1.4° - 5.8° C by the year 2100. How will climate change affect Neotropical migrants? Models of changes in the breeding distributions of North American birds predict that most species will undergo some shift in their ranges. In parts of northern Minnesota and southern Ontario, this could lead to an avifauna with as many as 16 fewer species of wood warblers than currently occur. Unless all components of the ecosystem change at the same rate, an unlikely prospect, this potential disruption of the ecosystem could lead to major impacts on forest health. Data show that many changes have already occurred with earlier arrival dates, breeding dates and changes in distributions. This includes preliminary results showing the average latitude of occurrence of some species of North American birds has shifted northward by almost 100 km in the last 20 years, and many species in Michigan arriving in the spring an average of 21 days earlier now than 30 years ago. Climate change will add more pressure to bird populations and greater challenges to conservation planners and land managers.

Introduction

The Earth's climate is changing. As of the end of July, 2002 was on pace to supplant 1998 as the warmest year on record (or be a close second). Of the more than 100 years for which instrumental records are available, 1998 was previously the warmest year on record and 7 of the top 10 warmest years all occurred in the 1990s. Overall, the 1990s were the warmest decade (so far) and the 1900s the warmest century of the last 1000 years. The annual global mean temperature is now 1.3°F (0.7°C) above that recorded at the beginning of the century. Limited data from other sources indicates that the global mean temperature for the 20th century is at least as warm as any other period since at least 1400 AD (IPCC 2001).

Since pre-industrial times, there have been significant increases in the amount of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the atmosphere, leading to an enhancement of the Earth's natural greenhouse effect. These increases in greenhouse gases can largely be attributed to human activities, including burning of fossil fuels and land use changes (such as deforestation). In 1996, the Intergovernmental Panel on Climate Change published the statement that "the balance of evidence suggests that there is a discernable human influence on global climate." Increases in greenhouse gases (past and projected), coupled with the length of time these gasses 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 between 1.5°C - 6°C by the year 2100. It is not only the magnitude of the change but also the rate of change that is of concern. The current projected rate of warming is thought to be greater than has occurred at any time in at least the last 10,000 years (IPCC 2001).

Anthropogenic warming due to increases in greenhouse gases is expected to be even greater in some areas, especially Northern Hemisphere land areas. For example, average temperatures in Alaska may increase by 5.4 - 18° F (1.5 - 6°C) (NAST 2000). With increases in temperature come increases in evaporation, likely leading to some increases in local precipitation but, coupled with increases in temperature, to declines in soil moisture in many areas. As such, both droughts and floods are expected to become more common in the future.

The summer ranges of birds are often assumed to be tightly linked to particular habitats. This is only partially true. While certain species are usually only found in certain habitats (e.g., Kirtland's Warbler breeding in jack pines), others are more flexible in their habitat use. Species found in a particular habitat type throughout their summer range may not be found in apparently equivalent habitat north or south of their current distribution. While habitat plays a role in bird distribution patterns, birds are also limited in their distributions by

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their physiology and food availability. The link between physiology and the winter distributions of many species is well known (Kendeigh 1934, Root 1988a, 1988b) and recent research shows that physiology plays a strong role in limiting summer distributions as well (Dawson 1992, T. Martin, pers. comm.). While habitat selection, food availability, and competition may all play a role in influencing the *local* distribution of a given bird species, looking at a species' overall distribution often yields different results. Building on earlier work that found that many winter bird distributions are associated with climate (Root 1988a, 1988b), this study examined the association between summer bird distributions and climate and how these distributions may change with climate change.

Ultimately, the greatest impact on wildlife may not be from climate change itself, but rather from the rate of change. Given enough time, many species would likely be able to adapt to shifts in the climate, 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 changes in the distributions of North America's neotropical migrants.

