

Climate Change, Birds, and Ecosystems — Why Should We Care?

Jeff Price

INTRODUCTION

A functioning ecosystem is made up of animals and plants, in a matrix of soil and surrounding abiotic conditions, interacting in myriad different ways. However, much of the published work on the potential impacts of climate change on ecosystems has dealt primarily with vegetative responses. While the amount of work on climate change and birds has recently increased, it is still relatively scant. Much of this research has focused on potential impacts on single organisms, or, at most, suites of organisms taken together. Little work has been done on how changes to organisms will, in turn, affect the ecosystems of which they are a part. A given ecosystem might continue to function if species were removed (or added). However, how well it would function would depend on the role of the lost species. While there may be redundancies in the roles of many species in maintaining ecosystem health, as more species are removed the probability increases that the system will break down.

Much of the climate change impacts research has focused on factors known to feed back on climate, such as albedo and vegetation. The strength of the feedbacks caused by birds, from even potentially large changes, has been assumed to be relatively low. Consequently, very little research has been conducted investigating ways in which climatic changes may affect birds. Yet birds are necessary or valued for a number of reasons, including economic benefits and, especially, the ecosystem services (and subsequent influences on climate) they exert.

One important concern of researchers examining the potential impacts of climate change on ecosystems is whether ecosystems will become decoupled. That is, will the species within an ecosystem respond differentially to a changing climate? The ecosystem services birds perform contribute significantly to a healthy ecosystem. Indeed, some ecosystems might break down if a number of birds and their accompanying services disappear.

OVERVIEW OF METHODS

In order to determine how climate change might affect bird distributions, investigators should first verify whether bird distributions are associated with climate at all. If they are (and most are), then models based on current climate can be projected into the future to see how the climatic distributions — that area having a climate suitable for the occurrence of a species — might change

under various climate scenarios. To date, models depicting how the suitable summer climatic distributions of more than 150 species of North American birds might change with a changing climate have been developed using the techniques outlined by Price (1995). Logistic regression was used to develop models of the association between bird distributions based on Breeding Bird Survey (BBS) data and 18 climate variables. The time period used for developing these models was 1985 to 1989. The short time period was chosen in order to minimize changes from anthropogenic influences or random noise. The models were then statistically validated against a separate data set. Maps of the model distribution were created following the techniques of Price et al. (1995). The maps were used to determine whether the model of the distribution was similar to the distribution developed from the BBS data (Price et al., 1995).

Output from the $2\times\text{CO}_2$ equilibrium run of the Canadian Climate Centre's General Circulation Model 2 (GCM2) was used to project how the climate of each of the BBS routes might change. These projected climate data were then processed through the logistic regression equations to determine the probability of a species occurrence on each BBS route. Maps were then generated from these data, and the maps were compared with the current distribution of the species. In short, these maps depict the area where the climate may be suitable for the species in the future based on information about their current distributions.

DISCUSSION

Birds and other wildlife perform a number of valuable services for the ecosystems of which they are a part. These services include seed dispersal, pollination, decomposition of organic matter, primary productivity, and predation on insect pests. This investigation examined how avian predation of insect pests benefits boreal forest, grassland, and agriculture ecosystems, and how these systems might break down as the climate changes.

Case Study 1: Birds, Spruce Budworms, and the Southern Boreal Forest

The eastern spruce budworm (*Choristoneura fumiferana*) is a common, native phytophagous (plant-eating) insect of boreal forests in eastern North America (Fleming and Volney, 1995). Its preferred foods include balsam fir (*Abies balsamea*) and several spruce species (*Picea* spp.). Budworms are estimated to annually defoliate approximately 2.3 million hectares in the U.S. (Haack and Byler, 1993) and affect 51 million m^3 of forests in Canada (Fleming and Volney, 1995). Losses in Canada attributed to budworms can be 1.5 times that due to wildfire and can constitute a notable proportion of the annual harvest volume. Spruce budworms are usually present at low densities ($<100,000$ larvae/ha), but periodic outbreaks occur throughout the species range with densities reaching 22 million larvae/ha (Crawford and Jennings, 1989). These outbreaks can extend over more than 70 million hectares and last for up to 15 years, causing an annual loss totaling greater than 80% of foliage on fir and spruce trees. This foliage loss kills almost all of the trees in mature stands of balsam fir (Crawford and Jennings, 1989; Fleming and Volney, 1995). Trees not killed by defoliation are often at risk from other phytophagous insects and pathogenic diseases, and standing dead trees increase the risk of fire.

