Christmas Bird Counts and Climate Change:

Northward Shifts in Early Winter Abundance

Daniel K. Niven[1], Gregory S. Butcher[2], and G. Thomas Bancroft[3]

1 National Audubon Society, Illinois Natural History Survey, 1816 South Oak Street, Champaign, IL 61820; dniven@audubon.org
2 National Audubon Society, 1150 Connecticut Avenue, NW, Suite 600, Washington, DC 20036; gbutcher@audubon.org
3 National Audubon Society, 1150 Connecticut Avenue, NW, Suite 600, Washington, DC 20036; tbancroft@audubon.org

Abstract

We used Christmas Bird Count data to investigate recent changes in the latitudinal center of abundance of North American birds. Among the 305 bird species in our study, there was a strong northward shift over the past 40 years. Of the 305 species, 208 (68.2 percent) shifted north. Wetland birds, forest birds, shrub birds, and generalists all had a majority of the species shifting northward, but grassland birds did not. These results and others are correlated with the warmer January weather experienced in the contiguous 48 United States over the past 40 years. There is no evidence that the species moving north are currently suffering population declines related to those moves, but if winters continue to warm, bird habitats and food supplies may not be able to track the warmer weather as effectively as many birds can.

The Rough-legged Hawk *(Buteo lagopus)* is an arctic raptor that moves to the south in winter months and is one of a host of species whose core CBC range has shifted northward. This one was photographed near Spearfish, South Dakota. Photo/Scott Weins

Introduction

Bird ranges are dynamic. The ornithological literature is filled with details of range expansions and contractions. Changes in bird ranges can be caused by a wide variety of factors, including disease, competition, predation, human intervention,

Daniel K. Niven is Audubon's Senior Scientist for Bird Conservation. Previously he directed Audubon's Important Bird Areas Program, where he guided the development of IBA criteria and helped launch state IBA programs. Niven, who received his Ph.D. from the University of Illinois, brings to Audubon a lifelong interest in birds and conservation, having participated in CBCs since he was a toddler.

Gregory S. Butcher is Director of Bird Conservation for the National Audubon Society. He has a Ph.D. in Zoology from the University of Washington. Butcher previously served as Director of Bird Population Studies at Cornell University's Laboratory and is a fellow of the American Ornithologists' Union.

G. Thomas Bancroft is Chief Scientist for the National Audubon Society. He received his Ph.D. in Biology from the University of South Florida. Before joining Audubon in 2007 he was Vice President of the Ecology and Economic Research Department at the Wilderness Society. He worked for Audubon on Everglades issues in the 1980s and early 1990s.

and habitat changes. In the face of growing concern about rapid global changes in climatic conditions, much of it due at least in part to human activities (Intergovernmental Panel on Climate Change [IPCC] 2007), we decided to assess patterns of change in the winter distributions of various guilds of North America birds. Previous studies have suggested that the northern ranges of birds especially should often be determined by climatic variables such as winter temperature (Root 1988a, b, c).

The distribution and abundance of birds, and their changes, are better known than for any other type of organism. Birds are generally easy to detect, identify, and count relative to other organisms. They are widely distributed both geographically and among habitats. They include both widespread and geographically restricted species, habitat specialists and generalists, and both sedentary species with little ability to disperse and migrants whose individual movements may span 10,000 kilometers. As a result, they are an ideal class of organisms with which to study range dynamics and their causes.

We have especially good information about the range and population dynamics of North American birds because of two continental-scale bird surveys—the Breeding Bird Survey (BBS), which is run in the United States by the U.S. Geological Survey and in Canada by the Canadian Wildlife Service, and the Christmas Bird Count (CBC), which is run in the United States by the National Audubon Society and in Canada by Bird Studies Canada. The present study is based on 40 years of data from the Christmas Bird Count.

In this paper we report changes in the distribution of various guilds of birds over the past 40 years in North America, with a focus on patterns found among various guilds of land birds, including those that do or do not use supplemental food supplies. This paper expands upon ongoing work first reported by the Associated Press in February 2009 (Niven et al. 2009) and in a companion paper (Niven et al. in prep) where we provide more detailed analyses about the relationship between changes in distribution and changes in winter temperature. We have included in our analyses all species that commonly occurred on the Christmas Bird Count during the 40-year period of the study.

