Articles

Expanding the North American Breeding Bird Survey Analysis to Include Additional Species and Regions

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Abstract

The North American Breeding Bird Survey (BBS) contains data for >700 bird species, but analyses often focus on a core group of ~420 species. We analyzed data for 122 species of North American birds for which data exist in the North American Breeding Bird Survey (BBS) database but are not routinely analyzed on the BBS Summary and Analysis Website. Many of these species occur in the northern part of the continent, on routes that fall outside the core survey area presently analyzed in the United States and southern Canada. Other species not historically analyzed occur in the core survey area with very limited data but have large portions of their ranges in Mexico and south. A third group of species not historically analyzed included species thought to be poorly surveyed by the BBS, such as rare, coastal, or nocturnal species. For 56 species found primarily in regions north of the core survey area, we expanded the scope of the analysis, using data from 1993 to 2014 during which ≥3 survey routes had been sampled in 6 northern strata (Bird Conservation regions in Alaska, Yukon, and Newfoundland and Labrador) and fitting log-linear hierarchical models for an augmented BBS survey area that included both the new northern strata and the core survey area. We also applied this model to 168 species historically analyzed in the BBS that had data from these additional northern strata. For both groups of species we calculated survey-wide trends for the both core and augmented survey areas from 1993 to 2014; for species that did not occur in the newly defined strata, we computed trends from 1966 to 2014. We evaluated trend estimates in terms of established credibility criteria for BBS results, screening for imprecise trends, small samples, and low relative abundance. Inclusion of data from the northern strata permitted estimation of trend for 56 species not historically analyzed, but only 4 of these were reasonably monitored and an additional 13 were questionably monitored; 39 of these species were likely poorly monitored because of small numbers of samples or very imprecisely estimated trends. Only 4 of 66 "new" species found in the core survey area were reasonably monitored by the BBS; 20 were questionably monitored; and 42 were likely poorly monitored by the BBS because of inefficiency in precision, abundance, or sample size. The hierarchical analyses we present provide a means for reasonable inclusion of the additional species and strata in a common analysis with data from the core area, a critical step in the evolution of the BBS as a continent-scale survey. We recommend that results be presented both 1) from 1993 to the present using the expanded survey area, and 2) from 1966 to the present for the core survey area. Although most of the "new" species we analyzed were poorly monitored by the BBS during 1993–2014, continued expansion of the BBS will improve the quality of information in future analyses for these species and for the many other species presently monitored by the BBS.

Keywords: birds; hierarchical models; North American Breeding Bird Survey

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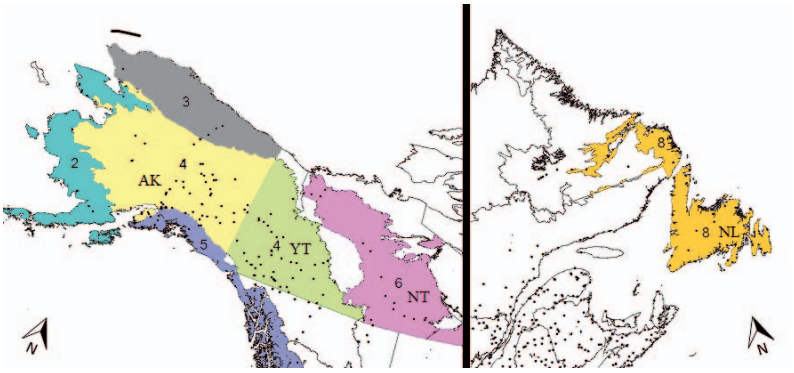

Figure 1. Map of strata for BBS analyses in Alaska and northern Canada. The BBS strata are formed by the intersection of states and provinces with Bird Conservation Regions (BCRs). Starting points of BBS routes are shown as (•); numbers index BCRs within Alaska (AK), Newfoundland and Labrador (NL), or Yukon (YT) and Northwest (NT) Territories. The strata included in analyses are Alaska—BCR 2 (Western Alaska), Alaska—BCR 3 (Arctic Plains and Mountains), Alaska—BCR 4 (Northwestern Interior Forest), Alaska—BCR 5 (Northern Pacific Rainforest), Yukon Territory—BCR 4 (Northwestern Interior Forest), Northwest Territories—BCR 6 (Boreal Taiga Plains), and Newfoundland—BCR 8 (Boreal Softwood Shield).

Introduction

The North American Breeding Bird Survey (BBS) contains data for >700 taxa (species, subspecies, and a variety of other groupings) of North American birds (Pardieck et al. 2015). Not all of these taxa are used in statistical analyses; for example, our comprehensive analysis provides population trend and annual indexes for only ~428 taxa (Sauer et al. 2013). Data exist for an additional 214 taxa in the BBS database (see Table S1, *Supplemental Material,* for a list of the taxa presently in the database that are not analyzed). The reasons these data remain unanalyzed differ among taxa. Some taxa (e.g., unidentifiable species) are irrelevant for estimation of population change; other species have undergone taxonomic revisions that occasionally require lumping of several species for summary (Sauer et al. 2014). The remaining taxa (we will use the term "species" from this point onward for convenience) do not meet criteria that historically have been used to define when a taxa is reasonably monitored by the BBS (e.g., Robbins et al. 1986; Droege and Sauer 1989; Sauer et al. 2003, 2013). These criteria include 1) portion of species' breeding range covered by the survey, 2) precision of estimates of population change or annual indices, 3) number of survey routes on which the species is encountered, and 4) relative abundance of species as estimated from BBS data (Sauer et al. 2013). In addition to these quantitative criteria, a variety of qualitative criteria are often applied to evaluation of BBS results; for example, nocturnal birds and secretive wetland species are often a priori considered poorly monitored by the BBS.

One reason that many of these species remain unanalyzed relates to expansion of the survey. Although >4,000 survey routes currently exist in the BBS database for the continental United States, Canada, and Mexico, analysis has traditionally been restricted to a "core survey area" in the contiguous United States and southern Canada within which the survey has collected data since 1968, the year BBS routes were established across the continuous United States (Robbins et al. 1986). Alaska, Yukon, Northwest Territories, and Newfoundland and Labrador (Figure 1) were historically excluded from the core area in routine U.S. Geological Survey analyses (Sauer et al. 2014) because limited data exist from the 1960s to 1980s. However, limited data have been collected in these regions, and beginning in the 1990s many additional survey routes were initiated in these regions. Alaska data have been assessed separately for a subset of years for the historically analyzed species (Sauer et al. 2014), but many previously unanalyzed species are encountered on the new routes that have been established in Alaska and other boreal regions, and sufficient data exist for the analysis of some of these species. Other unanalyzed species include those with ranges largely south of the BBS area, as well as some species that were always encountered in small numbers along BBS routes but were not considered to be adequately sampled by the survey. Possibly because of population increases, distributional changes, more years of sampling, and increased BBS coverage, some of these species may now have sufficient data to justify their inclusion in future analyses. We evaluated the information for all species with limited data from the BBS, analyzed the subset that our initial screening indicated may provide useful information, and evaluated the results to determine whether they should become a part of routine BBS analyses.

Many of the unanalyzed northern species occur on survey routes not presently included in BBS analyses; therefore, we defined additional strata beyond the core northern edge of the survey area defined by Sauer et al. (2014) to accommodate new data from these routes in Alaska, Yukon, the Northwest Territories, and Newfoundland. These new strata only provided data from later years of the survey (~1993 onward), requiring that analyses that include those strata be limited to the interval 1993–2014. We also imposed hierarchical structure to better accommodate the differences in quality of information among strata. These new routes also contained information for many species historically analyzed in the BBS; we thus conducted analyses for

these species using the entire BBS data set including all data from these new strata. As with the new species, summaries of population change within the augmented BBS area could only be conducted for the interval 1993–2014. For species historically included in our analyses (e.g., Sauer et al. 2014), we compared results for the core survey area to those from the augmented survey area.

Study Area

BBS survey routes sample the continental United States and Canada, although the absence of roads and observers in some regions leads to limited coverage. Data from recent years exist from Mexico, but those data have not been edited for analysis and are not considered here. Typically, BBS analyses are conducted within strata that are defined as the intersection of Bird Conservation Regions (BCRs) with States or provinces; these strata cover North America (Sauer et al. 2003). Analyses within the core-survey-area strata presented in Sauer et al. (2014) constrain the scope of inference to the contiguous United States and southern Canada (excluding Newfoundland and Labrador, and Canadian territories). Smith et al. (2014) combined data from northern BCRs to produce population summaries for Canada; in the present analyses we retained the original strata based on the intersection of states or provinces and BCRs to provide a consistent framework for continental-scale analyses. In the discussion, we address the relationship between the spatial structuring used in our analysis and that used by Smith et al. (2014). Although BBS samples are constrained by limited road networks in northern regions, the inclusion of data from northern regions outside the core strata must be considered in an evaluation of the species not historically analyzed by the BBS. To expand the survey analysis to include these formerly extralimital BBS routes, we evaluated BCR regions within Alaska, Yukon, Northwest Territories, and Newfoundland and Labrador to determine which strata met minimum sample size criteria. All strata in those regions had very limited data for the early years of the survey, but several of these strata had consistent coverage starting in the early 1990s. Based on an assessment of the initial years during which the number of BBS routes surveyed in each stratum was $\geq$3, we chose 1993 as a reasonable starting year for the inclusion of 7 new strata: Alaska–Western Alaska BCR 2 (Area = 313,340 km^2, N routes = 24), Alaska–Arctic Plains and Mountains BCR 3 (Area = 336,125 km^2, N routes = 5), Alaska–Northwestern Interior Forest BCR 4 (Area = 805,836 km^2, N routes = 67), Alaska–Northern Pacific Rainforest BCR 5 (Area = 148,904 km^2, N routes = 37), Yukon Territory–Northwestern Interior Forest BCR 4 (Area = 438,758 km^2, N routes = 49), Northwest Territories–Boreal Taiga Plains BCR 6 (Area = 503,502 km^2, N routes = 7), and Newfoundland–Boreal Softwood Shield BCR 8 (Area = 165,221 km^2, N routes = 33). These "new" strata comprise large areas (Figure 1). We refer to the entire survey area containing both core and new strata as the "augmented" survey area.