While the exact mechanisms behind the beginning and end of outbreaks are unknown, weather is thought to play a role in at least a portion of the budworm's range. Outbreaks in some areas frequently follow droughts (Mattson and Haack, 1987), and outbreaks in central Canada tend to start in stands with high concentrations of mature firs flowering after hot, dry summers (Fleming and Volney, 1995). Drought stresses host trees, leading to increases in concentrations of sugar and sugar alcohols but to decreases in complex carbohydrates. This frequently leads to a reduction in plant defense mechanisms. Drought also changes the microhabitat around affected plants. Drought-stressed plants average 2 to 4°C warmer (maximum 15°C warmer) than abundantly watered plants

(Mattson and Haack, 1987). Average temperature also plays a role in regulating the number of eggs laid by spruce budworms. The number of eggs laid at 25°C is 50% greater than the number laid at 15°C (Jardine, 1994). Drought and higher temperatures may also shift the timing of reproduction in budworms sufficiently that they may no longer be affected by some of their natural parasitoid predators (Mattson and Haack, 1987). Weather may also play a role in stopping outbreaks. Many outbreaks in central Canada are thought to have been halted by late spring frosts that killed new growth on trees, depriving budworms of their food source.

The control of some endemic populations of eastern spruce budworm may be aided by avian predators, especially some of the wood warblers (Crawford and Jennings, 1989). Several warbler species, including Cape May warbler (*Dendroica tigrina*), bay-breasted warbler (*D. castanea*), Blackburnian warbler (*D. fusca*), Tennessee warbler (*Vermivora peregrina*), and Nashville warbler (*V. ruficapilla*) are important predators of spruce budworms. Many of these species, but especially bay-breasted warbler, show functional responses to increases in budworms — individuals moving into the area and increasing their reproductive output in response to increases in the insect's population (Crawford and Jennings, 1989). Birds consume up to 84% of budworm larvae and pupae when budworm populations are low (approximately 100,000/ha) and up to 22% when populations reach approximately 500,000/ha. However, bird predation cannot effectively neutralize budworm populations in concentrations exceeding 1 million larvae/ha (Crawford and Jennings, 1989). These warblers, in concert with other budworm predators (mostly predatory insects), are thought to be able to control some populations of budworms under normal conditions.

Climate change may influence almost every component of this system, both individually and in species interactions. For example, the spruce budworm's northern range may increase with rising temperatures. Currently, this species' distribution is thought to be tied to the completion of larval development before autumn freezes begin (Jardine, 1994). Increasing temperatures and a greater frequency of drought could lead to more frequent and possibly more severe outbreaks. This change would occur because of the effects of both drought and temperature on host plants and insects (Mattson and Haack, 1987; Fleming and Volney, 1995). Increasing temperatures may also reduce the frequency of late spring frosts in southern boreal forests, possibly increasing the duration of budworm outbreaks in those areas.

A changing climate might also decouple budworm population cycles from those of some of its parasitoid and avian predators (Mattson and Haack, 1987). Distributions of most of the warblers that feed on spruce budworms could shift significantly farther north. One set of models projects that three of the most significant predators — Tennessee, Cape May, and bay-breasted warblers — may all be extirpated from below 50°N latitude with a doubling of CO₂ (Price, 2001). Indeed, the average latitude of occurrence of both Cape May and bay-breasted warblers has already shifted significantly farther north in the last 24 years.

This decoupling of predator and prey may exert the greatest change on southern boreal forests. Replacing biological control mechanisms with chemical control mechanisms (e.g., pesticides) could ultimately yield a different set of problems. Besides the economic and social issues relating to large-scale pesticide application, some pesticides may not work as well as expected. Some insects are known to have reduced susceptibility to pyrethrins, DDT, and some carbamate pesticides with increased temperatures (Mattson and Haack, 1987).