Methods

● Climate data and analysis

Monthly average temperature estimates were available for each of the lower 48 U.S. states and the continental aggregate of these states (NOAA, National Climatic Data Center 2009). For each month we used least squares regression to assess the extent of change in continental temperatures over a 40-year time period from 1966 through 2005.

● Avian data, survey area, and time period covered

The Christmas Bird Count is the oldest and largest wildlife survey in the world. Currently, more than 2000 counts are conducted annually during a three-week period between mid-December and early January, with the participation of more than 30,000 volunteer observers contributing more than 60,000 person-days. Each local count is conducted once annually during a 24-hour period in a 15-mile-diameter circle. A variable number of observers divide into separate field parties and tally the total number of individuals of each species detected. An attempt is made to detect all species, but cryptic, rare, and nocturnal species, may be undersampled. Nonetheless, the CBC is applicable to assess continental change in the abundance and distribution of most species of relatively common birds in the continental U.S. and southern Canada.

We based our analysis on the 40-year time period from the winter of 1966–67 through the winter of 2005–06. Although the CBC began in 1900, we chose 1966–67 as a starting point because by that year the CBC survey methods had become standardized, and sample sizes, particularly in the western part of the survey area, were sufficient for statistical analyses.

The survey area was defined as the contiguous lower 48 U.S. states and the southern portions of Alaska and the Canadian provinces. The northern portions of Alaska and Canadian provinces were too poorly covered to provide meaningful data; therefore, the northern extent of coverage was defined based on the ecological boundaries of Bird Conservation Regions 5, 10, 11, 12, and 14, as defined by the North American Bird Conservation Initiative (NABCI 2000).

The primary sampling units (strata) for our analyses are the portions of the 55 states and provinces occurring within the survey area as defined above. In all analyses, Rhode Island was merged with Connecticut; Washington, D.C., and Delaware were merged with Maryland; Prince Edward Island was merged with Nova Scotia; and the small portion of the Yukon was merged with British Columbia.

● Preliminary data analysis and choice of species

For all North American species, 40-year population trends and annual indices of abundance were estimated, both continentally and for each state and province (strata), with hierarchical models in a Bayesian analysis using Markov chain Monte Carlo techniques (Link et al. 2006, Niven et al. 2004, Sauer et al. 2004). Because the number of observers and amount of time devoted to each survey varies among CBCs, differences in effort among circles were accounted for in the model based on the number of party hours devoted to each survey (Link and Sauer 1999). This method estimates the best nonlinear effort adjustment appropriate for each species in each stratum and applies those adjustments to each circle in the strata.

To focus on widespread species for which we would be able to detect distributional change, our analyses only include species that met the following criteria continentally and in at least five strata: (1) the minimum number of CBC circles in the analysis was at least 25 continentally and five in each of at least five strata, (2) the precision estimate was sufficient that a trend of 10 percent per year or greater



Familiar birds both eastern and western are shifting their CBC ranges northward, including the Carolina Wren *(Thryothorus ludovicianus),* left; Steller's Jay *(Cyanocitta stelleri),* middle; and Purple Finch *(Carpodacus purpureus),* right. Photos (left to right)/ Richard Lee, Ashok Khosla, Darrell E. Spangler

would be statistically significant; (3) the mean relative abundance was at least 0.01 (approximately equal to the average number of birds detected per circle with the average amount of effort), and (4) the percentage of the species' hemispheric early-winter range included within the CBC survey area was at least 1.0 percent. By applying these rules we were left with a total of 305 species.

Definitions and Classifications

Each of the 305 species was classified into one of the following ecological guilds based on their distribution and habitat use during early winter:

Coastal birds—species whose distributions are largely restricted to the immediate coast or offshore waters. This group includes mostly waterbirds but also a few land birds (Saltmarsh and Seaside sparrows).