Methods

North American Breeding Bird Survey

The BBS is a continental-scale, roadside survey of breeding birds. Conducted primarily in June, but with varying temporal survey windows to accommodate latitudinal variation in phenology, each BBS route is composed of 50, 3-min point counts conducted along roadsides in a single morning by a single observer. Counts are spaced at ~800-m intervals as safety and survey conditions allow, and observers record all birds heard, or seen within 400 m of the counting location (Sauer et al. 2013). In 2015, >4,000 survey routes existed in the database for the continental United States, Canada, and Mexico. BBS data are publically available from the program website (http://www.pwrc.usgs.gov/bbs/).

Species data

The BBS Office maintains a master list of >700 taxa that have been encountered in BBS surveys, including >50 "taxa" that represent hybrids or incompletely identified birds reported by observers (e.g., unidentified crow). Current BBS analyses evaluate population change for 428 taxa, including several aggregated taxa that consist of species that have been split as a result of taxonomic changes subsequent to the origin of the BBS in 1966 (cf., Sauer et al. 2014, http://www.mbr-pwrc.usgs.gov/bbs/lumpnam.html). Not included among the 428 taxa are 57 species detected on <3 survey routes, 35 taxa that may be included in various aggregate analyses (e.g., races or hybrids of current species that at one time had species status), and an additional 157 species that were observed on $\geq$3 BBS routes during the interval 1966–2013. We evaluated these 157 species for possible inclusion in routine BBS analyses (Table S1, *Supplemental Material*).

For operational reasons, it is convenient to consider species with significant amounts of data in the BBS database, but that have not historically been analyzed, as falling into two primary groups: species with or without a substantial boreal component to their distributions. This distinction is necessary because analysis of boreal species requires modification of the survey to include new strata and must be limited to a subset of the survey interval, whereas analysis of the non–boreal species can be conducted using existing strata and summarized over the entire BBS interval (1966–2014).

Species with boreal distributions. All BBS routes scattered across the northern part of the continent contain significant amounts of data from recent years that contain information both for "Northern Species" that fall mostly outside the northern edge of the core survey area (i.e., with analyzable data only from the newly defined northern strata), and for species occurring in the core survey area but which have significant additional portions of their range north of the core area. Analysis of data for both groups of species requires a significant modification of the present analysis via the

addition of new northern strata and restriction of the analysis to a more limited time period.

Species not occurring in the boreal strata. These species generally consist of 3 groups. "Predominantly Southern Species" have breeding ranges primarily below the United States (i.e., >50% of their breeding range occurs south of the core BBS area according to an analysis of NatureServe range maps [Sauer et al. 2013]) that appear in small numbers on BBS routes in border states. In earlier evaluations (e.g., Robbins et al. 1986), abundance of these species was insufficient to provide meaningful results, but over time additional observations have accrued and data for these species in the BBS database may now be sufficient for analysis. "Rare, Coastal, or Nocturnal" species have ranges that are well covered by the BBS, but were not considered analyzable. Species in this diverse group include rare species, those breeding outside the seasonal window for BBS surveys, species not well covered by roadside surveys such as coastal or mountaintop species, and nocturnal species, such as flammulated owl *Psiloscops flammeolus*. These species, excluded from analyses using criteria developed for previous analytic methods for the BBS (e.g., route regression; Link and Sauer 1994), may now be suitable for analysis because of gradual accrual of information with the addition of more years of data. "Introduced" species have been released in urban areas and gradually have accrued observations on BBS routes that sample near urban areas.

Hierarchical model analysis

We analyzed BBS data using a log-linear hierarchical model fit using Bayesian methods (Sauer and Link 2011), employing Markov-chain Monte Carlo methods to produce the posterior distributions of model parameters on which inference is based. In the model, we described counts (assumed to be independent overdispersed Poisson random variables) with expected values $\lambda_{i,j,t}$ (*i*, *j*, and *t* index stratum, route/observer, and year, respectively) by the following:

$$log(\lambda_{i,j,t}) = S_i + \beta_i(t - t^*) + \omega_j + \gamma_{i,t} + \eta I(j,t) + \varepsilon_{i,j,t}. \quad (1)$$

Explanatory variables included trend slopes (β), stratum-specific intercepts (S), route/observer (ω), year (γ), start-up effects η (indicator $I(j,t)$ takes value 1 for a first year of observer's survey on a route, 0 otherwise), and overdispersion effects (ε). The value t^* was a fixed year ($t^* = 1986$, in our analysis) that centered the slope index to facilitate estimation.

We assigned a normal prior distribution with mean zero and variance 1×10^6 for η. Stratum effects S_i, slopes β_i , route/observer effects ω_j, and overdispersion effects $\varepsilon_{i,j,t}$, were all treated as normally distributed random effects. The means of the random effect distributions for S_i , and β_i were assigned vague normal priors (having mean = 0 and variance = 10^6); the means for ω_j and $\varepsilon_{i,j,t}$ were fixed at zero. The variances of the random effect distributions (σ_s^2,σ_β^2,σ_ω^2, andσ_ε^2) were all assigned vague inverse gamma priors (with shape and rate parameters equal to 10^{-3}).

Year effects $\gamma_{i,t}$ were treated as mean zero normal random effects, with hierarchically structured variances. We allowed variances for year effects $\sigma_{\gamma,i}^2$ to differ among strata, treating these as lognormally distributed random effects. The means and variances of these random effect distributions were assigned vague normal and vague inverse gamma priors.

Annual indices and trend are functions of the model parameters. We defined stratum-specific annual indices as

$$n_{i,t} = z_i exp\left(S_i + \beta_i(t - t^*) + \gamma_{i,t} + 0.5\sigma_\omega^2 + 0.5\sigma_\varepsilon^2\right).$$

We defined annual indices of larger areas such as states, provinces, or the entire survey area as area-weighted sums of the annual indices (i.e., for the entire surveyed area, $n_t = [\Sigma_{i=1}^{I} A_i n_{i,t}]/\Sigma_{i=1}^{I} A_i$). We defined trend as interval-specific geometric mean of changes in population size. Trend for the interval year t_a to year t_b for stratum *i* was

$$B_i = \left\{\frac{n_{i,t_b}}{n_{i,t_a}}\right\}^{\frac{1}{t_b - t_a}};$$

Similarly, we defined regional trends as the geometric means of the regional annual indices. We presented trend as a percentage, $100(B_i - 1)\%$. An appealing aspect of Markov-chain Monte Carlo analyses is that posterior distributions of functions of model parameters are readily computed as derived parameters.

We fitted the models to data using Program WinBUGS (Lunn et al. 2000). For each analysis, we ran the Markov-chain Monte Carlo analysis for 20,000 iterations as a "burn-in" period to permit each chain of estimates to converge, then calculated the median, and 2.5% and 97.5% credible intervals (CI) of the posterior distributions from 20,000 Markov-chain Monte Carlo replicates, thinning the results by 2.

We analyzed data for the 157 species not included on the list of 428 historically analyzed taxa, but which occurred on ≥3 routes in the BBS data set (Table S1, *Supplemental Material*). We set a minimum data standard that a species must have been encountered on ≥3 standard survey routes in a stratum for analysis of that stratum; 35 of the low-sample-size species did not meet this criterion for any strata and we did not include them in the analysis, leaving 122 species in our analysis. Moreover, to document the consequences of adding the northern strata to the analysis of the 428 taxa historically analyzed, we analyzed all species for the 1993–2014 period using both the augmented strata and only the core area.

Summary analyses

"*New*" *species*. For species with northern distributions, we computed trend estimates for the augmented survey

area for the interval 1993–2014. We also computed annual indices for the northern species, presenting the abundance for 2003 as an index of relative abundance. Some of the new northern species also had substantial data from the core survey area; we present estimates of trend for 1993–2014 for the core survey area for these species. For the other previously unanalyzed species whose ranges do not include Alaska, Yukon, or northern Canada strata, we provide trend estimates for 1966–2014 and evaluate the credibility of their resulting trend estimates.

Augmented survey results for historically analyzed BBS species. Many species historically included in BBS analyses occur in the new strata. Any expansion of scope of inference of the BBS must include an evaluation of the consequences of expansion for these species. We present trend estimates for these species for 1993–2014 for both the core survey area and the augmented survey area, compare trends and relative abundances for these areas, and evaluate differences in width of 95% credible intervals between core and augmented survey area results.

Alaska trends. We provide a summary of Alaska BBS trends for the interval 1993–2014. We note that Alaska results are composite, in that they are an aggregate of results from four of the newly analyzed strata. Trends for Alaska BBS routes have previously been calculated for the species historically included in the BBS analyses (e.g., Sauer et al. 2014), but not in the comprehensive analysis framework described here. We provide summary results for all species for the interval 1993–2014.

Evaluating credibility of results. Sauer et al. (2003, 2014) suggested criteria based on 1) the number of routes, N (''small samples'' is defined as $N < 14$ but > 4; ''very small samples'' consist of $N < 5$), 2) the precision of trend estimates (a trend is considered ''imprecise'' if the half-width of the CI is $>3\%$/yr but $<5\%$/yr, and is considered ''very imprecise'' if the CI half-width contains 5%/yr), and 3) relative abundances, RA (RA <1 but >0.1 birds/route constitutes ''low abundance;'' RA <0.1 birds/route constitutes ''very low abundance'') to assess the credibility of the population change results (see Sauer et al. [2003] for rationales for these cut-points). As a summary categorization, Sauer et al. (2014) group these criteria into three levels of credibility. Species that exceed these criteria in all categories are deemed ''reasonably monitored,'' species with small samples, imprecise results, or low abundances are deemed ''questionably monitored'' (stated as ''view with caution'' in Sauer et al. [2014]), and species with very small samples, very imprecise results, or very low abundances are deemed ''poorly monitored.'' In Sauer et al. (2014), these categories were visually represented as Blue, Yellow, and Red, respectively. Although all threshold values are arbitrary, these values have been generally accepted as credibility criteria for BBS analyses and we have applied these criteria to all species traditionally analyzed using BBS data (Sauer et al. 2013, 2014). We apply these criteria here for 1966 – 2014 and 1993 – 2014 results, assessing precision in terms of half-widths of credible intervals for trends from the appropriate interval (Sauer and Link 2011).

