Christmas Bird Count Provides Insights Into Population Change in Land Birds That Breed in the Boreal Forest

Daniel K. Niven, John R. Sauer, Gregory S. Butcher, William A. Link

Christmas Bird Count Provides Insights Into Population Change in Land Birds That Breed in the Boreal Forest

Daniel K. Niven[1], John R. Sauer[2], Gregory S. Butcher[3], William A. Link[2]
[1]*National Audubon Society, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, IL 61820*
[2]*USGS Patuxent Wildlife Research Center, 12100 Beech Forest Drive, Laurel, MD 20708*
[3]*National Audubon Society, 1150 Connecticut Avenue, N.W., Washington, DC 20036*

The boreal region is a vast area, representing one of the largest remaining intact forest ecosystems (Canadian Boreal Initiative, 2003). It spans North America, covering six Bird Conservation Regions (BCRs) (Rich et al. 2004). Four BCRs comprise the heart of the Canadian boreal forest: the Northwestern Interior Forest (BCR 4), the Boreal Taiga Plains (BCR 6), the Taiga Shield and Hudson Plains (BCR 7), and the Boreal Softwood Shield (BCR 8) (Figure 1). Most of the region is remote, far from roads or other access points for humans, but visiting it can be a breathtaking experience. Given its size and remoteness, the boreal forest may seem to be largely removed from the conservation threats facing much of the developed world. In fact, it isn't. The boreal forest is influenced directly by human activities such as changing forestry practices and hydroelectric development, and indirectly by global climate change. As these changes influence the region, increasing concern about populations of wildlife has led to initiatives that focus conservation activities and increase public awareness of this critical forest resource and the species it harbors (e.g., Boreal Songbird Initiative [www.borealbirds.org], Canadian Boreal Initiative [www.borealcanada.ca/], and Ducks Unlimited Canada, [www.ducks.ca]).

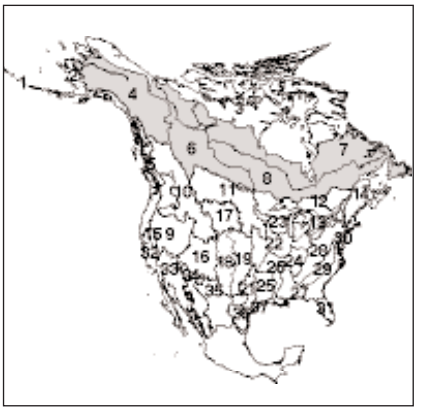


Figure 1. Bird Conservation Regions (BCRs) of the United States and Canada. Source: www.nabci-us.org/bcrs.html. The four highlighted BCRs constitute the boreal region for the purpose of this paper: the Northwestern Interior Forest (BCR 4), the Boreal Taiga Plains (BCR 6), the Taiga Shield and Hudson Plains (BCR 7), and the Boreal Softwood Shield (BCR 8). BCR names are given in the Appendix.

At least 186 species of land birds breed in the boreal forest, and more than 1 billion of these birds overwinter in the United States, accounting for an estimated 10 percent of the number of land birds that spend the winter in the continental United States (Blancher 2003). Unfortunately, we know very little about the population trends of the birds that are most highly dependent upon the boreal forest ecosystem. The primary source of information on population change in land birds is the continentwide North American Breeding Bird Survey (BBS). Administered by the United States Geological Survey and the Canadian Wildlife Service and initiated in 1966 (Sauer et al. 2004), the BBS is currently monitoring more than 4,000 survey routes in the United States and Canada. However, the BBS is conducted by volunteers and is a roadside survey, and the extremely limited number of both roadsides and volunteer observers in the boreal forest have limited BBS coverage to only a small part of the southern boreal region. Consequently, BBS results provide an incomplete picture of continentwide population trends of boreal species.

Luckily, for the suite of boreal species that winter in the United States and/or

Daniel K. Niven, Ph.D., is Audubon's Senior Scientist for Bird Conservation and was Director of the Important Bird Areas program. He has conducted research on the ecology of neotropical migrants on their breeding and wintering grounds, and has led efforts to develop indicators for assessing environmental change in Illinois. He has been a Christmas Bird Count compiler for more than 20 years.

John R. Sauer, Ph.D., a wildlife biologist, studies population dynamics and ecology of birds. In recent years his research has focused on developing and implementing methods for estimation of population change from North American Breeding Bird Survey and Christmas Bird Count data.

Gregory S. Butcher, Ph.D., Audubon's Director of Bird Conservation, works with the State of the Birds report, the WatchList, the Important Bird Areas program, analysis of Christmas Bird Count data, birds as bioindicators, and conservation planning. He previously served as Director of Bird Population Studies at Cornell University's Laboratory of Ornithology.

William A. Link, Ph.D., a mathematical statistician, has been actively involved in the development and analysis of models for count survey data for 17 years. He has published more than 25 papers on the topic.

southern Canada, we can address some of these deficiences with population data available from Audubon's Christmas Bird Count (CBC). Begun in 1900, the CBC is the world's largest and oldest database on bird populations (Butcher 1990). In this paper we apply recently developed statistical techniques to CBC data to assess regional population trends of 13 boreal forest breeding birds that overwinter extensively in the United States and southern Canada. This is part of a larger project to assess the population trends of all species that overwinter extensively in the area covered by the CBC.

METHODS

Species and areas included

We restricted our analysis to migrant land bird species that are largely dependent during the breeding season on habitats in the boreal region. We define the region primarily in terms of the four boreal BCRs mentioned above and in Figure 1. Our interest was in documenting population change for species with wintering ranges that fall primarily in the CBC survey region. To do this, we restricted our analysis to the 13 boreal-breeding species identified by Blancher (2003) that have at least 75 percent of their population breeding in the boreal region and also have significant portions of their wintering ranges in the area well surveyed by the CBC. For these species we estimated population change from CBCs for the interval from 1965/66 to 2002/03. We chose the winter of 1965/66 as the beginning year because it is coincident with the year the BBS was initiated. Moreover, the number of CBCs conducted increased dramatically through the 1950s and 1960s; prior to 1966, sample sizes (number of CBC circles surveyed) are considerably lower, especially in the western region of the United States.