Methods

To determine how summer distributions of birds might change, it is first necessary to look at whether there is any association between bird distributions and climate. If an association exists, then an examination of projected future climates can be used to see how the climatic ranges of birds might change. Logistic regression was used to develop models of the association between bird distributions (from Breeding Bird Survey data) and eighteen climate variables. These climate variables included average seasonal temperature and precipitation, temperature and precipitation ranges, extreme values (e.g., temperature in the hottest month and coldest months, precipitation in the wettest and driest months) and combinations (e.g., precipitation in the hottest month, temperature in the driest month). Climate variables used in these models act as surrogates for many factors possibly limiting a species distribution, including physiology, habitat, and food availability, and are similar to those used in other bioclimatic studies. Models developed for this study were then checked to see how well they predicted species occurrence at independent locations (statistically validated) and checked to see how well predicted species distributions matched maps of actual distributions based on similar bird data (Price et al. 1995). The results indicated that at least a portion of the summer distributions of many North American birds can actually be modeled quite well based on climate alone.

The next step was to examine how bird distributions might change in response to a changing climate. For this study climate projections from the Canadian Climate Center's General Circulation Model (CCC-GCM2) were used. This model projects what average climate conditions may be once CO_2 has doubled from pre-industrial levels, sometime in the next 75 to 100 years. Differences between modeled current climate and modeled future $2xCO_2$ climate, both derived from CCC-GCM2, were then applied to the original climate variables used in developing the bird-climate models. All bird distribution models were then run using $2xCO_2$-derived climate variables. The combined bird-$2xCO_2$ climate models were then used to create maps of the projected possible future climatic ranges of many North American birds. A complete explanation of the methods used to develop the models and maps has been published elsewhere (Price 1995, in press).

Distributional models and distributional maps have been developed for almost all passerine bird species. What these maps actually show are areas projected to have the proper climate for the species under conditions derived from CCC-GCM2, a *climatic range*. While model results cannot be used to look at fine points of how a given species' distribution might change, they can provide an impression of the possible direction and potential magnitude of change in suitable climate for the species. By examining these maps it is possible to develop lists of how species ranges might change in particular states or regions (Price and Glick 2002; Price 2001, 2000a, 2000b, 2000c, 2000d) or used to estimate how groups of species, such as neotropical migrants may change (Price 2000e; Price and Root 2001, 2000).

Results

The results in table 1 show how climate change might change the percentage of Neotropical migrants present in each of the U.S. National Assessment regions. Gross changes depict the overall loss of species currently found in areas while net changes depict species loss from an area offset by species moving into the area from outside of the region. For example, under climate change conditions projected by Canadian Climate Center, the Great Lakes region could see a potential gross loss of 53 percent of the Neotropical migrants currently found in the region's states. These losses would be somewhat offset by birds colonizing from outside the region so the net change would be 29 percent fewer species than are currently found there.

Bird lists used in creating this table are not all inclusive, since results obtained from models of some species were not adequate to assess how their climatic ranges might change. Additionally, the bird lists are based on output from a single, commonly used climate model. There are many different models, and results vary between them. While the magnitude of projected temperature increase is somewhat similar between models, projected precipitation changes are often different. Using output from different climate models may therefore yield somewhat different results. Additionally, the geographic scale of these models, like those of the underlying climate change model, is quite coarse. As such, the models are unable to take into account localized topographic changes and the possible existence of suitable microclimates – along rivers, for example. Therefore, some species whose *climatic* ranges are projected as shifting out of a region may be able to persist in refugia if a suitable microclimate is available, especially in higher montane areas, on north facing slopes, or along riparian areas.

Table 1—*Changes in percent of neotropical migrants in U.S. National Assessment regions under the equilibrium conditions from the Canadian Climate Center GCM. See text for more information.*

	Neotropical migrants (%)	
Region	**Gross**	**Net**
California	-29	-6
Eastern Midwest	-57	-30
Great Lakes	-53	-29
Great Plains - Central	-44	-8
Great Plains - Northern	-44	-10
Great Plains - Southern	-32	-14
New England	-44	-15
Pacific Northwest	-32	-16
Rocky Mountains	-39	-10
Southeast	-37	-22
Southwest	-29	-4
Mid-Atlantic	-45	-23

Discussion

Observed Changes

How quickly these distributional changes might occur is unknown. The rate of change will largely depend on whether a given species' distributional limits are more closely linked with 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, changes could occur 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 100 km (Price, unpublished data). In another study, the arrival date of 20 species of migratory birds was found to be 21 days earlier in 1994 than in 1965 (Root, unpublished data; Price and Root 2000). Many other species have been found to be arriving and breeding earlier, not only in the United States but in Europe and elsewhere (Root et al. 2003, this volume).