Results

Of the 214 species in the BBS database that have not historically been analyzed, 122 occurred on ≥ 3 routes in at least one stratum and could therefore be considered for inclusion in future analyses (Table S1, *Supplemental Material*). Of the 122 species, 56 occurred in the newly added strata; 37 of these were detected exclusively in the new northern strata (Table 1). Sixty-six of the 122 species did not occur in the new northern strata.

Species occurring predominantly in the newly added northern strata

Twenty-seven of the 37 species only found along BBS routes in the new strata had very imprecisely estimated trends and seven species had imprecisely estimated trends during the 1993–2014 interval, with a median CI half-width of 7.2%/yr (Table 1). Sample sizes varied greatly; common redpoll *Acanthis flammea* occurred on 122 routes, but many species have limited data (the median N of routes $= 14$ for the 37 species; two species have $N < 5$, 17 species have $N < 14$). Five species had very low relative abundances, and 19 species had low relative abundances. Only two of these species, gray-cheeked thrush *Catharus minimus* and common redpoll, would be considered reasonably monitored using the BBS criteria; eight species (pacific loon *Gavia pacifica,* semipalmated plover *Charadrius semipalmatus,* least sandpiper *Calidris minutilla,* long-tailed jaeger *Stercorarius longicaudus,* arctic tern *Sterna paradisaea,* arctic warbler *Phylloscopus borealis,* eastern yellow wagtail *Motacilla tschutschensis,* and lapland longspur *Calcarius lapponicus*), would be in the BBS questionably monitored category, generally because of imprecision of results. Among these species, four had significantly declining populations (arctic warbler, eastern yellow wagtail, gray-cheeked thrush, and common redpoll; Table 1). Four species, greater white-fronted goose *Anser albifrons,* black scoter *Melanitta americana,* gyrfalcon *Falco rusticolus,* and hoary redpoll *Acanthis hornemanni,* were significantly increasing.

Nineteen additional northern species occurred in both the core area and newly added strata (Table 1). Of these, only black oystercatcher *Haematopus bachmani* had a small sample size ($N < 14$) for the augmented area, and the trend estimates for the group were still very imprecise overall (median CI half-width $= 5.0\%$); only two species were reasonably precisely estimated (CI half-width $<3\%$). Ten species were very imprecisely estimated (CI half-width $>5\%$). Eight species had low abundances; four species had very low abundances. By BBS criteria, mew gull *Larus canus* and golden-crowned sparrow *Zonotrichia atricapilla* appear to be reasonably monitored, and trumpeter swan *Cygnus buccinator,* red-

Table 1. Estimated population change for northern species not presently summarized in BBS analyses (Sauer et al. 2014). For all species, we present results for the combined northern strata that cover portions of Alaska, Canadian territories, and Newfoundland and Labrador. For those species with additional data from strata in lower latitudes (the "core" strata), we also present composite results based on data from the core strata. Analysis is based on log-linear hierarchical models; trend is defined as the change in annual indexes over a specified time period (Sauer et al. 2013). For each species, we present sample size (number of routes, *N*), trend estimate (% change/yr, 1993–2014), 2.5% and 97.5% credible intervals (CI) for trend, relative abundance (RA, defined as the annual index in the midyear of the interval) and 2.5% and 97.5% CIs for relative abundance, half-width of the CIs for trend, and a credibility score (R = reasonably monitored, Q = questionably monitored (estimates have at least one deficiency), and P = poorly monitored (Sauer et al. 2014). Values <0.1 are indicated as 0.0.

		1993–2014 Analysis, Augmented Area				
Common name	Scientific name	N	Trend	2.5% CI	97.5% CI	RA
Northern species predominantly occurring north of the core BBS area that can be analyzed with the inclusion of additional northern strata						
Greater white-fronted goose	*Anser albifrons*	17	9.6	0.3	21.7	12.0
Tundra swan	*Cygnus columbianus*	24	−2.5	−9.2	5.4	1.2
Greater scaup	*Aythya marila*	43	2.2	−4.2	9.2	4.3
Black scoter	*Melanitta americana*	12	11.1	0.1	24.5	1.3
Long-tailed duck	*Clangula hyemalis*	14	−6.7	−12.4	0.0	0.5
Willow ptarmigan	*Lagopus lagopus*	32	0.8	−5.3	7.5	5.6
Rock ptarmigan	*Lagopus muta*	8	12.7	−0.4	27.3	0.2
Pacific loon	*Gavia pacifica*	44	−0.3	−5.1	4.1	0.2
Rough-legged hawk	*Buteo lagopus*	23	−0.4	−5.8	6.3	0.1
American golden-plover	*Pluvialis dominica*	11	−1.9	−10.1	4.8	0.3
Pacific golden-plover	*Pluvialis fulva*	9	−0.6	−7.9	7.9	1.9
Semipalmated plover	*Charadrius semipalmatus*	41	−4.1	−8.8	0.2	0.5
Wandering tattler	*Tringa incana*	7	3.2	−8.5	15.7	0.1
Whimbrel	*Numenius phaeopus*	17	2.5	−3.8	10.7	1.6
Bar-tailed godwit	*Limosa lapponica*	4	−6.1	−24.5	14.3	0.5
Ruddy turnstone	*Arenaria interpres*	5	−7.7	−17.5	4.2	0.1
Least sandpiper	*Calidris minutilla*	28	−2.4	−6.5	2.1	0.3
Western sandpiper	*Calidris mauri*	11	−7.9	−18.0	2.0	16.3
Short-billed dowitcher	*Limnodromus griseus*	9	0.9	−5.6	7.4	0.7
Red-necked phalarope	*Phalaropus lobatus*	21	−4.0	−11.1	2.8	0.3
Parasitic jaeger	*Stercorarius parasiticus*	8	−0.3	−9.2	8.7	0.4
Long-tailed jaeger	*Stercorarius longicaudus*	17	−2.9	−7.5	1.8	2.7
Glaucous gull	*Larus hyperboreus*	15	4.9	−3.0	14.8	6.7
Arctic tern	*Sterna paradisaea*	65	−2.6	−5.7	0.6	2.1
Aleutian tern	*Onychoprion aleuticus*	5	−4.8	−16.0	9.1	10.9
Boreal owl	*Aegolius funereus*	10	−4.2	−17.2	7.0	0.0
Gyrfalcon	*Falco rusticolus*	6	8.2	0.1	24.5	0.1
Northern shrike	*Lanius excubitor*	15	−2.2	−6.7	3.5	0.0
Arctic warbler	*Phylloscopus borealis*	28	−5.0	−8.5	−1.1	12.3
Bluethroat	*Luscinia svecica*	7	−6.7	−16.0	5.6	0.2
Northern wheatear	*Oenanthe oenanthe*	4	3.3	−5.2	12.5	0.2
Gray-cheeked thrush	*Catharus minimus*	109	−2.8	−4.9	−0.8	8.7
Eastern yellow wagtail	*Motacilla tschutschensis*	12	−4.8	−9.0	−0.7	6.3
Lapland longspur	*Calcarius lapponicus*	19	0.0	−4.3	4.2	39.6
American tree sparrow	*Spizella arborea*	70	−1.4	−8.1	1.9	45.3
Common redpoll	*Acanthis flammea*	122	−2.6	−5.3	−0.2	18.3
Hoary redpoll	*Acanthis hornemanni*	6	25.2	8.3	51.7	0.2
Northern species not historically included in BBS analyses, but for which it was possible to generate 21-y trends for the core BBS region						
Trumpeter swan	*Cygnus buccinator*	106	7.7	3.6	12.5	0.4
Common eider	*Somateria mollissima*	22	1.4	−7.1	10.8	773.3
Harlequin duck	*Histrionicus histrionicus*	43	−3.1	−9.1	3.6	0.9
Surf scoter	*Melanitta perspicillata*	21	3.1	−10.1	21.7	41.9
White-winged scoter	*Melanitta fusca*	25	−5.5	−16.1	9.3	0.7
Spruce grouse	*Falcipennis canadensis*	54	5.2	1.1	10.3	0.0
Red-throated loon	*Gavia stellata*	46	0.5	−2.9	4.3	0.3
Black oystercatcher	*Haematopus bachmani*	13	−3.8	−13.7	5.6	0.3
Pigeon guillemot	*Cepphus columba*	15	4.6	−2.0	12.8	1.0
Marbled murrelet	*Brachyramphus marmoratus*	35	3.7	−0.1	8.1	6.2
Black-legged kittiwake	*Rissa tridactyla*	17	1.8	−9.2	13.7	74.6
Bonaparte's gull	*Chroicocephalus philadelphia*	102	−1.1	−4.5	2.6	0.6
Mew gull	*Larus canus*	115	−4.1	−6.6	−1.7	7.3
Northern hawk owl	*Surnia ulula*	36	3.8	−1.0	9.1	0.0
Great gray owl	*Strix nebulosa*	46	3.6	−0.1	8.4	0.0
Northern saw-whet owl	*Aegolius acadicus*	44	1.9	−6.2	9.5	0.0
American pipit	*Anthus rubescens*	32	0.0	−8.6	9.2	0.4
Bohemian waxwing	*Bombycilla garrulus*	95	−3.0	−6.2	0.1	1.1
Golden-crowned sparrow	*Zonotrichia atricapilla*	46	−1.6	−3.2	0.3	22.9

Table 1. Extended.