Although interest is often focused on determining population trends at the continental level, it is also informative to assess change at the regional level. The 37 BCRs defined in the continental United States and Canada form the geographic template used for conservation planning by the major continental bird conservation initiatives (www.nabci-us.org/bcrs.html) and are therefore logical strata for regional analyses (Figure 1, with associated names in the Appendix). For each species, we included in our analyses all BCRs where the species was reported from four or more CBC circles at least once during the 38-year period of this study. This process is inclusive, in that many areas that are essentially peripheral to the species' wintering ranges are included. The total number of CBCs in each BCR is given in the Appendix.

Individual species analyses

We estimated population change by BCRs and for the entire survey area using a hierarchical model (Sauer et al. this volume). In this model, year effects were estimated using a loglinear model that assumes an over-dispersed Poisson distribution for counts. Variation in effort was accounted for using a model suggested by Link and Sauer (1999) in which the effect of effort is modeled parametrically. The model is hierarchical in that many of the factors in the model are treated as random effects; distributional assumptions were made for year, stratum, effort, and circle effects. The hierarchical analysis fit the loglinear model to estimate annual indices at the scale of BCRs and then aggregated results from the BCR scale to the continental scale by area-weighting the BCR estimates. Trend (yearly percentage change) was defined as the ratio of the yearly indices, scaled to the appropriate power. See Sauer et al. (this volume) or Link and Sauer (2002) for details of the hierarchical analysis.

The model was fit in a Bayesian analysis, using Markov-chain Monte Carlo fitting procedures in program WinBUGS (Spiegelhalter et al. 1999). This simulation procedure requires a series of "burn-in" iterations, in which the Markov chain reaches stability, then estimates are derived as summary statistics from successive iterations (Link et al. 2002).

The statistical significance of the trend results is judged by evaluating credible intervals (Bayesian counterpart to more traditional confidence intervals) associated with each trend estimate (Sauer et al., this volume). Credible intervals define the region within which an estimated parameter would fall 95 percent of the time. Therefore, if the credible interval does not overlap zero, then the estimated trend is considered to be significantly different from zero.

Area importance (AI) as defined by Partners in Flight (Panjabi et al. 2001) provides an estimate of relative density of a species among strata (in this case BCRs). For each species, we calculated AI in each BCR by dividing the index of abundance in the baseline year (baseline abundance) by the highest baseline abundance value for that species, and then multiplying this value by 100. We arbitrarily selected the 82nd CBC as the baseline year. The AI for each BCR was then assigned an AI score of 1 to 5 as described in Panjabi et al. (2001; see also the legend to Figures 2–14). BCRs with AI scores of 1, which reflect relative densities less than 1/100th of the BCR with the maximum relative density, were not included in our results, because the species' presence in those BCRs was considered to be peripheral to the core range of the species. We note that most of the species we analyzed have limited wintering populations in the boreal region and none of the 13 species had AI scores of 2 or more in the four boreal BCRs.

Where possible, results were compared to trend data available for the same time period from the Breeding Bird Survey (Sauer et al. 2004). It is important to recognize that comparisons of estimated population change between CBC and BBS results are complicated by the differing portions of the populations covered by each survey. Inconsistencies may simply reflect differences in the sampled populations.

Composite analyses

To summarize patterns of population change among species, we used a hierarchical model that treats trends and variances among species as random effects (Sauer and Link 2002). This model effectively accommodates the relative precision of trend estimates from individual species in summary analyses so that large yet imprecise estimates are "reigned-in" in summary ranking of species trends, in estimates of number of species with increasing populations, and in evaluation of population stability. Population stability is the probability that a species trend falls between some threshold values, and can be estimated directly from the hierarchical model results. We chose ±2 percent per year as our threshold stability values for trends, and any species that has a <5 percent chance of falling within the interval (–2, 2 percent/year) is deemed unstable. Although any threshold value for judging stability must be arbitrary, 2 percent/year is similar to thresholds used in other conservation activities.

RESULTS

The 13 species are a heterogeneous group, both in terms of life history and in terms of wintering distributions. As one might expect, they showed a variety of patterns of population change. We summarize results in terms of pattern of population change: increasing populations, stable or imprecisely estimated populations, or declining populations.

Increasing populations

Four species experienced significant increases between 1965–1966 and 2002–2003. The Merlin showed the largest positive trend (Figure 2a) with an average annual increase of 3.3 percent per year, which is statistically significant based on the credible intervals of 2.8 and 3.7 (Table 1). This pattern agrees with results from the BBS. The Merlin is widespread throughout North America in early winter, particularly in the West (Figure 2b), and its increases are significant and consistent across most of its early-winter range (Figure 2c).

The Ruby-crowned Kinglet and Hermit Thrush also increased significantly (Table 1, Figures 3a and 4a), although each of these species experienced moderate declines (less than 2 percent per year) in some BCRs (Figures 3c and 4c). Trend data for these species are also available from the BBS and results are very consistent for the Hermit Thrush, but the BBS reports a significant decline of –0.9 percent per year over the same period for the Ruby-crowned Kinglets (Figures 3a and 4a).



The Merlin showed a significant increase in population over the study period. Photo/George Jameson

Of the 13 species considered here, Palm Warblers may have the smallest percent of their early-winter range in the United States. Many migrate south to the Caribbean and coastal Mexico and Central America. Nonetheless, the populations in our range (Figure 5b) have increased significantly (Table 1, Figure 5c). Data from the BBS also cover only

Table 1. Population trends and group rankings based on a hierarchical analysis of CBC data for the 38-year period from 1965–1966 to 2002–2003 (CBC counts Nos. 66–103).