Waterbirds—species primarily dependent on aquatic or wetland habitats for feeding and/or roosting that are not restricted to coastal habitats. This guild includes some species found only in freshwater habitats and others that use both fresh and saltwater.

Land birds—species primarily dependent upon terrestrial habitats. Because land birds represent a large and diverse guild, we further subdivided them into additional habitat guilds as follows: (1) Grassland birds—occurring primarily in natural or artificial grassland habitats in winter, (2) Shrubland birds—occupying natural shrubland or rangeland habitat, as well as species characteristic of edge and young second-growth habitats (3) Woodland birds—species characteristic of mature or late-successional deciduous or coniferous forests, savannahs, open woodlands, or gallery or riparian woodlands, (4) Generalists—species not easily classified within one of the other guilds due to approximately equal use of two or more habitat types during winter. We also included in this guild species often associated with urban or suburban environments.

We further subdivided land birds based on their use of supplemental food provided at feeding stations. Our classification generally follows that of Dunn and Tessaglia-Hymes (2001), but has been expanded and modified based on our personal experience and consideration of species accounts from the Birds of North America series (Poole 2005) as follows:

Regular feeder users—species that make regular use of human-supplemented food, and as a result may at times become partially reliant upon these food sources.

Occasional feeder users—Species that may use supplemental food sources when they are available, but are unlikely to develop any dependence upon these sources.

Non-feeder users—Species that rarely or never visit feeding stations.

Change in Center of Abundance

Year-specific latitudinal centers of abundance within our survey area were estimated for each species as the mean centroid latitude among all strata (states and provinces) included in the analysis, weighted by the species' strata-specific indices of abundance and the area (in km^2) of each stratum.

To facilitate the comparison of annual changes in latitudinal distribution among species, for each species we subtracted the value of the centroid latitude in year one (winter 1966–67) from each of the 40 yearly estimates. This standardized the centroid latitudes of all species to start at zero in year one (1966–67) such that the values in all subsequent years reflected the amount of change since year one. For each species, and for the median values among all species in each guild, standard least squares linear

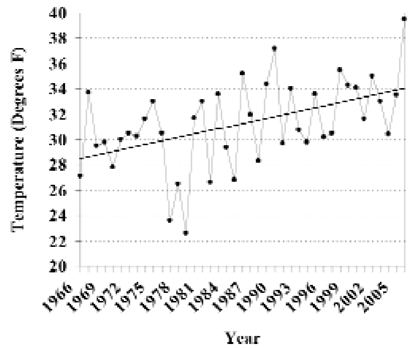

Figure 1. Change in average January temperature across the 48 contiguous United States, 1966–2006.

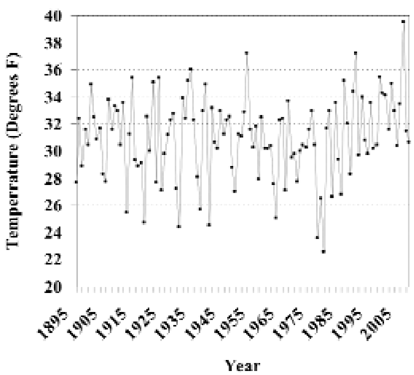

Figure 2. Change in average January temperature across the 48 contiguous United States, 1895–2008.