1993–2014 Analysis, Augmented Area				1993–2014 Analysis, Core Area								
2.5% CI RA	97.5% CI RA	Half–width	Credibility score	N	Trend	2.5% CI	97.5% CI	RA	2.5% CI RA	97.5% CI RA	Half-width	Credibility score
2.3	206.1	10.7	P	***	***	***	***	***	***	***	***	***
0.4	6.6	7.3	P	***	***	***	***	***	***	***	***	***
1.6	18.3	6.7	P	***	***	***	***	***	***	***	***	***
0.2	65.7	12.2	P	***	***	***	***	***	***	***	***	***
0.2	1.9	6.2	P	***	***	***	***	***	***	***	***	***
1.7	30.6	6.4	P	***	***	***	***	***	***	***	***	***
0.0	5.4	13.9	P	***	***	***	***	***	***	***	***	***
0.1	0.4	4.6	Q	***	***	***	***	***	***	***	***	***
0.0	0.1	6.0	P	***	***	***	***	***	***	***	***	***
0.1	0.7	7.5	P	***	***	***	***	***	***	***	***	***
0.6	21.9	7.9	P	***	***	***	***	***	***	***	***	***
0.3	1.4	4.5	Q	***	***	***	***	***	***	***	***	***
0.0	1.3	12.1	P	***	***	***	***	***	***	***	***	***
0.6	6.9	7.2	P	***	***	***	***	***	***	***	***	***
0.1	45.7	19.4	P	***	***	***	***	***	***	***	***	***
0.0	0.6	10.8	P	***	***	***	***	***	***	***	***	***
0.2	0.9	4.3	Q	***	***	***	***	***	***	***	***	***
2.9	998.2	10.0	P	***	***	***	***	***	***	***	***	***
0.1	35.5	6.5	P	***	***	***	***	***	***	***	***	***
0.1	1.0	7.0	P	***	***	***	***	***	***	***	***	***
0.1	2.4	9.0	P	***	***	***	***	***	***	***	***	***
1.4	5.8	4.7	Q	***	***	***	***	***	***	***	***	***
1.7	64.7	8.9	P	***	***	***	***	***	***	***	***	***
1.3	3.8	3.1	Q	***	***	***	***	***	***	***	***	***
0.8	> 1,000.00	12.6	P	***	***	***	***	***	***	***	***	***
0.0	0.0	12.1	P	***	***	***	***	***	***	***	***	***
0.0	0.2	12.2	P	***	***	***	***	***	***	***	***	***
0.0	0.0	5.1	P	***	***	***	***	***	***	***	***	***
4.7	53.6	3.7	Q	***	***	***	***	***	***	***	***	***
0.1	0.9	10.8	P	***	***	***	***	***	***	***	***	***
0.0	0.3	8.8	P	***	***	***	***	***	***	***	***	***
5.7	14.6	2.1	R	***	***	***	***	***	***	***	***	***
3.0	20.4	4.1	Q	***	***	***	***	***	***	***	***	***
12.5	241.5	4.2	Q	***	***	***	***	***	***	***	***	***
18.9	139.0	5.0	P	***	***	***	***	***	***	***	***	***
12.7	28.2	2.6	R	***	***	***	***	***	***	***	***	***
0.1	10.0	21.7	P	***	***	***	***	***	***	***	***	***
0.2	0.8	4.5	Q	67	9.2	3.5	14.2	0.1	0.5	0.2	5.4	P
43.7	> 1000.0	9.0	P	19	1.0	−8.8	9.2	798.9	41.6	> 1000.0	9.0	P
0.3	3.3	6.4	P	13	−2.4	−14.0	6.8	0.3	0.3	1.4	10.4	P
1.2	> 1000.0	15.9	P	3	0.4	−14.3	25.8	3.4	0.7	> 1000.0	20.1	P
0.1	30.7	12.7	P	7	−5.4	−13.6	10.2	0.1	0.0	1.3	11.9	P
0.0	0.1	4.6	P	44	5.9	1.6	11.2	0.0	0.0	0.1	4.8	P
0.2	0.6	3.6	Q	4	1.2	−6.3	8.3	0.1	0.2	0.2	7.3	P
0.1	3.5	9.7	P	11	−1.5	−6.6	4.0	0.1	0.1	0.4	5.3	P
0.3	5.0	7.4	P	8	−1.0	−6.3	4.9	0.2	0.4	1.1	5.6	P
2.5	21.6	4.1	Q	19	−5.7	−10.4	1.2	0.5	3.0	2.1	5.8	P
6.4	> 1000.0	11.5	P	4	6.0	−5.4	19.6	104.8	7.3	> 1000.0	12.5	P
0.3	1.2	3.5	Q	49	−0.4	−5.3	5.2	0.3	0.3	0.8	5.2	P
4.8	12.4	2.4	R	10	−7.3	−17.3	2.4	0.1	2.9	0.6	9.8	P
0.0	0.0	5.0	P	11	2.0	−5.2	10.2	0.0	0.0	0.0	7.7	P
0.0	0.0	4.3	P	37	3.8	−0.6	9.5	0.0	0.0	0.0	5.0	P
0.0	0.0	7.9	P	39	2.5	−4.9	10.8	0.0	0.0	0.0	7.8	P
0.1	2.0	8.9	P	14	−7.1	−13.2	0.1	0.1	0.1	0.4	6.7	P
0.7	2.0	3.2	Q	12	−0.7	−11.5	11.3	0.0	0.5	0.1	11.4	P
9.7	53.0	1.7	R	6	−0.7	−6.3	7.6	0.0	7.9	0.2	6.9	P

throated loon *Gavia stellata,* marbled murrelet *Brachyramphus marmoratus,* Bonaparte's gull *Chroicocephalus philadelphia,* and bohemian waxwing *Bombycilla garrulus* were in the questionably monitored category. All species were poorly monitored in the core survey area, and the additional data in the augmented survey area improved the credibility of seven species; two species improved to reasonably monitored status and five species improved to questionably monitored status in the augmented survey results. Mew gull showed significant declines. One of the five questionably monitored species, trumpeter swan, showed a significant increase; none were declining.

Species not occurring in the newly added northern strata

Predominantly southern species. Excluding Heerman's gull *Larus heermanni* (a nonbreeding species in the BBS area), we conducted analyses for 44 predominantly southern species not previously included in our BBS analyses (Table 2). Four species, great kiskadee *Pitangus sulphuratus,* black-whiskered vireo *Vireo altiloquus,* bridled titmouse *Baeolophus wollweberi,* and red-faced warbler *Cardellina rubrifrons* were reasonably monitored using BBS criteria, 18 species were questionably monitored, and 22 species were poorly monitored. Five species had very small sample sizes, and 17 species were encountered on >13 routes. Although the estimates were very imprecise overall (average CI half-width $= 5.5\%$), nine species had relatively precise estimates. Ten species had very low abundances. Seven of the reasonably or questionably monitored species showed significant increases over 1966–2014; whereas, one species (red-faced warbler) showed a significant decline. Among the poorly monitored species, five significantly increased and one (smooth-billed ani *Crotophaga ani*) decreased in population.

Rare, coastal, or nocturnal species. This diverse collection of 19 species includes a variety of species of management concern, including lesser prairie-chicken *Tympanuchus pallidicinctus,* black rail *Laterallus jamaicensis,* yellow rail *Coturnicops noveboracensis,* American oystercatcher *Haematopus palliatus,* spotted owl *Strix occidentalis,* black-capped vireo *Vireo atricapilla,* Florida scrub-jay *Aphelocoma coerulescens,* Bicknell's thrush *Catharus bicknelli,* Kirtland's warbler *Setophaga kirtlandii,* and golden-cheeked warbler *Setophaga chrysoparia* (Table 2). Unfortunately, none of these species were reasonably monitored by the BBS, and only black-capped vireo and Florida scrub-jay were in the questionably monitored category; all others were poorly monitored primarily because of very imprecise estimated trends (average CI half-width $= 7.7\%$). Only 2 species had very small sample sizes, and 13 species had small sample sizes, as defined by the criteria stated earlier. Five of the species showed significant increases; 2 showed significant declines over the 1966–2014 interval, including the Florida scrub-jay and Bicknell's thrush.

Introduced species. Three introduced species not included in prior analyses had sufficient data to be included in this analysis (Table 2). Each of these species were seen on <14 BBS routes. All were poorly monitored by the BBS. The quality criterion displayed serious deficiencies that differed among species. Spotted dove *Streptopelia chinensis* and spot-breasted oriole *Icterus pectoralis* had very low abundances, and monk parakeet *Myiopsitta monachus* had very imprecise trend estimates.

Augmented area results for species included in previous analyses

Adding the new northern strata provided additional data for 168 species previously included in our BBS analyses (Table 3). In the 1993 - 2014 results, the addition of the new strata increased the number of routes (*N*) per species by an average of 49 routes relative to the core survey area. Although many common species in the core survey area had among the largest number of new routes (e.g., 170 additional routes for American robin *Turdus migratorius* and 165 additional routes for common raven *Corvus corax*), several species that had little data in core BBS strata occurred on many routes in the new northern strata (e.g., 122 routes for varied thrush *Ixoreus naevius,* 161 routes for fox sparrow *Passerella iliaca,* and 77 routes for rusty blackbird *Euphagus carolinus*). Comparing the ratios of the sizes of credible intervals (i.e., half-width of CI of trends from augmented area analysis / half-width of CI of trends from core area analysis) as a measure of relative precision, on average there is little change between the analysis based on the core area versus the augmented area (ratio $= 1.04$). Several species (e.g., rusty blackbird [0.72], fox sparrow [0.37], blackpoll warbler *Setophaga striata* [0.30], and varied thrush [0.82]) had marked increases in precision when the new data were added; other species, including lesser scaup *Aythya affinis* (2.21), yellow warbler *Setophaga petechia* (1.50), Townsend's solitare *Myadestes townsendi* (1.34), and savannah sparrow *Passerculus sandwichensis* (1.40) were much less precise when the new areas were added.