Species	Trend[a] (% change/yr.)	Standard Error (Trend)	Credible Intervals[b] (2.5%, 97.5%)	Baseline Abundance[c]	# CBCs / # CBCs in BCRs[d]	Rank[e]	Probability (Stable)
Rusty Blackbird	-5.1	1.22	(-6.57, -2.42)	0.3	1604 / 3009	1.2	0.09
Harris's Sparrow	-1.8	0.41	(-2.62, -1.02)	5.8	865 / 2578	2.7	0.76
Northern Shrike	-1.3	0.29	(-1.84, -0.8)	1.0	1539 / 2639	3.6	0.99
Le Conte's Sparrow	-0.9	0.86	(-2.64, 0.7)	0.1	378 / 1434	5.1	0.95
Swamp Sparrow	-0.4	0.26	(-0.9, 0.1)	5.4	1765 / 2889	5.7	1.00
Bohemian Waxwing	-4.5	6.47	(-25.47, -0.14)	11.9	858 / 1983	6.2	0.68
White-throated Sparrow	0.1	0.23	(-0.36, 0.5)	33.5	2220 / 2931	7.2	1.00
Smith's Longspur	0.8	3.74	(-7.15, 7.7)	0.05	58 / 452	7.3	0.73
Lincoln's Sparrow	0.2	0.45	(-0.7, 1.1)	2.2	1122 / 2762	7.4	1.00
Ruby-crowned Kinglet	1.1	0.19	(0.7, 1.5)	17.7	2040 / 2900	9.6	1.00
Palm Warbler	1.6	0.52	(0.5, 2.6)	1.9	701 / 2174	10.4	0.84
Hermit Thrush	2.2	0.25	(1.7, 2.6)	1.9	1770 / 2900	11.6	0.26
Merlin	3.3	0.23	(2.8, 3.7)	0.2	1694 / 2943	12.9	0.00

[a] Trends are based on means from the Markov-chain Monte Carlo (MCMC) fitting procedures.

[b] Credible intervals (CI) are a Bayesian analogue to confidence intervals.

[c] Baseline abundance is defined as the effort-adjusted index of abundance on the 82nd CBC.

[d] Number of CBCs on which species occurred. / Total number of CBCs in BCRs included in the analysis.

[e] Mean ranks from Markov-chain Monte Carlo (MCMC) procedure.

a small part of their range during the breeding season, but likewise show a significant increase (3.9 percent per year, Sauer et al. 2004).

Stable populations / imprecise estimates

Five species showed no strong population trend. The Le Conte's Sparrow has occurred most frequently in the lower Mississippi Valley (Figure 6b); however, its baseline abundance is one of the lowest of the 13 species (Table 1), indicating the overall rarity with which it is reported on the CBC, even though it winters primarily in the United States. Although its trend is –0.9 percent per year (Table 1), this decline is not significant, even though the credible intervals are relatively small and precise considering its low overall detection rate (Figure 6a). These results are in agreement with the BBS data (Figure 6a). Nonetheless, the Le Conte's Sparrow has experienced a significant decline in the Central Hardwoods region, BCR 24 (Figure 6c).

The Smith's Longspur has one of the smallest winter ranges of these 13 species, with most detections concentrated in the Central Mixed-grass Prairie and Oaks and Prairies, BCRs 19 and 21, respectively (Figure 7b). Its baseline abundance was lower than any other species (Table 1), and the credible intervals associated with its trend (Figure 7a) reflect the high degree of imprecision in the trend estimate, such that definitive statements about its overall trends are tenuous. Nonetheless, a statistically significant decline was detected in BCRs 25 and 26 (Figure 7c), although these are not the species' core areas of winter abundance (Figure 7b).

Like the Palm Warbler, the Lincoln's Sparrow also has a large portion of its population wintering to the south of the United States. In the United States, its maximum AI scores were in Texas (Figure 8b). Although it has been significantly declining in some areas (Figure 8c), its overall population trend was 0.2 percent per year (Table 1). This contrasts somewhat with results from the BBS that report a marginally significant increase of 1.8 percent per year (Sauer et al. 2004, Figure 8a).

Swamp Sparrows occur widely throughout the eastern forest biome, with a high concentration in the Mississippi Alluvial Valley and to a lesser extent in the Southeastern Coastal Plain (Figure 9b). Their slight decline of –0.4 percent per year is not significant (Table 1, Figure 9a); however, examination of regional trends suggests a gradual expansion of their range to the north and west (Figure 9c), with a significant decline in Florida.

White-throated Sparrows occupy a similar winter range as Swamp Sparrows, although they occur at a higher relative density along the Piedmont (BCR 29) and west of the lower Mississippi River (BCR 25) (Figure 10a). Their baseline abundance of 33.5 is by far the highest of all these species (Table 1). (Baseline abundance is the effort-adjusted index of abundance in the baseline year, arbitrarily defined as the 82nd CBC [based on the posterior mean values for each BCR]. Baseline abundance can roughly be taken to mean the average number of birds that one CBC would be expected to report given an average amount of effort.) White-throated Sparrows are also the most stable of all 13 species with a trend of 0.1 percent per year (Table 1, Figure 10a). This result contrasts with the BBS analysis that reports a small but significant surveywide decline of –0.7 percent

Legend and key to Figures 2–14. Winter distribution and population change in the CBC region.

a) 38-year population change, based on annual indices—see text for explanation of methods. Year refers to the year the CBC ended, i.e. 1966 refers to CBC count No. 66 conducted during the winter of 1965–1966.

- CBC Index
- 2.5% and 97.5% CIs
- BBS Index

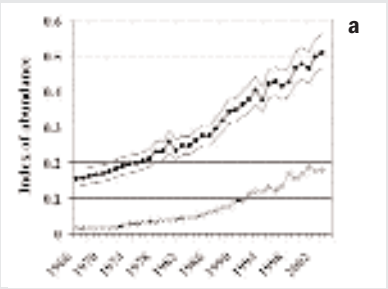
b) Early-winter distribution in CBC area, by BCRs, based on Area Importance scores. AI scores follow Panjabi et al. (2001). See text for details.

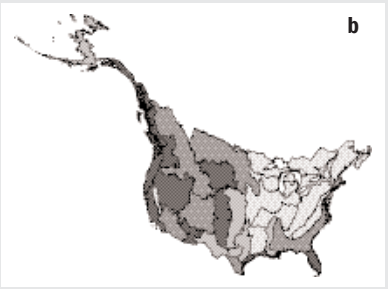
- 1 (AI = 0-0.09)
- 2 (AI = 1.0-9.9)
- 3 (AI = 10.0-24.9)
- 4 (AI = 25.0-49.9)
- 5 (AI = 50 or more)

c) Geographic distribution of population trends, by BCR. See text for details. Yearly percent changes in population size estimates are categorized below.