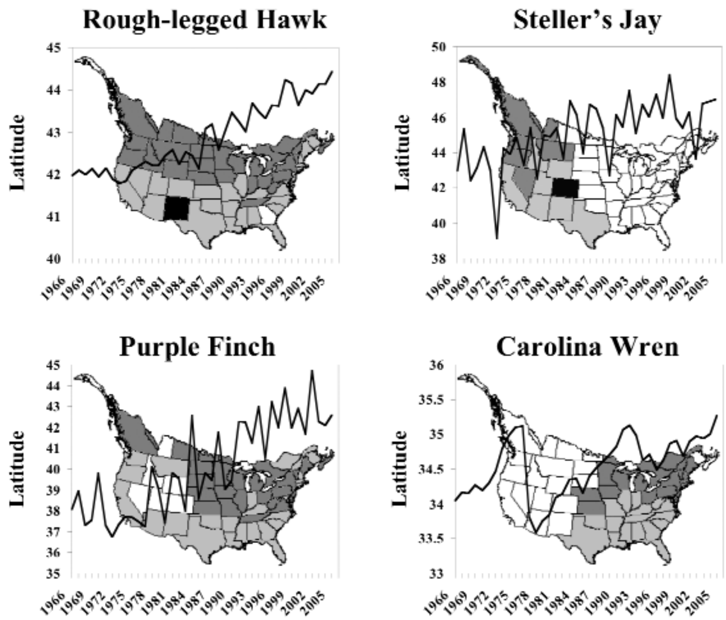

Figure 3. Change in latitudinal center of abundance and regional differences in population trends of selected species.

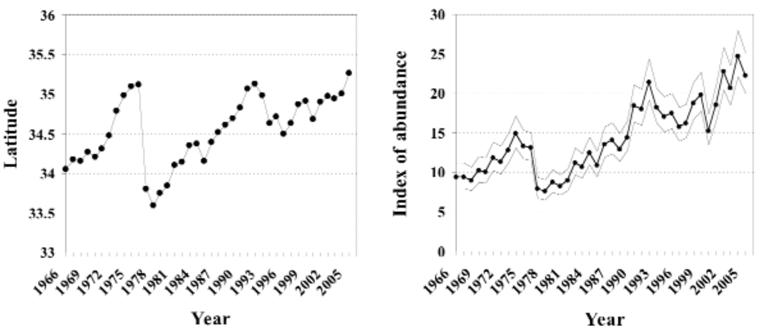

Figure 4. Annual change in the latitudinal center of abundance (left) and change in estimated continental abundance, with 95 percent confidence intervals, (right) for the Carolina Wren.

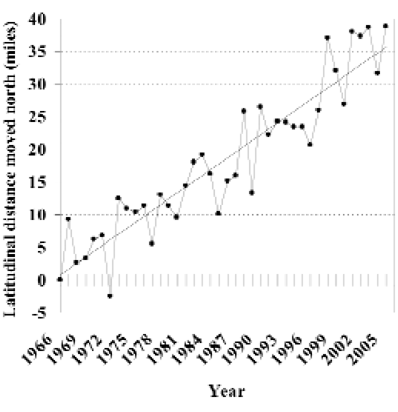

Figure 5. Average amount of change in the latitudinal center of abundance (in miles) of 305 widespread bird species in North America.

regression was used to determine the total amount of latitudinal change in miles.

Geographic Variation in Population Trends

To explore geographic variation in population trends, for each species and each stratum in which it occurred, we calculated the deviation of the stratum-specific population trend from the continental population trend by subtracting the 40-year continental population trend estimate from the 40-year stratum population trend estimate. For simplicity we will refer to these differences as the "stratum trend deviations." A positive stratum trend deviation indicates that the 40-year population trend in that state or province was higher than the overall continental average and vice versa.

Results

Temperature patterns

Based on regression analyses, January was the month that experienced the greatest amount of annual temperature change in the lower 48 states over the past 40 years (the period of our study). During this period the average January temperature increased more than 4.5 degrees Fahrenheit (Figure 1). In fact, both the coldest and warmest average January temperatures during the 114-year period for which we have data (from 1895 through 2008) occurred within our 40-year study period: the coldest two Januarys were in 1977 and 1979; the warmest was in 2006 (Figure 2).

Distributional Changes of Selected Species

Our study confirmed northward shifts in many species, such as Red-bellied Woodpecker, Tufted Titmouse, Carolina Wren, and Northern Cardinal, that have been mentioned as moving north in other studies, informal writings, and personal conversations. Many other species that have been less subject to such discussions have also moved north, including Rough-legged Hawk, Steller's Jay, and Purple Finch (Figure 3). These changes may or may not involve overall range shifts, including retraction from the south and/or expansion to the north, but in all cases the pattern of change in relative abundance is reflected in regional differences in population trends.