Overall, among the 168 species historically included in BBS analyses, the credibility of the trend results for the augmented area was very good; 155 of the 168 species (92%) were reasonably monitored (109) or questionably monitored (48 species). Only 15 of the 170 (9%) species changed credibility scores as a consequence of adding the additional regions. The credibility of lesser scaup dropped from reasonably to poorly monitored (lower precision) and 4 other species dropped from reasonably to questionably monitored, whereas the credibility scores of 10 species improved. The blackpoll warbler increased from poorly to reasonably monitored, and 9 other species increased either from questionably to reasonably monitored, or poorly to questionably monitored (Table 3).

Among the 155 species in the augmented area analysis with reasonably or questionably monitored

credibility scores, 37 species (24%) were significantly increasing, whereas 46 species (30%) were significantly decreasing, including 3 reasonably monitored species with decreases of >5%/y: evening grosbeak *Coccothraustes vespertinus* (–6.2%/y), blackpoll warbler (–4.3%/y), and pine siskin *Spinus pinus* (–5.2%/y). In comparison with the results from the core area, 20 of the 151 species that were reasonably or questionably monitored in both the core and augmented area analyses exhibited a change in trend. For nine species with trends estimated to be stable or undeterminable in the core area, the addition of the northern strata produced significantly decreasing (five species) or increasing (four species) trend estimates. However, 11 species that exhibited significant decreases (3 species) or increases (8 species) in the core area analysis had stable or undeterminable trends when the analysis included the additional northern strata. Nonetheless, as judged by overlap of credible intervals, only two species (bald eagle *Haliaeetus leucocephalus* and varied thrush) had significant changes in estimated trends due to the addition of the new strata, and differences in both of these species reflected only changes in magnitude; our conclusion about direction of trend did not change. However, adding the new routes caused our estimates of relative abundance to change for many species. The largest changes in relative abundance among reasonably or questionably monitored species were northwestern crow *Corvus caurinus,* with a decrease of –76% (55.1 in the core area, 13.2 in the augmented area) and fox sparrow, with an increase of 908% (1.4 in the core area, 14.5 in the augmented area).

Alaska species

The BBS contained data that could be analyzed for 176 species in Alaska (Table S2, *Supplemental Material*), an increase of 56 species in comparison to those historically analyzed. On average, species were seen on 31 Alaskan survey routes. In general, results from Alaska are imprecise; the mean half-width of the 95% CI is 5.8. Eighty-seven of the species are poorly monitored, including 39 of the newly added species. Forty-two were reasonably monitored by BBS criteria, whereas 47 were questionably monitored.

Discussion

Extending the analysis to the augmented survey area

The BBS has been growing in extent since 1966. In addition to increasing route density in the core survey area (a process that is still occurring), northern regions and more recently Mexico have initiated BBS routes. Strata with limited or no data from the early years of the survey should be included in analyses using statistical methods that effectively use all the data and accommodate the unbalanced design imposed by the expansion of the BBS. The hierarchical model we implemented here accomplishes this by including hierarchical structure in slope and stratum parameters. This structure accommodates differences in precision among strata, allowing us to analyze all data simultaneously and summarize results for regions and time intervals when data are available. American black duck *Anas rubripes* survey analyses in eastern North America (Zimmerman et al. 2012) adopted a similar approach. In American black duck surveys, a core area was surveyed for 5 y before additional surveys were implemented for an expanded survey area, and separate results were presented for core and expanded survey areas. Population change was estimated for the extended survey area and for portions of the survey area, constrained to time periods of common coverage. Using a similar approach, we provide trends for the expanded BBS survey area for 170 species for the interval of data overlap (1993–2014). Prediction of population change for the "new" survey areas for the interval 1966–1992 is possible, if one is willing to assume that change in the unsampled regions could be predicted from either recent data for the new areas or data from 1966 to 1993 from strata in the core area. Both of these extrapolations seem difficult to justify without evidence of consistency over time or space, and we chose not to implement such a prediction.

Our results indicate that estimates of population change in these augmented regions tend to be quite imprecise. However, these data provide our only view of population change for these regions and species, increasing the scope of inference for many northern species. Even with the imprecise results, the analysis documented significant changes in some species. For many species that are already monitored over part of their breeding ranges by the BBS, these new data can greatly enhance the value of the BBS data. Rusty blackbird, for example, is a declining species that previously had only been monitored on the edge of its breeding range by the BBS, and the expanded survey area provides significant new information for the species. Incorporating the additional data and presenting results for the expanded survey area for the post–1993 years seems to be a reasonable strategy, and precision of results will likely increase as more years of data accrue.

Unfortunately, fundamental concerns still exist regarding the limitations of the BBS sampling protocols from those regions, and opportunities to expand the BBS are limited in northern parts of the continent. Road networks are very limited, and issues about the lack of representativeness of regional habitats in roadside samples are likely of great concern when there is very little randomness in selection of roads for sampling (Sauer et al. 2013). These large areas can be influential in the overall analysis and caution is warranted when considering whether to include the strata in regional summaries.

Traditional means of reducing uncertainty through additional samples (i.e., adding more routes) is unlikely to be feasible in these strata, and Smith et al. (2014) suggested aggregation of strata to the scale of BCRs

Table 2. Estimated population change for species not presently summarized in BBS analyses but that occur in nonnorthern regions. Species are categorized as either 1) primarily southern in distribution; 2) rare, coastal, or nocturnal; or 3) introduced into North America. Analysis is based on log-linear hierarchical models; trend is defined as the change in annual indexes over a specified time period (Sauer et al. 2013). For each species, we present sample size (number of routes, *N*), trend estimate (% change/yr, 1966–2014), 2.5% and 97.5% credible intervals (CI) for trend, relative abundance (RA, defined as the annual index in the midyear of the interval) and 2.5% and 97.5% CIs for relative abundance, half-width of the CIs for trend, and a credibility score (R = reasonably monitored, Q = questionably monitored (estimates have at least one deficiency), and P = poorly monitored (Sauer et al. 2014). Values <0.1 are indicated as 0.0.

		1966–2014 Analysis, Core Area								
Common name	Scientific name	*N*	Trend	2.5% CI	97.5% CI	RA	2.5% CI RA	97.5% CI RA	Half-width	Credibility score
Predominantly southern species: 50% hemispheric range included within core BBS area (some are also coastal, nocturnal and/or rare)										
Plain chachalaca	*Ortalis vetula*	4	4.5	−9.9	22.9	3.5	0.1	>1,000	16.4	P
Montezuma quail	*Cyrtonyx montezumae*	10	4.2	−2.5	12.3	0.3	0.1	11.1	7.4	P
Least grebe	*Tachybaptus dominicus*	14	0.6	−8.9	9.7	0.1	0.0	18.6	9.3	P
Magnificent frigatebird	*Fregata magnificens*	9	−1.0	−5.1	3.3	0.7	0.2	6.9	4.2	Q
Neotropic cormorant	*Phalacrocorax brasilianus*	46	6.0	1.3	11.0	15.9	7.7	101.7	4.9	Q
Reddish egret	*Egretta rufescens*	26	2.2	−1.4	5.2	0.2	0.1	0.5	3.3	Q
Gray hawk	*Buteo plagiatus*	6	11.0	4.8	17.8	0.5	0.6	5.7	6.5	P
Short-tailed hawk	*Buteo brachyurus*	9	6.2	−0.4	14.8	0.0	0.0	0.0	7.6	P
White-tailed hawk	*Buteo albicaudatus*	26	3.8	1.8	6.0	0.4	0.3	0.6	2.1	Q
Zone-tailed hawk	*Buteo albonotatus*	22	5.6	1.9	10.0	0.0	0.1	0.1	4.1	P
Limpkin	*Aramus guarauna*	39	1.0	−2.5	4.7	0.1	0.0	0.4	3.6	Q
White-crowned pigeon	*Patagioenas leucocephala*	9	4.1	0.8	7.3	49.4	9.1	>1,000	3.2	Q
White-tipped dove	*Leptotila verreauxi*	19	9.7	5.5	14.1	3.5	2.1	13.9	4.3	Q
Mangrove cuckoo	*Coccyzus minor*	9	1.9	−3.0	7.0	0.1	0.0	0.3	5.0	P
Smooth-billed ani	*Crotophaga ani*	10	−8.9	−14.1	−3.7	0.1	0.0	0.6	5.2	P
Elf owl	*Micrathene whitneyi*	14	3.5	−2.5	9.3	0.1	0.0	1.1	5.9	P
Common pauraque	*Nyctidromus albicollis*	26	1.6	−1.4	4.8	0.2	0.1	0.4	3.1	Q
Broad-billed hummingbird	*Cynanthus latirostris*	7	7.9	2.4	12.8	0.7	0.2	405.7	5.2	P
Buff-bellied hummingbird	*Amazilia yucatanensis*	9	6.1	−3.1	14.5	0.1	0.0	0.6	8.8	P
Blue-throated hummingbird	*Lampornis clemenciae*	3	−1.5	−14.6	9.6	0.1	0.0	427.1	12.1	P
Magnificent hummingbird	*Eugenes fulgens*	4	4.7	−4.7	22.3	0.0	0.0	0.3	13.5	P
Elegant trogon	*Trogon elegans*	4	5.7	−7.3	23.6	0.1	0.0	>1,000	15.4	P
Green kingfisher	*Chloroceryle americana*	6	1.4	−8.8	14.0	0.0	0.0	1.4	11.4	P
Arizona woodpecker	*Picoides arizonae*	5	1.0	−2.1	4.6	0.2	0.1	0.4	3.4	Q
Northern beardless-tyrannulet	*Camptostoma imberbe*	6	2.1	−1.0	5.5	0.2	0.1	0.3	3.2	Q
Greater pewee	*Contopus pertinax*	8	4.9	−1.4	12.7	0.6	0.1	26.1	7.1	P
Dusky-capped flycatcher	*Myiarchus tuberculifer*	12	0.4	−1.2	2.1	4.1	1.2	54.9	1.7	Q
Great kiskadee	*Pitangus sulphuratus*	30	5.5	3.2	7.7	0.8	0.9	1.4	2.3	R
Sulphur-bellied flycatcher	*Myiodynastes luteiventris*	4	6.3	1.2	11.7	0.3	0.2	1.1	5.2	P
Thick-billed kingbird	*Tyrannus crassirostris*	3	−2.1	−8.2	3.6	0.1	0.0	0.4	5.9	P
Gray kingbird	*Tyrannus dominicensis*	30	−0.9	−3.0	1.7	0.5	0.2	1.4	2.3	Q
Black-whiskered vireo	*Vireo altiloquus*	15	−0.9	−2.6	0.8	6.3	1.5	73.6	1.7	R
Mexican jay	*Aphelocoma wollweberi*	13	−1.0	−3.7	1.8	14.9	4.6	70.0	2.7	Q
Bridled titmouse	*Baeolophus wollweberi*	15	−1.2	−3.3	1.0	4.5	1.3	39.6	2.1	R
California gnatcatcher	*Polioptila californica*	5	−4.3	−14.3	3.8	0.0	0.0	121.6	9.1	P
Olive warbler	*Peucedramus taeniatus*	14	4.6	−1.1	9.4	0.7	0.5	4.0	5.3	P
Red-faced warbler	*Cardellina rubrifrons*	16	−2.7	−6.1	−0.8	2.8	0.8	18.9	2.6	R
Painted redstart	*Myioborus pictus*	11	−0.2	−2.0	1.8	0.8	0.4	3.2	1.9	Q
Rufous-winged sparrow	*Peucaea carpalis*	6	9.9	4.2	16.6	0.7	0.5	6.9	6.2	P
Botteri's sparrow	*Peucaea botterii*	11	5.3	0.5	10.5	0.4	0.3	1.6	5.0	Q
Yellow-eyed junco	*Junco phaeonotus*	6	−2.9	−5.3	1.3	44.6	1.7	>1,000	3.3	Q
Varied bunting	*Passerina versicolor*	33	1.2	−2.5	4.0	0.2	0.1	0.3	3.3	Q
Altamira oriole	*Icterus gularis*	6	−2.8	−22.3	7.8	0.1	0.0	>1,000	15.1	P
Audubon's oriole	*Icterus graduacauda*	20	9.0	5.9	11.9	0.3	0.4	0.9	3.0	Q
Rare, coastal, and/or nocturnal species (i.e., rarely detected on BBS)										
Lesser prairie-chicken	*Tympanuchus pallidicinctus*	12	10.1	0.8	20.0	0.6	0.4	15.2	9.6	P
Northern gannet	*Morus bassanus*	9	14.9	3.4	28.0	51.9	16.3	>1,000	12.3	P
Brandt's cormorant	*Phalacrocorax penicillatus*	9	−1.5	−9.0	9.0	3.1	0.1	>1,000	9.0	P
Yellow rail	*Coturnicops noveboracensis*	57	5.1	0.2	9.3	0.0	0.0	0.1	4.5	P
Black rail	*Laterallus jamaicensis*	3	8.4	−2.6	26.7	0.1	0.0	5.6	14.7	P
Snowy plover	*Charadrius nivosus*	4	1.3	−9.7	12.0	0.7	0.2	9.2	10.9	P
Wilson's plover	*Charadrius wilsonia*	13	−3.1	−8.6	1.7	0.1	0.0	1.1	5.2	P
American oystercatcher	*Haematopus palliatus*	7	−0.8	−8.8	3.8	0.1	0.0	0.7	6.3	P