- * Significant
- < 2
- -2 < 0
- 0 - 2
- > 2

Figure 2. Merlin *(Falco columbarius)*







per year (Sauer et al. 2004, Figure 10a). Of all species, however, the White-throated Sparrow shows the most consistent pattern of decline in the south of its range and increase in the north, suggesting a northward shift of its wintering distribution (Figure 10c).

Declining populations

Four species have experienced population declines of varying degrees over the 38-year period of this analysis. The Northern Shrike occurs widely over much of the United States and southern Canada, with the exception of the southeast (Figure 11b). Although its baseline abundance is rather low (Table 1) and its populations have fluctuated considerably (Figure 11a), it has nonetheless shown a significant continentwide decline of –1.3 percent per year (Table 1). These declines, however, have occurred largely in the western United States with increases in most of the central and eastern United States (Figure 11c).

Bohemian Waxwings also occur at a relatively higher density in the western United States, except on the West Coast (Figure 12b). However, their abundance has fluctuated considerably such that the estimated annual indices of abundance, and therefore the estimated trends, are very imprecise (Figure 12a). Small sample sizes of CBC circles in the early years also contribute to this imprecision, as reflected in the fact that the 97.5 percent credible intervals for the first few years were very large. (Large upper credible intervals were not plotted for two years because they were off the scale of the graph.) In spite of the imprecision, a negative trend was detected in the Great Basin (BCR 9), which is a core area of their winter range (Figures 12b,c).

The Harris's Sparrow occupies a range very similar to the Smith's Longspur, with a maximum relative density in the Central Mixed-grass Prairie (BCR 19) (Figure 13b). It has experienced a steady and significant decline of –1.8 percent per year (Table 1, Figure 13a), with declines occurring across its entire wintering range (Figure 13c).

The Rusty Blackbird's winter range (Figure 14b) is very similar to that of the other largely wetland-inhabiting species considered here, the Swamp Sparrow (Figure 9b). The core of the Rusty Blackbird's winter range is in the Mississippi Alluvial Valley (BCR 26).

Figure 3. Ruby-crowned Kinglet *(Regulus calendula)*



Figure 4. Hermit Thrush *(Catharus guttatus)*



Figure 5. Palm Warbler *(Dendroica palmarum)*



The Southeastern Coastal Plain (BCR 27) and Central Hardwoods (BCR 24) are also important wintering areas (Appendix, Figure 14b). Rusty Blackbirds have experienced by far the steepest decline of the 13 species, with an annual decline of –5.1 percent per year (Table 1, Figure 14a). These declines have consistently occurred at greater than 2 percent per year in all the BCRs in which it regularly occurs (Appendix). Sauer et al. (2004) report an even steeper decline of –9.9 percent per year based on BBS analysis, although it is likely that the CBC covers a greater portion of the population than the BBS.

Composite analyses

When considered as a group, there is little evidence of a consistent pattern of decline among the species we analyzed (Table 1). The estimated number of species with increasing populations (trends >0) was seven (95 percent CI: 5,9), which is about the number one would expect due to chance. The Rusty Blackbird was the species ranked as most declining, and it had only an 8.7 percent chance that its trend fell in the stable interval (–2,2). Although the estimated trend of the Bohemian Waxwing was –4.5 and significant (based on the credible intervals), the imprecise estimate caused it to be ranked sixth in declining species, and its estimate had a 67 percent chance of falling into the stable interval. The Merlin had clearly increasing populations, with an estimated trend of 3.3 percent per year and a very small probability that it was within the range of stability (Table 1).



The Rusty Blackbird experienced the steepest decline among the species studied. Photo/Dave Menke, USFWS

DISCUSSION

The 13 species included in this analysis share the common trait of being distrib-

Figure 6. Le Conte's Sparrow *(Ammodramus leconteii)*



Figure 7. Smith's Longspur *(Calcarius pictus)*



Figure 8. Lincoln's Sparrow *(Melospiza lincolnii)*



uted largely in the boreal region in the breeding season and in the United States and/or southern Canada in the nonbreeding season. Apart from sharing that common distributional trait, they are an extremely diverse and heterogeneous group of species. For example, they represent seven families of passerine birds and a raptor. A few are irruptive in winter (the Bohemian Waxwing and Northern Shrike), whereas most are more sedentary and site faithful in the winter months. A few are predacious (the Merlin and Northern Shrike), whereas the rest are insectivores, granivores, frugivores, or omnivores. The White-throated Sparrow, Ruby-crowned Kinglet, Swamp Sparrow, Lincoln's Sparrow, and Palm Warbler are among the most abundant boreal forest species (Blancher 2003), whereas others, such as the Smith's Longspur and Le Conte's Sparrow, have much smaller populations (Rich et al. 2004). Some species are relative generalists in their habitat use, whereas the Rusty Blackbird and Swamp Sparrow are wetland specialists. Some species, such as the Merlin and Northern Shrike, are widely distributed in winter, whereas the Harris's Sparrow and Smith's Longspur are restricted to the use of a few BCRs. Moreover, some of the species in this analysis are not forest breeders, but rather occupy tundra, open taiga, or grasslands within the boreal BCRs.

Given the ecological diversity of this suite of species, it is not surprising that as a group they do not show consistent patterns of population change. However, they do provide a good cross section of the array of boreal species, and it is interesting to consider the range of factors responsible for population change in this diverse group. To be in a better position to successfully manage these species for their long-term protection, we must consider the ecological characteristics of these species and the unique threats they face. We provide brief commentaries on a few of the species with interesting patterns of population change.