While there may be decoupling of some budworm populations from their control mechanisms, the range and timing of reproduction of the species would probably stay synchronized with their host species. A large outbreak area could contain as many as 7.2×10^{15} insects. Even assuming a budworm genetic mutation rate on the order of 1×10^{-5} per generation, billions of rare genotypes would still be present in the population (Fleming and Volney, 1995). These genotypes could help budworms adapt to remain in synchrony with their host species.

One result of these changes may be an increase in the rate of conversion from boreal forests to other habitat types (especially in southern boreal forests). Rising temperatures, drought conditions, and insect damage may increase the likelihood of major fires, particularly in combination.

Indeed, fire frequency in Canada, the western U.S., Alaska, and Russia has increased during the last several decades (Jardine, 1994), although several likely causes may be involved. Scientists need to confront two key questions: how quickly might southern boreal forests be converted to a different habitat type, and what might that habitat be? As fire frequency increases, the successional pathway changes from fir/spruce to aspen/birch to grasslands (Jardine, 1994). If the climate changes quickly, more southerly species may not have the time to migrate into areas as fast as boreal species are lost. That could mean a shift to grassland or grass/shrubland in areas currently dominated by southern boreal forest. That, in turn, may affect regional economies and distributions of species using southern boreal forests.

Case Study 2: Birds, Grasshoppers, and Grasslands

In pastureland and grassland ecosystems, birds are important predators of grasshoppers. Bioenergetic models estimate that a single pair of Savannah sparrows (*Passerculus sandwichensis*) raising their young consumes approximately 149,000 grasshoppers over a breeding season. Considering typical bird densities in these same areas, this implies that approximately 218,000 grasshoppers/ha are consumed each season (Kirk et al., 1996). In many areas, the economic threshold for spraying insecticides occurs when densities reach approximately 50,000 grasshoppers/ha (McEwen, 1987). Thus, birds may help keep grasshopper populations at lower levels, avoiding pesticide spraying. However, models project that the distribution of Savannah sparrows could shift north with climate change (Price, 1995). This shift may then decouple this predator from its prey in much of the U.S. Many other grassland birds are also projected to undergo similar shifts in their distributions (Price, 1995). Unless all components (grasslands, grasshoppers, and birds) of this ecosystem were to change at the same rate — an unlikely prospect — the decoupling of the predators from their prey could lead to an increase in grasshopper outbreaks in the future.

Case Study 3: Birds in Agricultural Ecosystems

Birds may also be effective predators of insect pests in agricultural settings. Numerous studies have documented the efficiency of bird predation on overwintering codling moth (*Cydia pomonella*) larvae in orchards in different parts of the world, with predation levels reaching 90% or more (Neff, 1942; MacLellan, 1959; Hagley, 1970; Solomon et al., 1976; Solomon and Glen, 1979; Stairs, 1985). In southeastern U.S. pecan orchards, a single tufted titmouse (*Parus bicolor*) feeding on pecan nut casebearers (*Acrobasis nuxvorella*) is estimated to save nut growers 52,000 pecans annually (Whitcomb, 1971). While models have yet to be developed for those birds preying on codling moths, the models for tufted titmouse project that the range of that species does not shift out of the southeastern U.S. (J.T. Price, personal communication, 1999).

CONCLUSION

While changes in bird distributions due to incipient modifications to climate may not exert strong feedbacks on climate (except possibly in the southern boreal forest), they could be significant because of disruptions to ecosystem services. Species within ecosystems have evolved together over time and depend on each other to various degrees for services such as food, protection, or reproduction. Rapidly separating, or decoupling, these species may cause detrimental changes. The examples presented here are just a few of the myriad interactions taking place in ecosystems on a daily basis. Furthermore, climate change is just one of the stressors that species in these systems face.