Table 2. Continued.

		1966–2014 Analysis, Core Area								
Common name	**Scientific name**	***N***	**Trend**	**2.5% CI**	**97.5% CI**	**RA**	**2.5% CI RA**	**97.5% CI RA**	**Half-width**	**Credibility score**
Sandwich tern	*Thalasseus sandvicensis*	7	2.6	−10.7	14.7	1.3	0.1	>1,000	12.7	P
Black guillemot	*Cepphus grylle*	10	6.6	1.2	12.4	0.4	0.2	2.8	5.6	P
Rhinoceros auklet	*Cerorhinca monocerata*	7	5.7	−7.0	19.5	84.5	0.7	>1,000	13.2	P
Spotted owl	*Strix occidentalis*	16	−2.7	−5.9	1.1	0.0	0.0	0.0	3.5	P
Long-eared owl	*Asio otus*	44	−0.6	−4.0	2.5	0.0	0.0	0.0	3.2	P
Black-capped vireo	*Vireo atricapilla*	9	2.9	−1.2	7.1	6.3	1.1	>1,000	4.1	Q
Florida scrub-jay	*Aphelocoma coerulescens*	12	−4.2	−6.7	−1.5	0.6	0.1	2.5	2.6	Q
Bicknell's thrush	*Catharus bicknelli*	21	−4.7	−8.0	−1.4	0.0	0.0	0.0	3.3	P
Kirtland's warbler	*Setophaga kirtlandii*	5	17.8	8.0	32.9	0.1	0.1	1.0	12.5	P
Golden-cheeked warbler	*Setophaga chrysoparia*	10	−0.3	−5.7	4.8	0.9	0.1	28.3	5.2	P
Saltmarsh sparrow	*Ammodramus caudacutus*	7	0.0	−8.5	7.8	0.1	0.0	0.9	8.2	P
Introduced species										
Spotted dove	*Streptopelia chinensis*	13	−4.6	−8.5	−1.1	0.1	0.0	0.5	3.7	P
Monk parakeet	*Myiopsitta monachus*	10	15.2	6.6	27.8	0.3	0.2	10.2	10.6	P
Spot-breasted oriole	*Icterus pectoralis*	5	−7.9	−12.2	−3.9	0.0	0.0	0.1	4.1	P

before the hierarchical model analysis as an approach for analysis of sparse data sets. We prefer to retain the strata defined at the scale of BCRs within states or provinces for several reasons. Although aggregation of northern strata into BCRs may provide sufficient data to compute a composite estimate, it likely compounds issues associated with lack of representativeness of sampling because summary results are based on very large regions with limited (and often clustered) coverage. Use of state- or province-BCR-scale strata more clearly defines portions of BCRs without data. Aggregating strata before analysis also limits our ability to produce estimates at scales relevant to management. We chose to retain the strata involving BCR 4 in Yukon and Alaska to allow for estimation of trends from Alaska without having to use the combined strata results. The hierarchical model we use allows for aggregation of results among strata during the analysis; summary results for Alaska demonstrate that computing trends based on a composite analysis state- or province-BCR strata can provide trend estimates with reasonable precision (Table S2, *Supplemental Material*).

Another way to increase the precision and representativeness of results is to combine BBS data with other bird-monitoring data sources from poorly BBS-sampled strata. The hierarchical models used in this analysis could readily be extended to incorporate additional information sources, allowing BBS route data to be augmented by data collected from alternative sources. Ample precedent exists for accommodating multiple data streams in composite analyses using BBS data (e.g., Zimmerman et al. 2012, 2015), and many data exist in boreal forest habitats and other roadless areas (Cumming et al. 2010). Off-road information collected in Alaska is presently being evaluated in development of composite analyses of on and off road data (C. Handel, United States Geological Survey, personal communication).

What species now can be analyzed using BBS data?

Many southern species provide significant amounts of data for analysis, and our analysis of 21 species provides information that, if used with caution, can provide information on population change. These species have limited ranges within the BBS survey area; therefore, interpretation of population trends must be viewed as relevant only to the surveyed segment of the population rather than reflecting the overall species' trends. Analysis of BBS data collected in Mexico will permit inference for larger portions of the species' ranges.

Of the Rare, Coastal, and Nocturnal species considered in our analysis, only two species, black-capped vireo and Florida scrub-jay, were not categorized as poorly monitored. Most of the results for these species show deficiencies that reflect aspects of their natural histories, particularly low detectability at time of sampling of BBS routes or occurrence in habitats that that do not occur along roadsides, which make them poorly suited for BBS monitoring. The owl species and rails have extremely low relative abundances; coastal species have small sample sizes and very large variances.

"New" northern species fall into two categories: 1) species that are only found in the new strata; and 2) species with significant amounts of data from the core strata. Both of these groups tend toward being poorly monitored by BBS criteria: for 1), although gray-cheeked thrush and common redpoll seem reasonably monitored, 27 of the 37 other species were poorly monitored; for 2), mew gull and golden-crowned sparrow were reasonably monitored but 12 of the 19 species were poorly monitored. The greater precision in estimates of species with some data in the core survey area is predictable because of larger sample sizes and increased precision associated with the longer time series of data in the better established survey in the core area. This cannot occur for species that do not occur in core strata because all the new strata lack long-term data that are used to estimate the slope parameter.

Table 3. Estimated population change for northern species historically summarized in BBS analyses. For each species, we present these results for the augmented survey area (including newly analyzed northern strata) and for the core survey area. Analysis is based on log-linear hierarchical models; trend is defined as the change in annual indexes over a specified time period (Sauer et al. 2013). For each species, we present sample size (number of routes, *N*), trend estimate (% change/yr, 1993–2014), 2.5% and 97.5% credible intervals (CI) for trend, relative abundance (RA, defined as the annual index in the midyear of the interval) and 2.5% and 97.5% CIs for relative abundance, half-width of the CIs for trend, and a credibility score (R = reasonably monitored, Q = questionably monitored (estimates have at least one deficiency), and P = poorly monitored (Sauer et al. 2014). Values <0.1 are indicated as 0.0. We document the change in sample size (*N*diff), the ratio of the sizes of the credible intervals (CIdiff; width of credible interval for augmented survey area trends / width of credible interval for core survey area trends), the difference in trend estimates (TrendDiff), and the difference in relative abundance between the two analyses (RaDiff). The differences in trend and relative abundance estimates are considered significant (indicated by *) if the CIs do not overlap between the two analyses.