Merlin

Among the increasing species, the Merlin stands out due to the magnitude and geographic extent of its increase (Table 1, Figure 2c). The cause of the increase is often attributed to human intervention. Merlins, which breed

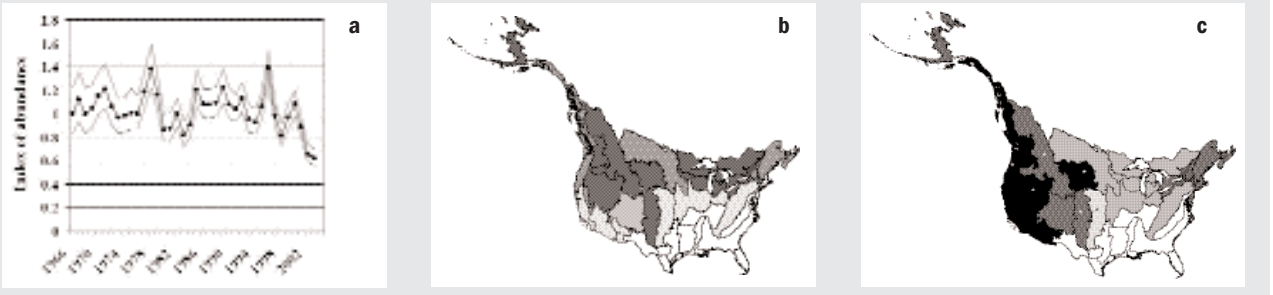
Figure 9. Swamp Sparrow *(Melospiza georgiana)*



Figure 10. White-throated Sparrow *(Zonotrichia albicollis)*



Figure 11. Northern Shrike *(Lanius excubitor)*



throughout the northern forests and prairies, suffered population declines as a result of pesticide use in the 1960s (Sodhi et al. 1993). The banning of organochloride pesticides in the 1960s initiated a recovery of the populations, and within the last 30 years the species range has expanded to include a number of urban centers in the northern Great Plains.

Northern Shrike

The Northern Shrike is holarctic, breeding across much of the Northern Hemisphere. It is a predatory passerine that experiences cyclic and irruptive movements (Cade and Atkinson 2002).

Cade and Atkinson (2002) suggest that periodic analysis of CBC data may be the only way to assess continental population trends. Using party miles traveled as an estimate of effort, Atkinson (1995) used CBC data to detect a continentwide decline in Neartic populations of the Northern Shrike. This result is supported by our analysis. However, he reported the declines to be nearly twice as high among eastern birds relative to those in the west. This is essentially the opposite of what we found (Figure 11c). The reason for the discrepancy may be partly due to the different time periods included in the analyses and his use of party miles traveled as the effort adjustment. Here we modeled the effort correction regionally, within the context of the hierarchical model, using party hours rather than party miles. Cade and Atkinson (2002) suggest that habitat loss may be a primary factor for the overall decline in Northern Shrikes, but they also speculate that increases in feeding stations for their prey farther north may short-circuit their migration. Since northern areas are not sampled well by either the BBS or CBC, this could presumably lead to an observed decline that may not be real.

Bohemian Waxwing

The Bohemian Waxwing is also a holarctic species that is experiencing greater declines in the western part of its range relative to the east (Figure 12c). It relies almost exclusively on a fruit diet in the winter; and as a consequence, it is nomadic and irruptive, following food supplies (Witmer 2002). Although Bohemian Waxwings breed primarily in the boreal forest, they occur in migration and winter in many areas with fruit

Figure 12. Bohemian Waxwing *(Bombycilla garrulus)*

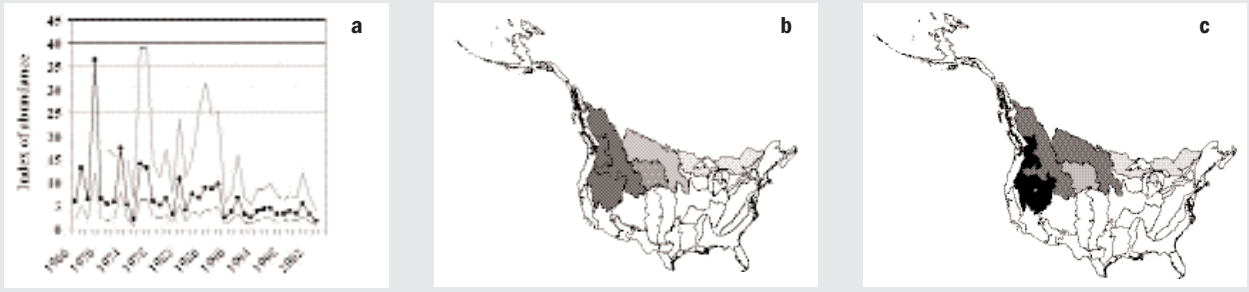


Figure 13. Harris's Sparrow *(Zonotrichia querula)*

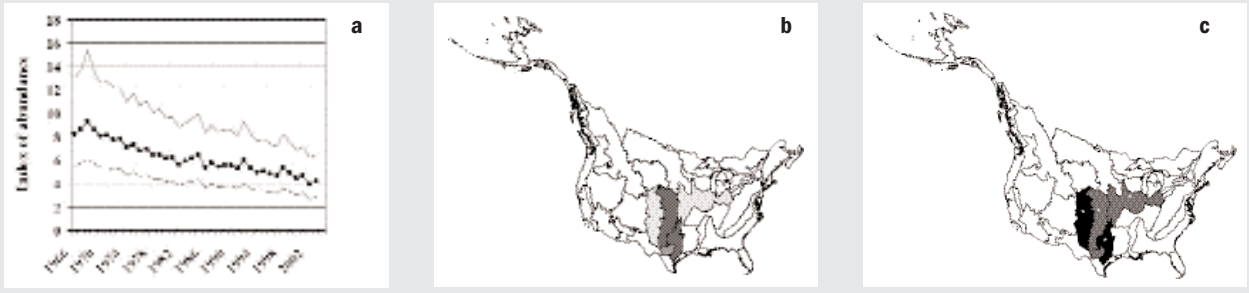
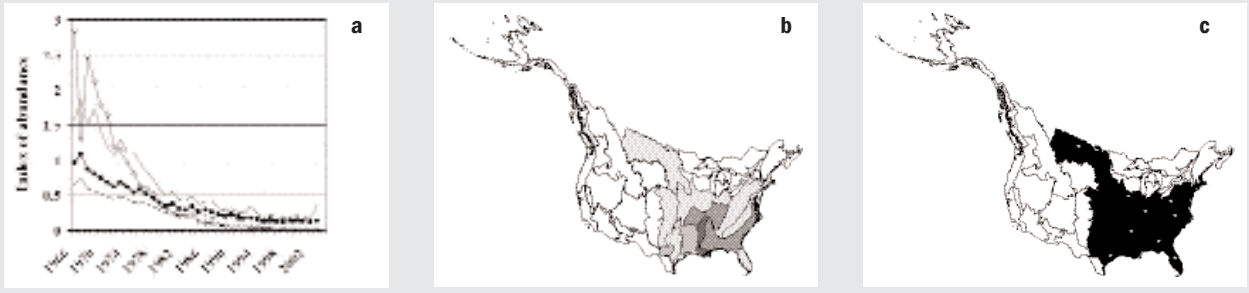