Shifts in individual species' distributions and phenologies are only part of the story. It is unlikely that ranges of coexisting species will shift in concert. Bird communities, as we currently know them, may look quite different in the future. As species move, they may have to deal with different prey, predators and competitors. So-called "optimal" habitats may no longer exist, at least in the short term. The potential rates-of-change of birds and the plants that shape their habitats are often quite different. While many birds may be able to respond quickly to a changing climate, some plant ranges may take from decades to centuries to move (Davis and Zabinski 1992).

Economic and Ecological Implications

Climatically induced changes in the ranges of Neotropical migratory birds may have other impacts. Ignoring aesthetic, cultural, and stewardship issues (all important), there are still economic and ecological reasons to be concerned about changes in bird distributions. Bird watching contributes to the United States' economic health. Watching and feeding wildlife (primarily birds) contributed more than $29 billion to the nation's economy in 1996 (USDOI 1997). Estimating how changes in bird distributions might affect the economics of watching and feeding birds is difficult. Although some birdwatchers might adjust to changes in distributions and diminished species richness, there could also be changes in the amount of money spent watching wildlife in the US as people traveled elsewhere to see birds.

Birds are critical components of their ecosystems. The ecological services provided by birds include, but are not limited to, seed dispersal, plant pollination, and pest control. Their role in the control of economically important insect pests should not be underestimated. Birds have been known to eat up to 98 percent of the overwintering codling moth (*Cydia pomonella*) larvae in orchards (Kirk et al. 1996) and several species of warblers are thought to be largely responsible for holding down numbers of spruce budworm (*Choristoneura fumiferana*) larvae, eating up to 84 percent of non-outbreak larvae (Crawford and Jennings 1989). Changes in bird distributions could lead to increases in outbreaks of some harmful insects with subsequent ecological and economic damage (Price 2002).

Management issues

One typically used method to adapt to declines in wildlife populations has been the establishment of refuges, parks and reserves. However, the placement of reserves has rarely taken into account potential climate change even though the problems of climate change and reserve placement were first pointed out in the mid-1980s (Peters and Darling 1985). Managers of current reserves and parks need to be encouraged to consider climate change in developing future management plans (Halpin 1997, Solomon 1994). Specifically, this includes assessing the vulnerability of the key taxa in the preserve (Herman and Scott 1994, Galbraith and Price in review) as well as monitoring for potential impacts related to climate change (Solomon 1994). It may also be possible to develop a series of bioindicators to monitor the potential impacts of climate change on parks and preserves (de Groot and Ketner 1994). In the light of potential climate change there is a need for a robust, adaptable nature conservation system. Site-based conservation needs to become more flexible, and non-site based conservation needs to be woven into other land use policies.

In part, the disparity between siting preserves where wildlife currently are versus where they may be in the future may stem from uncertainties in the rate and amount of projected climate change. If a species' range shifts out of a reserve created for its survival, then the current reserve placement could even be considered mal-adaptive. However, if reserves are not created and species are lost to other pressures then the potential effects of climate change on species distributions are moot.

Another way in which humans have dealt with endangered wildlife populations has been through the use of captive breeding and translocations. These techniques have been put forward in the past as methods to deal with future population pressures caused by climate change (Peters 1992). However, captive breeding and translocation, while effective tools for the conservation of some species, may be appropriate for only a handful of species owing to the expense and technical difficulty inherent in any such effort (IPCC 2001).