		1993–2014 Analysis, Augmented Area								
Common name	**Scientific name**	***N***	**Trend**	**2.5% CI**	**97.5% CI**	**RA**	**2.5% CI RA**	**97.5% CI RA**	**Half-width**	**Credibility score**
Canada goose	*Branta canadensis*	2,799	12.4	10.9	14.9	39.5	31.1	63.5	2.0	R
Gadwall	*Anas strepera*	642	3.9	2.6	5.4	2.8	2.2	3.7	1.4	R
American wigeon	*Anas americana*	540	0.4	−1.3	2.3	1.5	1.1	2.1	1.8	R
American black duck	*Anas rubripes*	325	0.7	−1.2	3.2	0.3	0.2	0.7	2.2	Q
Mallard	*Anas platyrhynchos*	3,060	1.3	0.4	2.4	7.3	6.4	8.4	1.0	R
Northern shoveler	*Anas clypeata*	580	5.0	−1.9	7.3	1.4	1.1	4.6	4.6	Q
Northern pintail	*Anas acuta*	591	2.4	−0.2	4.9	1.5	1.1	2.1	2.6	R
Green-winged teal	*Anas crecca*	705	1.3	−0.3	3.1	0.5	0.4	0.8	1.7	Q
Ring-necked duck	*Aythya collaris*	451	4.1	−0.3	7.6	0.5	0.3	0.9	3.9	Q
Lesser scaup	*Aythya affinis*	447	−0.5	−8.2	2.8	2.8	1.9	4.8	5.5	P
Bufflehead	*Bucephala albeola*	251	3.2	1.4	5.2	0.5	0.4	0.7	1.9	Q
Common goldeneye	*Bucephala clangula*	310	1.6	0.0	3.4	0.3	0.2	0.4	1.7	Q
Barrow's goldeneye	*Bucephala islandica*	113	−0.2	−2.5	2.6	0.3	0.2	0.5	2.5	Q
Hooded merganser	*Lophodytes cucullatus*	371	5.7	3.6	8.4	0.1	0.0	0.1	2.4	P
Common merganser	*Mergus merganser*	802	0.8	−0.7	2.6	0.3	0.2	0.4	1.6	Q
Red-breasted merganser	*Mergus serrator*	89	−2.9	−6.7	1.5	1.2	0.6	2.6	4.1	Q
Ruffed grouse	*Bonasa umbellus*	1,002	1.9	−0.3	3.8	0.4	0.3	0.6	2.0	Q
Sooty grouse	*Dendragapus fuliginosus*	109	0.5	−1.2	2.4	0.8	0.5	1.2	1.8	Q
Sharp-tailed grouse	*Tympanuchus phasianellus*	274	1.2	−0.6	3.5	0.4	0.3	0.5	2.0	Q
Common loon	*Gavia immer*	865	0.7	−0.4	1.6	1.0	0.8	1.2	1.0	Q
Pied-billed grebe	*Podilymbus podiceps*	837	2.8	1.1	4.6	0.2	0.2	0.3	1.7	Q
Horned grebe	*Podiceps auritus*	166	−0.6	−2.9	1.9	0.2	0.1	0.2	2.4	Q
Red-necked grebe	*Podiceps grisegena*	202	0.9	−0.7	2.9	0.4	0.3	0.6	1.8	Q
Double-crested cormorant	*Phalacrocorax auritus*	1,013	6.0	3.6	13.9	1.6	1.2	2.5	5.1	P
Pelagic cormorant	*Phalacrocorax pelagicus*	18	−3.1	−8.4	2.8	1.2	0.3	8.8	5.6	P
American bittern	*Botaurus lentiginosus*	829	1.4	0.2	2.7	0.4	0.3	0.5	1.3	Q
Great blue heron	*Ardea herodias*	3,143	1.7	1.3	2.5	0.8	0.7	0.8	0.6	Q
Osprey	*Pandion haliaetus*	899	5.5	3.6	7.5	0.3	0.2	0.4	1.9	Q
Bald eagle	*Haliaeetus leucocephalus*	896	4.2	3.1	5.4	0.3	0.3	0.4	1.1	Q
Northern harrier	*Circus cyaneus*	1,624	−1.1	−1.7	−0.6	0.3	0.3	0.3	0.5	Q
Sharp-shinned hawk	*Accipiter striatus*	1,028	1.7	0.8	2.7	0.0	0.0	0.0	1.0	P
Northern goshawk	*Accipiter gentilis*	327	0.9	−1.2	2.8	0.0	0.0	0.0	2.0	P
Red−tailed hawk	*Buteo jamaicensis*	3,730	1.7	1.4	2.0	1.1	1.0	1.1	0.3	R
Golden eagle	*Aquila chrysaetos*	571	−0.1	−0.9	0.7	0.1	0.1	0.2	0.8	Q
Sora	*Porzana carolina*	838	2.2	0.7	3.8	0.5	0.4	0.6	1.5	Q
American coot	*Fulica americana*	792	3.5	0.5	6.3	3.0	2.2	4.5	2.9	R
Sandhill crane	*Grus canadensis*	740	5.4	3.6	6.8	2.2	1.8	2.9	1.6	R
Killdeer	*Charadrius vociferus*	3,722	−0.6	−0.9	−0.4	4.6	4.4	4.8	0.2	R
Spotted sandpiper	*Actitis macularius*	1,428	−1.1	−1.7	−0.4	0.5	0.4	0.5	0.7	Q
Solitary sandpiper	*Tringa solitaria*	148	1.9	−0.5	4.6	0.2	0.2	0.3	2.6	Q
Greater yellowlegs	*Tringa melanoleuca*	162	2.5	0.4	4.9	0.9	0.6	1.5	2.2	Q
Lesser yellowlegs	*Tringa flavipes*	207	−2.7	−4.8	−0.5	2.5	1.8	3.7	2.2	R
Upland sandpiper	*Bartramia longicauda*	760	0.7	0.0	1.5	2.5	2.2	3.1	0.8	R
Wilson's snipe	*Gallinago delicata*	1,663	1.1	−0.1	2.1	6.2	5.3	7.6	1.1	R
Ring-billed gull	*Larus delawarensis*	1,082	1.8	−0.5	3.9	29.5	21.6	42.6	2.2	R
Herring gull	*Larus argentatus*	534	−2.6	−4.7	−0.1	12.2	7.9	27.0	2.3	R
Glaucous-winged gull	*Larus glaucescens*	87	−3.3	−7.1	0.4	29.5	12.9	84.3	3.7	Q
Great black-backed gull	*Larus marinus*	132	−3.8	−7.2	−0.6	6.1	3.5	13.2	3.3	Q
Caspian tern	*Hydroprogne caspia*	168	2.6	−0.3	6.4	0.2	0.1	0.3	3.4	Q
Black tern	*Chlidonias niger*	381	1.8	−0.7	4.9	3.2	2.2	4.9	2.8	R
Common tern	*Sterna hirundo*	179	−1.9	−4.8	1.4	0.9	0.6	1.8	3.1	Q

Table 3. Extended.

1993–2014 Analysis, Core Area									Augmented Area vs. Core Area			
N	Trend	2.5% CI	97.5% CI	RA	2.5% CI RA	97.5% CI RA	Half-width	Credibility score	*N*diff	CIdiff	TrendDiff	RaDiff
2,709	13.2	11.6	15.8	45.6	35.8	75.8	2.1	R	90	1.0	−0.7	−6.2
640	3.9	2.6	5.3	3.2	2.6	4.2	1.4	R	2	1.0	0.0	−0.4
468	−0.6	−2.0	1.1	1.1	0.8	1.4	1.5	R	72	1.2	1.0	0.4
314	0.5	−1.4	3.2	0.3	0.2	0.6	2.3	Q	11	0.9	0.2	0.0
2,976	1.3	0.4	2.4	8.6	7.6	10.0	1.0	R	84	1.0	0.0	−1.4
548	5.5	3.4	7.8	1.8	1.4	2.5	2.2	R	32	2.1	−0.6	−0.4
536	3.5	0.5	6.3	1.7	1.2	2.5	2.9	R	55	0.9	−1.1	−0.2
625	1.9	0.0	4.0	0.4	0.3	0.5	2.0	Q	80	0.8	−0.6	0.1
414	4.0	−0.9	7.6	0.5	0.3	0.9	4.2	Q	37	0.9	0.0	0.0
401	1.7	−0.6	4.4	3.0	2.1	4.5	2.5	R	46	2.2	−2.2	−0.2
212	3.8	1.9	5.8	0.5	0.4	0.7	1.9	Q	39	1.0	−0.6	0.0
259	1.4	−0.3	3.3	0.3	0.2	0.5	1.8	Q	51	1.0	0.2	0.0
80	−0.1	−2.7	3.8	0.2	0.1	0.4	3.2	Q	33	0.8	−0.1	0.1
368	5.8	3.6	8.4	0.1	0.0	0.1	2.4	P	3	1.0	0.0	0.0
748	0.6	−0.5	1.8	0.3	0.2	0.3	1.2	Q	54	1.4	0.2	0.0
46	−1.1	−8.4	13.8	0.0	0.0	0.2	11.1	P	43	0.4	−1.8	1.2 *
957	2.0	−0.5	4.1	0.4	0.3	0.7	2.3	Q	45	0.9	−0.1	0.0
100	−1.2	−2.8	0.6	0.6	0.4	0.9	1.7	Q	9	1.1	1.6	0.2
270	1.2	−0.6	3.5	0.5	0.4	0.7	2.0	Q	4	1.0	0.0	−0.1
763	0.7	−0.3	1.6	1.2	1.0	1.5	0.9	R	102	1.1	0.0	−0.3
834	2.9	1.1	4.8	0.2	0.2	0.3	1.8	Q	3	1.0	−0.1	0.0
142	−0.3	−2.7	2.7	0.2	0.2	0.4	2.7	Q	24	0.9	−0.4	−0.1
168	2.3	0.7	4.6	0.4	0.3	0.6	2.0	Q	34	0.9	−1.4	0.0
1,001	5.8	3.4	13.9	1.6	1.2	2.6	5.2	P	12	1.0	0.2	0.0
14	−2.4	−7.4	4.1	1.2	0.3	10.0	5.7	P	4	1.0	−0.6	−0.1
813	1.5	0.3	2.8	0.4	0.3	0.5	1.3	Q	16	1.0	−0.1	0.0
3,130	1.8	1.3	2.5	0.8	0.8	0.8	0.6	Q	13	1.0	0.0	0.0
867	5.6	4.4	6.7	0.2	0.2	0.2	1.2	Q	32	1.6	−0.1	0.1 *
805	7.0	5.8	8.5	0.1	0.1	0.1	1.3	Q	91	0.9	−2.9 *	0.2 *
1,564	−1.2	−1.7	−0.6	0.3	0.3	0.4	0.5	Q	60	1.0	0.0	−0.1
993	1.7	0.8	2.7	0.0	0.0	0.0	0.9	P	35	1.0	0.0	0.0
282	0.6	−1.3	2.7	0.0	0.0	0.0	2.0	P	45	1.0	0.3	0.0
3,664	1.8	1.5	2.0	1.2	1.2	1.3	0.3	R	66	1.1	0.0	−0.1 *
556	−0.1	−0.9	0.7	0.2	0.1	0.2	0.8	Q	15	1.0	0.0	0.0
821	2.7	1.2	4.2	0.5	0.4	0.6	1.5	Q	17	1.0	−0.4	0.0
789	3.7	1.0	6.4	3.2	2.3	4.7	2.7	R	3	1.1	−0.1	−0.1
679	6.3	5.2	7.4	1.9	1.6	2.4	1.1	R	61	1.5	−0.9	0.3
3,714	−0.6	−0.9	−0.4	4.9	4.8	5.1	0.2	R	8	1.0	0.0	−0.3
1,323	−0.9	−1.5	−0.4	0.4	0.3	0.4	0.5	Q	105	1.3	−0.1	0.1
88	1.5	−1.8	5.6	0.1	0.1	0.2	3.7	P	60	0.7	0.4	0.1
99	3.6	−0.6	7.7	0.3	0.2	0.9	4.1	Q	63	0.5	−1.1	0.5
108	−3.1	−6.0	0.8	0.3	0.2	0.6	3.4	Q	99	0.6	0.3	2.2 *
751	0.7	0.0	1.5	3.2	2.7	3.9	0.8	R	9	1.0	0.0	−0.6
1,505	2.1	1.4	2.9	3.8	3.3	4.3	0.8	R	158	1.5	−1.0	2.4 *
1,064	1.6	−0.7	3.8	28.8	21.0	42.0	2.2	R	18	1.0	0.2	0.7
451	−2.8	−5.3	0.4	6.0	3.7	23.3	2.8	R	83	0.8	0.2	6.2
45	−0.5	−3.5	1.9	19.9	8.8	51.6	2.7	R	42	1.4	−2.8	9.6
110	−1.7	−8.3	2.9	1.7	0.9	7.1	5.6	P	22	0.6	−2.1	4.3
163	2.0	−0.9	5.8	0.1	0.1	0.3	3.4	Q	5	1.0	0.6	0.0
378	2.0	−0.6	5.0	3.5	2.4	5.4	2.8	R	3	1.0	−0.1	−0.3
161	−1.4	−4.5	2.7	0.5	0.3	1.1	3.6	Q	18	0.8	−0.5	0.4