Figure 14. Rusty Blackbird *(Euphagus carolinus)*



trees, including gardens and urban areas. Habitat modifications, especially near human settlements, could alter winter distribution and abundance patterns (Witmer 2002). They may be especially vulnerable to pesticide poisoning and collisions with windows near settlements (Witmer 2002). Although their populations showed a significant decline (Figure 12a), the BCR trend estimates were generally imprecise, reflecting the variability in their local abundance patterns as a consequence of their irruptive behavior. This highlights an inherent difficulty in estimating trends for irruptive species.

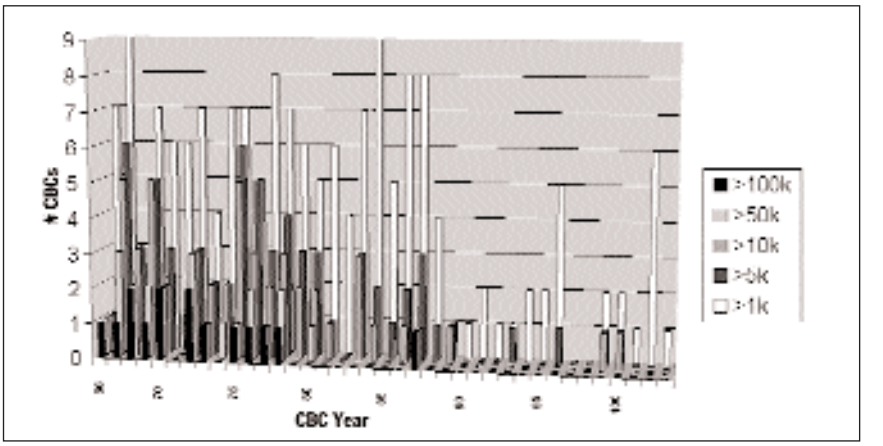


Figure 15. Annual changes in the number of CBCs reporting counts of Rusty Blackbirds in five abundance categories. (CBC count No. 66 was conducted in the winter of 1965–1966.)

Harris's Sparrow

The Harris's Sparrow is the only passerine that breeds endemically in Canada (Norment and Shackleton 1993). Its steady long-term decline is one of the more interesting results of this study. It breeds in the forest-tundra zone of Ontario, Manitoba, and the Northwest Territories, where it is essentially restricted to habitat edges; it is not a boreal forest breeder. In the winter it is associated with hedgerows, shelterbelts, and other brushy areas, often areas undergoing succession (Norment and Shackleton 1993). Apparently not much has been reported about the population trends of the Harris's Sparrow, although these same authors suggest that due to the isolated nature of its breeding habitat and its use of ecotonal disturbed areas in the winter, it is unlikely to be strongly impacted by human activities. Norment and Shackleton (1993) point out, however, that predation by Northern Shrikes and Merlins, the latter being a species that is drastically increasing (Figure 2a), may be a major factor controlling populations in the breeding season. Further research is needed to determine the possible impact of predation versus other causes such as long-term effects of climate change.

Rusty Blackbird

The Rusty Blackbird is a boreal species that is relatively specialized for breeding and wintering in forested wetlands (Avery 1995; Greenberg and Droege 1999). This is reflected in its high relative abundance in the Mississippi Alluvial Valley (BCR 26), where it often feeds in the floodplain of the Mississippi River (Figure 14b). However, it is also found throughout the southeast and into the Midwest, and it is declining significantly throughout its entire wintering range (Figure 14c). To put its population decline in context, prior to 1980 it was not unusual for CBCs to regularly report counts of more than 10,000 Rusty Blackbirds, and in most years it was typical to have at least one CBC report in excess of 100,000 Rusty Blackbirds (Figure 15). In 1969 the Rome, Georgia, CBC reported 1,100,000 Rusty Blackbirds (National Audubon Society 1970). High estimates such as these may well have been imprecise, yet they passed through the regional CBC editors because these experts believed such high counts were not out of the question. Since about 1980, however, it has become rare to have counts in excess of 5,000 birds, and even reports of more than 1,000 birds have declined dramatically (Figure 15). A recent population size estimate by Partners in Flight based on recent BBS data (Rich et al. 2004) suggests that the global population size of Rusty Blackbirds is currently only 2 million birds. When extrapolated over the 38-year period of our analysis, our estimate that the population has declined at a rate of 5.1 percent per year (which is conservative relative to the BBS estimate of a 9.9 percent annual decline, Sauer et al. 2004) extrapolates to a total population decline of about 85 percent during that period. That would place the 1965 population at about 13,333,000 birds, meaning that we may have lost more than 11 million Rusty Blackbirds since then. Even if these estimates are very imprecise, the declines appear quite staggering. And the declines may in fact have continued for much longer than the 38-year period we have analyzed in this paper. Greenberg and Droege (1999) present evidence that Rusty Blackbird populations may have been declining for at least 100 years, although they suggest that the rate of decline has accelerated in recent decades. Many factors may contribute to this decline, from habitat loss on the wintering grounds (about 25 percent of the remaining forested wetlands were lost between the 1950s and 1980s; Hefner and Brown 1984), to acid rain and blackbird control measures at winter roosts. Further research will be needed to address these issues.