Humans may be able to intervene to help prevent disruption of many ecosystem services, but the costs of such intervention could be large. For example, loss of predators may lead to the need to apply more pesticides. This will not only have direct monetary costs but also indirect costs such

as other ecosystem damages or possible human health problems. Over time, new predators might migrate into the ecosystem, or the prey might become pesticide resistant. Problems may be caused not necessarily by the change itself, but rather by the rate of change. Unless all components of the ecosystem change at the same rate, the systems will decouple, and the new systems may bear little resemblance to the ecosystems to which managers are accustomed. More research is needed to determine not only how more of the pieces of the ecosystem work together but also how they might move and at what rates relative to each other.

REFERENCES

- Crawford, H.S. and Jennings, D.T., Predation by birds on spruce budworm *Choristoneura fumiferana*: functional, numerical and total responses, *Ecology*, 70:152–63, 1989.
- Fleming, R.A. and Volney, W.J.A., Effects of climate change on insect defoliator population processes in Canada's boreal forest: some plausible scenarios, *Water Air Soil Pollut.*, 82:445–454, 1995.
- Haack, R.A. and Byler, J.W., Insects and pathogens: regulators of forest ecosystems, *J. For.*, September:32–37, 1993.
- Hagley, E.A.C., The distribution and survival of overwintering codling moth larvae in southern Ontario, *Proc. Entomol. Soc. Ontario*, 100:40–47, 1970.
- Jardine, K., Finger on the carbon pulse: climate change and the boreal forests, *Ecologist*, 24:220–224, 1994.
- Kirk, D.A., Evenden, M.D., and Mineau, P., Past and current attempts to evaluate the role of birds as predators of insect pests in temperate agriculture, in Nolan, V., Jr. and Ketterson, E., Eds., *Current Ornithology* Vol. 13, Plenum Press, New York, 1996, pp. 175–269.
- MacLellan, C.R., Woodpeckers as predators of codling moth in Nova Scotia, *Can. Entomol.*, 91:673–80, 1959.
- Mattson, W.J. and Haack, R.A., The role of drought in outbreaks of plant-eating insects, *BioScience*, 37:110–118, 1987.
- McEwen, L.C., Function of insectivorous birds in a shortgrass IPM system, in Capinera, J.L., Ed., *Integrated Pest Management on Rangeland: A Shortgrass Prairie Perspective*, Westview Press, Boulder, CO, 1987, pp. 324–333.
- Morris, R.F., Cheshire, W.F., Miller, C.A., and Mott, D.G., The numerical response of avian and mammalian predators during a gradation of the spruce budworm, *Ecology*, 39:487–494, 1958.
- Neff, J.A., Comments on birds and codling moth control in the Ozarks, *Wilson Bull.*, 54:21–24, 1942.
- Price, J.T., Potential impacts of global climate change on the summer distributions of some North American grassland birds, Ph.D. dissertation, Wayne State University, Detroit, MI, 1995.
- Price, J.T., Climate change, warblers and spruce budworms, in Green, R.E. et al., Eds., *Impacts of Climate Change on Wildlife*, Royal Society for the Preservation of Birds, U.K., 2001, pp. 60–63.
- Price, J.T., Droege, S., and Price, A., *The Summer Atlas of North American birds*, Academic Press, San Diego, CA, 1995.
- Solomon, M.E. and Glen, D.M., Prey density and rates of predation by tits (*Parus* spp.) on larvae of codling moth (*Cydia pomonella*) under bark, *J. Appl. Ecol.*, 16:49–59, 1979.
- Solomon, M.E., Glen, D.M., Kendall, D.A., and Milsom, N.F., Predation of overwintering larvae of codling moth (*Cydia pomonella* L.) by birds, *J. Appl. Ecol.*, 13:341–52, 1976.
- Stairs, G.R., Predation on overwintering codling moth populations by birds, *Ornis Scand.*, 16:323–324, 1985.
- Whitcomb, W.H., The tufted titmouse, *Parus bicolor*, as a predator of the pecan nut casebearer, *Acrobasis caryae*, in Komarek, E.V., Ed., *Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Manage.*, Vol. 2, Tall Timbers Research Station, Tallahassee, FL, 1971, pp. 305–308.