The potential effect of temperature on distribution can be seen by considering the pattern of yearly change in the latitudinal center of abundance for Carolina Wren (Figures 3 and 4) in relation to changes in average January temperature (Figure 1). The pattern of expansion north was clearly reversed, according to the CBC data, in the winter of 1977–78 following the previously cold winter. Moreover, based on the continental annual indices of abundance, the southern shift in center of abundance in 1977–78 appears to accompany a continental

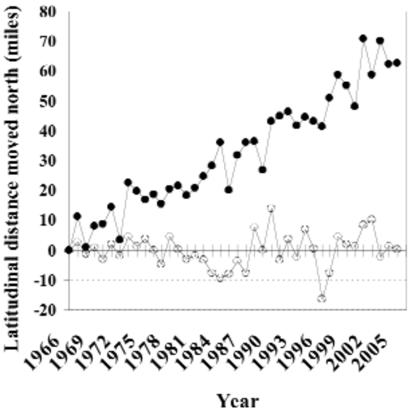

Figure 7. Change in center of abundance of species with significantly increasing (N=60; solid circles) or significantly decreasing (N=24; open circles) population trends. Definitions of significantly increasing and decreasing trends are given in Butcher and Niven (2007).

Table 1. Latitudinal change in center of abundance and continental population trends for the 305 species analyzed, according to their habitat guild classification and use of feeders. Analyses are based on Christmas Bird Count data from 1966-2005.

Species Groups	Number of species	Percent of species shifting north:		Average distance shifted north (miles)	Average population trend (percent change / year)
		> 0 miles	> 50 miles		
All Species	**305**	**68.2**	**40.3**	**34.8**	**0.9**
Coastally-Restricted Species	**33**	**57.6**	**33.3**	**19.9**	**0.5**
Species not restricted to coast					
Waterbirds	**93**	**59.1**	**34.4**	**14.6**	**2.2**
Land birds	**179**	**74.9**	**44.7**	**48.1**	**0.3**
Regular feeder user	64	81.3	57.8	82.1	0.7
Occasional feeder user	56	73.2	33.9	37.3	0.0
Rarely / Never visit feeders	59	69.5	40.7	21.6	0.2
Generalist	**26**	**65.4**	**42.3**	**27.1**	**1.7**
Grass	**26**	**50.0**	**26.9**	**-3.2**	**-1.1**
Shrub	**39**	**76.9**	**38.5**	**36.8**	**-0.6**
Woodland	**88**	**84.1**	**53.4**	**74.5**	**0.7**
Regular feeder user	37	91.9	64.9	107.1	0.7
Occasional feeder user	27	77.8	40.7	53.1	1.3
Rarely / Never visit feeders	24	79.2	50.0	48.4	0.3

population decline likely reflecting mortality in the north, rather than simply a migration south (Figure 4).

Distributional Changes of Groups

By aggregating annual patterns of distributional change among all 305 bird species in our study, we found a strong average shift in center of abundance to the north over the past 40 years (Figure 5, Niven et al. 2009, Niven et al. in prep.). The average distance moved was approximately 35 miles, or slightly less than one mile per year. Of these 305 species, 208 (68.2 percent) shifted north (Table 1), with 123 species (40.3 percent) shifting north more than 50 miles. (An appendix with species-specific information is available at http://www.audubon.org/news/pressroom/bacc/pdfs/Appendix.pdf).

Among the 305 species in our analysis, 179 were classified as land birds. Land birds as a group exhibited more latitudinal movement than did waterbirds or species restricted to the coast. Seventy-five percent of land birds shifted north an average of 48 miles (Table 1).

We divided land birds into four habitat guilds. Within three of the four guilds the birds shifted north on average (Table 1). Woodland birds shifted the most, whereas grassland birds showed almost no change (a negligible shift south of 3.2 miles). We also divided the land birds into those that regularly, occasionally, or rarely/never use supplemental food provided at bird feeders. All three of these groups shifted their centers of abundance to the north (Table 1). Because feeder birds and woodland birds exhibited such strong patterns, and because many feeder birds are woodland species, we divided woodland birds by feeder use status. Woodland species showed significant northward shifts in the center of abundance regardless of whether or not they used feeders, indicating that shifts north are widespread and not simply an artifact of increased feeder availability and use.