Scale Issues and Bird Conservation

Concerns about boreal birds highlight the need for hemispheric-scale, region-specific monitoring and conservation for birds. At face value it may seem odd to focus conservation atten-

tion on an ecosystem like the boreal that is among the largest and most pristine in the hemisphere, one that supports many of the most abundant bird species on the continent. Yet, four of the 13 species we considered are already showing declining populations, and the Rusty Blackbird is one of the most precipitously declining species in North America. Historical experience with North American birds suggests that even species with large populations can be vulnerable to extinction. Analysis of wintering populations of these species highlights the complexity of conserving migratory birds. Unless the entire life cycle of the species is considered and information is gathered at scales commensurate with the distribution of the species in all seasons, it is unlikely that we will be able to adequately manage regional populations.

Moreover, the boreal forest provides one of the few remaining opportunities to consider *a priori* how to be wise stewards of a vast and relatively undisturbed ecosystem. The Boreal Forest Initiative (www.borealcanada.ca/) and the Boreal Songbird Initiative (www.borealbirds.org/) are working to plan future development in ways that will assure the long-term sustainability of the boreal forest ecosystem. To do so will require reliable information about the ecosystem and the species it supports, including information on the population trends of, and threats to, the species we hope to protect.

A primary goal of this paper was to use CBC data to identify possible species of concern. Population data for three of the four declining species we detected had not been previously analyzed at the continental level by the BBS because their breeding range is too far north. Although we had previous evidence of declines in Rusty Blackbirds from the BBS and other sources (Sauer et al. 2004, Greenberg and Droege 1999), information on the other species was largely based on analysis of regionally collected data, with the exception of previous analysis of some CBC data (e.g. Atkinson 1995).

ACKNOWLEDGMENTS

We thank the following partners for their support: Ducks Unlimited, Canadian Boreal Initiative, Boreal Songbird Initiative, and The Pew Charitable Trusts. This work would not have been possible without the participation of tens of thousands of citizen scientists who volunteered their time to collect the Christmas Bird Count data. Thanks also to Jane Fallon and Jill Lau for help in producing maps.

REFERENCES

Atkinson, E. C. 1995. Northern Shrikes (*Lanius excubitor*) wintering in North America: a Christmas Bird Count analysis of trends, cycles, and interspecific interactions. Proceedings Western Foundation Vertebrate Zoology 6:39-44.

Avery, M. L. 1995. Rusty Blackbird (*Euphagus carolinus*). In *The Birds of North America*, No. 200. (A. Poole and F. Gill, eds.). Acad. Nat. Sci., Philadelphia, PA, and Am. Ornithol. Union, Washington, DC.

Blancher, P. 2003. Importance of Canada's boreal forest to land birds. Canadian Boreal Initiative and Boreal Songbird Initiative. 40pp. (www.borealbirds.org/bsi-bscreport.pdf)

Butcher, G. S. 1990. Audubon Christmas Bird Counts. Pp. 5-13 in *Survey Designs and Statistical Methods for the Estimation of Avian Population Trends* (J. R. Sauer and S. Droege, eds.). U.S. Fish and Wildlife Service, Biol Rep. 90(1).

Cade, T. J. and E. C. Atkinson. 2002. Northern Shrike (*Lanius excubitor*). In *The Birds of North America*, No. 671. (A. Poole and F. Gill, eds.). Acad. Nat. Sci., Philadelphia, PA, and Am. Ornithol. Union, Washington, DC.

Canadian Boreal Initiative, 2003. The boreal forest at risk: A progress report. 14pp. (www.borealcanada.ca/pdf/cbi_2003_senate_report.pdf)

Greenberg, R. and S. Droege. 1999. On the decline of the Rusty Blackbird and the use of ornithological literature to document long-term population trends. *Conservation Biology* 13:553-559.

Hefner, J. M. and J. P. Brown. 1984. Wetland trends in the southeastern U.S. *Wetlands* 4:1-11.

Link, W. A., E. Cam, J. D. Nichols, and E. G. Cooch. 2002. Of BUGS and Birds: Markov-chain Monte Carlo for hierarchical modeling in wildlife research. *Journal of Wildlife Management* 66:277-291.

Link, W. A., and J. R. Sauer. 1999. Controlling for varying effort in count surveys: An analysis of Christmas Bird Count Data. *Journal of Agricultural, Biological and Environmental Statistics* 4:116-125.

Link, W. A., and J. R. Sauer. 2002. A hierarchical model of population change with application to Cerulean Warblers. *Ecology* 83: 2832–2840.

National Audubon Society. 1970. Seventieth Christmas Bird Count. *Audubon Field Notes* 24:235.

Norment, C. J. and S. A. Shackleton. 1993. Harris's Sparrow (*Zonotrichia querula*). In *The Birds of North America*, No. 64. (A. Poole and F. Gill, eds.). Acad. Nat. Sci., Philadelphia, PA, and Am. Ornithol. Union, Washington, DC.

Panjabi, A., C. Beardmore, P. Blancher, G. Butcher, M. Carter, D. Demarest, E. Dunn, C. Hunter, D. Pashley, K. Rosenberg, T. Rich, and T. Will. 2001. The Partners in Flight handbook on species assessment and prioritization. Version 1.1. Rocky Mountain Bird Observatory, Brighton, Colorado.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S.W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Inigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J.S. Wendt, and T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY.

Sauer, J. R., J. E. Hines, and J. Fallon. 2004. In The North American Breeding Bird Survey, Results and Analysis 1966–2003. Version 2004.1. USGS Patuxent Wildlife Research Center, Laurel, MD

Sauer, J. R., and W. A. Link. 2002. Hierarchical modeling of population stability and species group attributes using Markov-chain Monte Carlo methods. *Ecology* 83:1743-1751.

Sauer, J. R., D. K. Niven, and W. A. Link. 2004. Statistical analyses make the Christmas Bird Count relevant for conservation. *American Birds 58 (The 104th Christmas Bird Count)*: 21 25.