Given the length of time it takes for species to adapt to new conditions how can mangers adapt their practices to dealing with a changing climate? Given that conservation resources are limited the goal needs to be moving towards 'no regrets' management practices. That is, practices that are beneficial now and are expected to also be beneficial in the future as the climate changes. For example, concentrating efforts to conserve species in areas where they both currently occur and are expected to occur under a changing climate – all things being equal. The models discussed here provide some measure of information as to where species might move in the future and maps showing the 'no regrets' zones are currently being prepared for a number of species.

Another 'rule-of-thumb' that managers can go by is that the better able they are to manage under climate variability (e.g. El Niño) or manage under climatic extremes (drought), the better they will likely be able to manage under climate change. The reverse is also true. If current management practices are not adequate to deal with drought, for example, then it is unlikely that they will be able to deal with climate change.

Conclusions

In summary, a high probability exists that climate change will lead to changes in bird distributions. Even a relatively small change in average temperature could impact neotropical migratory bird distributions, arrival and departure dates and breeding dates. Some of these changes could occur (and are occurring) relatively quickly. While these changes may have some ecological and, possibly, economic effects, the magnitude of these effects is unknown.

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

Managers may ultimately need to adapt not only in terms of wildlife conservation but also to replace lost ecosystem services normally provided by wildlife. For example, it may be necessary to develop adaptations to losses in 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 cases where the losses of the values of wildlife are associated with subsistence hunting, cultural and religious ceremonies, any attempt at replacement may represent a net loss.

Literature Cited

Crawford, H. S. and D. T. Jennings. 1989. **Predation of birds on spruce budworm *Choristoneura fumiferana*: functional, numerical, and total responses.** Ecology 70: 152-163.

Davis, M. B. and C. Zabinski. 1992. **Changes in geographical range resulting from greenhouse warming: effects on biodiversity in forests.** In: R. L. Peters and T. E. Lovejoy, editors. Global Warming and Biological Diversity. New Haven, CT: Yale University Press; 297-308.

Dawson, W. R. 1992. **Physiological responses of animals to higher temperatures.** In: R. L. Peters and T. E. Lovejoy, editors. Global Warming and Biological Diversity. New Haven, CT: Yale University Press; 158-170.

DeGroot, R. S. and P. Ketner. 1994. **Sensitivity of NW European species and ecosystems to climate change and some implications for nature conservation and management.** In: J. Pernetta, R. Leemans, D. Elder, and S. Humphrey, editors. Impacts of climate change on ecosystems and species: implications for protected areas. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources (IUCN); 29-53.

Halpin, P. N. 1997. **Global climate change and natural-area protection: management responses and research directions.** Ecological Applications 7: 828-43.

Herman, T. B. and F. W. Scott. 1994. **Protected areas and global climate change: assessing the regional or local vulnerability of vertebrate species.** In: J. Pernetta, R. Leemans, D. Elder, and S. Humphrey, editors. Impacts of climate change on ecosystems and species: implications for protected areas. Gland, Switzerland: IUCN; 13-27.

Intergovernmental Panel on Climate Change [IPCC]. 1996. **Summary for policymakers.** In: J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A Kattenberg and K. Maskell, editors. Climate change 1995: the science of climate change. Cambridge, England: Cambridge University Press; 3-7.

IPCC. 2001. **Climate Change 2001: Synthesis Report.** Cambridge, UK: Cambridge University Press.

Kendeigh, S. C. 1934. **The role of environment in the life of birds.** Ecological Monographs 4: 297-417.

Kirk, D. A., M. D. Evenden and P. Mineau. 1996. **Past and current attempts to evaluate the role of birds as predators of insect pests in temperate agriculture.** In: V. Nolan, Jr. and E. D. Ketterson, editors. Current Ornithology, Volume 13 New York, NY: Plenum Press; 175-269.

National Assessment Synthesis Team (NAST). 2000. **Climate change impacts on the United States.** Cambridge, UK: Cambridge University Press.

Peters, R. L. 1992. **Conservation of biological diversity in the face of climate change.** In: R. L. Peters, and T. E. Lovejoy, editors. Global warming and biological diversity. New Haven, CT: Yale University Press; 15-30.