Population trends

CBC population trends show a positive bias relative to those for the same species on the BBS (Butcher and Niven 2007). Therefore, trends are likely not as positive as those shown in Table 1. Nonetheless, grassland and shrubland birds show declines as a group, woodland and coastal birds show small increases, and generalists and aquatic/wetlands birds show large increases (Table 1). When considering the complete suite of 305 species in our analysis, we found that species with significantly increasing trends showed strong northerly shifts in their center of distribution, whereas species experiencing significant declines did not (Figure 7).

Discussion

LaSorte and Thompson (2007) and Hitch and Leberg (2007) previously reported that North American birds, on average, have shifted their distributions to the north in recent decades. Our study supports their findings and expands upon them by including a larger and more inclusive suite of species. In each of these studies and ours, the average yearly shift north of North American birds was approximately one mile per year. January temperatures rose significantly across the 48 states in the last 40 years, so it may not be surprising that a majority of the common and widespread bird species shifted to the north on the Christmas Bird Count during this period of warmer weather. Our results for the Carolina Wren (Figure 4) and those of Mehlman (1997) represent an example of how annual weather patterns (in this case, severe weather patterns) may affect both distribution and abundance. Niven et al. (in prep.) report strong evidence that the northward shifts in winter center of abundance are caused by the warmer temperatures. For example, annual variation in latitudinal centers of avian abundance is correlated with annual variation in temperature, and among the lower 48 states, rates of population change are strongly correlated with rates of temperature change, independent of latitude. Because we found northward movements among almost all types of birds, a general factor such as temperature must be responsible rather than anything specific to a particular habitat or guild. However, provisioning of supplemental food at feeders may contribute to these patterns by increasing survivorship in northern areas with harsher winter conditions.

Our study has shown that birds are good indicators of warming winter weather, but the results do not generally suggest that the birds that moved over the past 40 years have suffered because of that movement. Among species with positive population trends, many shifted north (Figure 7). The major explanation for differences in population change over the last 40 years appears to be related to habitat rather than climate change: waterbirds, woodland birds, and generalists are all increasing, while shrubland and grassland birds are declining (Table 1). Therefore, if current winter temperature patterns were to stabilize, there may be little reason for concern for the future of most of the bird species included in this study. However, the IPCC (2007) has predicted that global warming will continue indefinitely unless humans act swiftly to curb the release of greenhouse gases into the atmosphere, and projected impacts of climate change are expected to be widespread (Karl et al. 2009). If winters continue to warm, many species that have done well over the past 40 years may not do so well in the future. Most plants and animals are unlikely to be able to respond to warming conditions as quickly as birds, and differences in the rate of movement may lead to ecological disruption of natural communities that could negatively affect even those birds that can quickly adjust their distributions (Lawler et al. 2009). Moreover, some groups of species may already be experiencing negative impacts of climate change. We found that birds with significantly declining populations did not exhibit latitudinal shifts to the north (Figure 7). In other words, birds that shifted significantly north did better than species that did not. Further research may clarify this issue, but it may be that the pool of declining species includes species that were unable, for ecological or behavioral reasons, to shift their distributions north in response to climate change and therefore suffered as a result (McLaughlin et al. 2002, Malcolm et al. 2006, Sekercioglu et al. 2008). Indeed, species dependent upon specialized or localized habitats (such as salt marshes) or nonmigratory species restricted to oceanic islands or habitat islands (such as mountaintop habitats) may be least able to disperse to new areas as conditions change, and these species may be most severely affected by climatic change.

LITERATURE CITED

Butcher, G.S., and D.K. Niven. 2007. Combining data from the Christmas Bird Count and the Breeding Bird Survey to determine the continental status and trends of North American birds. http://stateofthebirds.audubon.org/cbid/report.php.