Sodhi, N. S., L. W. Oliphant, P. C. James and I. G. Warkentin. 1993. Merlin (*Falco columbarius*). In *The Birds of North America*, No. 44. (A. Poole and F. Gill, eds.). Acad. Nat. Sci., Philadelphia, PA, and Am. Ornithol. Union, Washington, DC.

Spiegelhalter, D. J., A. Thomas, and N. G. Best. 1999. WinBUGS version 1.2 user manual, MRC Biostatistics Unit, University of Cambridge, U.K.

Witmer, M. C. 2002. Bohemian Waxwing (*Bombycilla garrulus*). In *The Birds of North America*, No. 714. (A. Poole and F. Gill, eds.). Acad. Nat. Sci., Philadelphia, PA, and Am. Ornithol. Union, Washington, DC.

Appendix. Bird Conservation Region (BCR) names, by biome, and Rusty Blackbird trend estimates, by BCR. Based on 38 years of Christmas Bird Count data (1965–1966 to 2002–2003).

Biome[a] BCR	Name	Total # CBCs in BCR	% CBCs where sp. reported[b]	Trend[c] (% change/yr.)	Credible Intervals[d] (2.5%, 97.5%)	Baseline Abundance[e]	AI[f]	AI Score[g]
Arctic								
1	Aleutian / Bering Sea Islands	3						
2	Western Alaska	12						
3	Arctic Plains and Mountains	12						
Boreal								
4	Northwestern Interior Forest	26	19.2	-11.3	(-21.4, 1.8)	0.012	0.14	1
6	Boreal Taiga Plains	46	30.4	-0.6	(-10.4, 10.3)	0.026	0.31	1
7	Taiga Shield and Hudson Plains	4						
8	Boreal Softwood Shield	47	17.0	-8.4	(-19.5, 4.1)	0.005	0.06	1
12[a]	Boreal Hardwood Transition	138	27.5	-6.3	(-10.6, -1.9)	0.005	0.06	1
14[a]	Atlantic Northern Forest	163	47.2	-1.7	(-6.0, 1.8)	0.011	0.12	1
Eastern								
13	Lower Great Lakes / St. Lawrence Plain	194	69.1	-1.1	(-3.9, 1.7)	0.040	0.47	1
24	Central Hardwoods	102	76.5	-6.2	(-8.8, -3.4)	2.314	27.15	4
25	Western Gulf Coastal Plain / Ouachitas	53	81.1	-3.9	(-7.6, 0.6)	1.123	13.18	3
26	Mississippi Alluvial Valley	45	86.7	-6.5	(-9.2, -3.6)	8.523	100.00	5
27	Southeastern Coastal Plain	132	85.6	-5.1	(-6.7, -3.3)	2.744	32.20	4
28	Appalachian Mountains	228	71.5	-4.7	(-6.9, -2.4)	0.334	3.92	2
29	Piedmont	104	87.5	-6.5	(-9.0, -3.8)	0.763	8.95	2
30	New England / Mid-Atlantic coast	158	82.9	-3.9	(-5.6, -1.8)	0.265	3.11	2
31	Peninsular Florida	75	68.0	-14.1	(-17.9, -10.4)	0.147	1.72	2
37	Gulf Coastal Prairie	61	60.7	-9.6	(-13.2, -5.9)	0.254	2.98	2
Prairie								
11	Prairie Potholes	127	65.4	-4.3	(-7.2, -1.0)	0.196	2.30	2
17	Badlands and Prairies	31	38.7	-3.5	(-9.2, 2.6)	0.064	0.76	1
18	Shortgrass Prairie	62	48.4	-1.1	(-5.4, 4.1)	0.020	0.23	1
19	Central Mixed-grass Prairie	67	64.2	-2.1	(-7.1, 3.2)	0.496	5.82	2
21	Oaks and Prairies	47	74.5	-3.6	(-7.6, 0.7)	0.362	4.24	2
22	Eastern Tallgrass Prairie	240	78.3	-2.9	(-5.0, -0.9)	0.477	5.60	2
23	Prairie Hardwood Transition	146	63.0	-2.3	(-5.5, 1.2)	0.026	0.31	1
Intermountain West								
9	Great Basin	116	10.3	3.2	(-5.5, 14.0)	0.001	0.01	1
10	Northern Rockies	114	15.8	-0.6	(-6.6, 5.6)	0.007	0.09	1
16	Southern Rockies / Colorado Plateau	78	9.0	-5.3	(-14.5, 3.8)	0.001	0.01	1
Pacific								
5	Northern Pacific Rainforest	176	15.9	-4.5	(-9.6, 0.4)	0.004	0.04	1
15	Sierra Nevada	11						
32	Coastal California	123	11.4	10.3	(1.4, 20.0)	0.000	0.00	1
Southwest								
20	Edwards Plateau	8	50.0	-3.4	(-20.1, 23.1)	1.604	18.82	3
33	Sonoran and Mohave Deserts	50	10.0	-3.4	(-22.3, 35.2)	0.000	0.01	1
34	Sierra Madre Occidental	30						
35	Chihuahuan Desert	37	18.9	-2.8	(-14.0, 13.9)	0.003	0.03	1
36	Tamaulipan Brushlands	15	26.7	-11.2	(-33.1, 9.7)	0.004	0.04	1
Rangewide in North America		3009 (3081)[h]	53.3	-5.1	(-6.6, -2.4)	0.313		

a Assignment of BCRs to biomes follows Rich et al. (2003). The Partners in Flight definition of the boreal includes two transitional BCRs (12 and 14) not considered part of the boreal region for the purposes of this paper.

b Excludes BCRs where the species was recorded in less than four CBC circles.

c Trends are based on means from the Markov-chain Monte Carlo (MCMC) fitting procedures.

d Credible intervals (CI) are a Bayesian analogue to confidence intervals.

e Baseline abundance is defined as the effort-adjusted index of abundance on the 82nd CBC.

f Area importance was calculated as the index of abundance proportional to the BCR with maximum index of abundance. Based on abundance values during the baseline year (82nd CBC).

g Area importance scores follow Panjabi et al. (2001) and are described in the text and the legend to Figures 2–14.

h Number of CBCs in BCRs included in the Rusty Blackbird analysis. (Total number of CBCs in all BCRs.)