Peters, R. L. and J. D. Darling. 1985. **The greenhouse effect and nature reserves.** Bioscience 35(11): 707-17.

Price, J. T. 1995. **Potential impacts of global climate change on the summer distributions of some North American grassland birds.** Ph.D. Dissertation, Detroit, MI: Wayne State University; 419 p.

Price, J. 2000a. **Modeling the potential impacts of climate change on the summer distributions of Massachusetts' passerines.** Bird Observer 28(4): 224-230.

Price, J. 2000b. **Modeling the potential impacts of climate change on the summer distributions of Michigan's nongame birds.** Michigan Birds and Natural History 7(1): 3-13.

Price, J. 2000c. **Modeling the potential impacts of climate change on the summer distribution of Colorado's nongame birds.** Journal of the Colorado Field Ornithologists 34: 160-167.

Price, J. 2000d. **Climate change and Minnesota birds.** Minnesota Birding 37(2): 14-15.

Price, J. 2000e. **Climate change and bird distributions in the Mid-Atlantic Region.** In: A. Fisher, D. Abler, E. Barron, R. Bord, R. Crane, D. DeWalle, C. G. Knight, R. Najjar, E. Nizeyimana, R. O'Connor, A. Rose, J. Shortle, B. Yarnal, editors. Preparing for a changing climate: Mid-Atlantic overview for the national assessment on the potential consequences of climate change for the United States. Mid-Atlantic regional assessment report, University Park, PA: The Pennsylvania State University; 32.

Price, J. 2001. **Modeling the potential impacts of climate change on the summer distributions of Ohio's non-game birds.** Ohio Birds and Natural History 2(1): 32-39.

Price, J. 2002. **Climate change, birds and ecosystems – Why should we care?** In: Rapport, D. J., W. L. Lasley, D. E. Rolston, N. O. Nielsen, C. O. Qualset and A. B. Damania, editors. Managing for Healthy Ecosystems. Boca Raton, FL: Lewis Publishers; 465-469.

Price, J. T. In press. **Potential impacts of climate change on the summer distributions of grassland birds.** Technical Report, Jamestown, ND: Northern Prairie Wildlife Research Center, Geological Survey, U.S. Department of the Interior.

Price, J., S. Droege and A. Price. 1995. **The summer atlas of North American birds.** San Diego, CA: Academic Press; 364 p.

Price, J. T. and P. L. Glick. 2002. **The Birdwatcher's Guide to Global Warming.** National Wildlife Federation and American Bird Conservancy; 36 p. plus CD-ROM of state fact sheets.

Price, J. T. and T. L. Root. 2000. **Focus: effects of climate change on bird distributions and migration Patterns.** In: P. J. Sousounis and J. M. Bisanz, editors. Preparing for a changing climate: The potential consequences of climate variability and change. Ann Arbor, MI: University of Michigan, Atmospheric, Oceanic, and Space Sciences Department; 65-68.

Price, J. T. and T. L. Root. 2001. **Climate change and Neotropical migrants.** Transactions of the 66th North American Wildlife and Natural Resources Conference; 371-379.

Root, T. L. 1988a. **Environmental factors associated with avian distributional boundaries.** Journal of Biogeography 15: 489-505.

Root, T. L. 1988b. **Energetic constraints on avian distributions and abundances.** Ecology 69: 330-339.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig and J. A. Pounds. 2003. **Fingerprints of global warming on animals and plants.** Nature 421: 57-60.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenweig, and J. A. Pounds. This volume. **The impact of climatic change on wild animals and plants: A meta-analysis.**

Solomon, A. M. 1994. **Management and planning of terrestrial parks and reserves during climate change.** In: J. Pernetta, R. Leemans, D. Elder, and S. Humphrey, editors. Impacts of climate change on ecosystems and species: implications for protected areas. Gland, Switzerland: IUCN; 1-12.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census (USDOI). 1997. **1996 National survey of fishing, hunting, and wildlife-associated recreation.** Washington, DC: Fish and Wildlife Service, U.S. Department of the Interior and Bureau of the Census, U.S. Department of Commerce; 168 p.