Dunn, E.H., and D.L. Tessaglia-Hymes. 2001. *Birds at Your Feeder: A guide to feeding habits, behavior, distribution and abundance.* W. W. Norton and Co. 432 pp.

Hitch, A.T., and P.L. Leberg. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21(2):534–539.

IPCC. 2007. *Climate change 2007: Synthesis report. Contribution of working groups I, II, and III to the fourth assessment report of the Intergovernmental Panel on Climate Change* [Core writing team, Pachauri, R. K., and A. Reisinger (eds.)]. 104 pp. Geneva, Switzerland: IPCC. http://ipcc.ch/

Karl, T.R., J.M. Melillo, and T.C. Peterson. (eds.). 2009. Global Climate Change Impacts in the United States, Cambridge University Press.

LaSorte, F.A., and F.R. Thompson. III. 2007. Poleward shifts in winter ranges of North American birds. Ecology 88(7):1803–1812.

Lawler, J.J., S.L. Shafer, D. White, P. Kareiva, E.P. Maurer, A.R. Blaustein, and P.J. Bartlein. 2009. Projected climate-induced faunal change in the Western Hemisphere. Ecology 90(3):588–597.

Link, W.A., J.R. Sauer, D.K. Niven. 2006. A hierarchical model for regional analysis of population change using Christmas Bird Count data, with application to the American Black Duck. Condor 108:13–24

Link, W.A. and J.R. Sauer. 1999b. Controlling for varying effort in count surveys: An analysis of Christmas Bird Count data. Journal of Agricultural, Biological and Environmental Statistics 4(2):116–125.

Malcolm, J.R., C. Liu, R.P. Neilson, L. Hansen, and L. Hannah. 2006. Global warming and extinctions of endemic species from biodiversity hotspots. Conservation Biology 20(2):538–548.

McLaughlin, J.F., J.J. Hellmann, C.L. Boggs, and P.R. Ehrlich. 2002. Climate change hastens population extinctions. Proceedings of the National Academy of Sciences USA 99:6070–6074.

Mehlman, D.W. 1997. Change in avian abundance across the geographic range in response to environmental change. Ecological Applications 7(2):614–624.

NABCI. 2000. North American Bird Conservation Regions: Bird Conservation Region Descriptions. North American Bird Conservation Initiative, U.S. Fish and Wildlife Service, Arlington, VA. http://www.nabci-us.org/bcrs.html.

Niven, D.K., G.S. Butcher, and G.T. Bancroft. In prep. Northward shifts in the abundance of North American birds in early winter: A response to warmer winter temperatures? http://birdsandclimate.audubon.org/techreport.html.

Niven, D.K., G.S. Butcher, and G.T. Bancroft. 2009. Birds and Climate Change: Ecological Disruption in Motion. National Audubon Society, New York, New York. http://birdsandclimate.audubon.org/

Niven, D.K., J.R. Sauer, G.S. Butcher, and W.A. Link. 2004. Christmas Bird Count provides insights into population change in land birds that breed in the boreal forest. American Birds 58:10–20.

NOAA, National Climatic Data Center. 2009. http://www.cdc.noaa.gov/cgi-bin/data/timeseries/timeseries1.pl.

Poole, A. (Editor). 2005. The Birds of North America Online: http://bna.birds.cornell.edu/BNA/. Cornell Laboratory of Ornithology, Ithaca, NY.

Root, T. 1988a. Energy constraints on avian distributions and abundances. Ecology 69(2):330–339.

Root, T. 1988b. Environmental factors associated with avian distributional boundaries. Journal of Biogeography 15(3):489–505.

Root, T. 1988c. Atlas of wintering North American Birds: *An analysis of Christmas Bird Count data.* Univ. of Chicago Press, Chicago. 312 pp.

Sauer, J.R., D.K. Niven, and W.A. Link. 2004. Statistical analyses make the Christmas Bird Count relevant for conservation. American Birds 58: 21–25.

Sekercioglu, C.H., S.H. Schneider, J.P. Fay, and S.R. Loarie. 2008. Climate change, elevational range shifts, and bird extinctions. Conservation Biology 22(1):140–150.