Table 3. Continued.

		1993–2014 Analysis, Augmented Area								
Common name	**Scientific name**	***N***	**Trend**	**2.5% CI**	**97.5% CI**	**RA**	**2.5% CI RA**	**97.5% CI RA**	**Half-width**	**Credibility score**
Rock pigeon	*Columba livia*	2,951	−0.4	−1.0	0.0	7.4	6.8	8.1	0.5	R
Eurasian collared-dove	*Streptopelia decaocto*	1,353	31.3	28.6	33.9	0.4	0.4	0.5	2.6	Q
Mourning dove	*Zenaida macroura*	3,944	0.0	−0.1	0.2	27.3	26.6	28.2	0.1	R
Great horned owl	*Bubo virginianus*	1,990	−0.2	−0.9	0.5	0.2	0.2	0.2	0.7	Q
Northern pygmy-owl	*Glaucidium gnoma*	194	1.0	−0.8	2.8	0.0	0.0	0.0	1.8	P
Short-eared owl	*Asio flammeus*	328	0.9	−2.0	4.2	0.1	0.1	0.2	3.1	P
Common nighthawk	*Chordeiles minor*	1,922	−1.4	−1.9	−1.0	1.7	1.6	1.9	0.5	R
Vaux's swift	*Chaetura vauxi*	225	−0.7	−2.4	2.9	0.5	0.4	0.7	2.6	Q
Rufous hummingbird	*Selasphorus rufus*	315	−1.4	−2.1	−0.7	1.2	1.0	1.4	0.7	R
Belted kingfisher	*Megaceryle alcyon*	2,622	−1.4	−1.9	−1.0	0.2	0.2	0.3	0.5	Q
Yellow-bellied sapsucker	*Sphyrapicus varius*	1,011	1.8	0.4	2.9	2.3	1.9	3.0	1.3	R
Red-breasted sapsucker	*Sphyrapicus ruber*	256	1.4	−0.1	2.9	1.7	1.3	2.4	1.5	R
Downy woodpecker	*Picoides pubescens*	3,115	0.1	−0.2	0.3	0.9	0.9	0.9	0.3	Q
Hairy woodpecker	*Picoides villosus*	2,916	1.0	0.6	1.5	0.5	0.5	0.6	0.4	Q
American three-toed woodpecker	*Picoides dorsalis*	183	4.7	1.0	7.7	0.1	0.1	0.2	3.3	Q
Black-backed woodpecker	*Picoides arcticus*	225	2.6	−0.7	5.3	0.1	0.1	0.1	3.0	P
Pileated woodpecker	*Dryocopus pileatus*	2,436	1.7	1.4	2.1	0.9	0.9	1.0	0.4	Q
American kestrel	*Falco sparverius*	2,964	−1.2	−1.5	−0.9	0.6	0.6	0.7	0.3	Q
Merlin	*Falco columbarius*	585	3.5	1.8	4.7	0.1	0.1	0.1	1.5	P
Peregrine falcon	*Falco peregrinus*	124	6.7	2.9	9.9	0.0	0.0	0.0	3.5	P
Olive-sided flycatcher	*Contopus cooperi*	1,101	−2.6	−3.3	−2.0	1.2	1.0	1.3	0.7	R
Western wood-pewee	*Contopus sordidulus*	1,177	−1.3	−1.8	−0.7	3.9	3.5	4.5	0.5	R
Yellow-bellied flycatcher	*Empidonax flaviventris*	463	0.6	−1.0	2.3	2.2	1.6	3.0	1.7	R
"Trail's" flycatcher complex[a]	*Empidonax alnorum + traillii*	2,317	−1.2	−1.9	−0.4	10.7	9.4	12.7	0.7	R
Least flycatcher	*Empidonax minimus*	1,602	−2.0	−2.5	−1.4	4.6	4.1	5.3	0.6	R
Hammond's flycatcher	*Empidonax hammondii*	476	0.8	−0.1	1.7	4.2	3.3	5.3	0.9	R
Dusky flycatcher	*Empidonax oberholseri*	524	−0.6	−1.7	0.5	4.1	3.2	5.4	1.1	R
"Western" flycatcher complex[a]	*Empidonax difficilis + occidentalis*	575	−0.1	−1.2	1.1	4.6	3.8	5.9	1.1	R
Eastern phoebe	*Sayornis phoebe*	2,284	0.1	−0.2	0.4	1.7	1.6	1.8	0.3	R
Say's phoebe	*Sayornis saya*	930	1.0	0.5	1.5	0.7	0.7	0.8	0.5	Q
Eastern kingbird	*Tyrannus tyrannus*	3,010	−1.5	−1.7	−1.2	3.3	3.1	3.4	0.2	R
Blue-headed vireo	*Vireo solitarius*	1,038	3.2	1.5	4.3	2.0	1.6	3.1	1.4	R
Warbling vireo	*Vireo gilvus*	2,478	1.3	1.0	1.7	5.3	4.8	5.9	0.4	R
Philadelphia vireo	*Vireo philadelphicus*	391	3.5	0.6	6.7	1.5	0.9	3.1	3.0	Q
Red-eyed vireo	*Vireo olivaceus*	2,843	0.9	0.6	1.2	16.2	15.1	17.5	0.3	R
Gray jay	*Perisoreus canadensis*	755	0.5	−0.6	1.5	4.9	4.1	6.1	1.0	R
Steller's jay	*Cyanocitta stelleri*	578	−0.4	−0.8	0.0	3.3	2.9	3.7	0.4	R
Blue jay	*Cyanocitta cristata*	2,778	−0.6	−0.8	−0.5	7.1	6.9	7.3	0.1	R
Black-billed magpie	*Pica hudsonia*	1,003	0.0	−0.5	0.4	8.3	7.4	9.5	0.4	R
American crow	*Corvus brachyrhynchos*	3,709	0.0	−0.2	0.1	24.8	23.9	25.6	0.1	R
Northwestern crow	*Corvus caurinus*	64	0.5	−0.8	1.7	13.1	8.3	22.7	1.3	R
Common raven	*Corvus corax*	2,444	2.8	2.3	3.3	8.1	7.5	8.8	0.5	R
Horned lark	*Eremophila alpestris*	2,082	−2.2	−2.6	−1.9	36.6	33.1	40.8	0.4	R
Tree swallow	*Tachycineta bicolor*	2,899	−0.5	−0.9	−0.1	4.2	3.9	4.6	0.4	R
Violet-green swallow	*Tachycineta thalassina*	878	−0.6	−1.2	−0.1	7.7	6.4	9.4	0.6	R
Bank swallow	*Riparia riparia*	1,394	−4.0	−5.8	−2.2	7.6	5.7	11.6	1.8	R
Cliff swallow	*Petrochelidon pyrrhonota*	2,646	2.8	2.1	3.5	72.1	62.1	84.0	0.7	R
Barn swallow	*Hirundo rustica*	3,834	−1.1	−1.3	−0.9	10.8	10.4	11.2	0.2	R
Black-capped chickadee	*Poecile atricapillus*	2,197	0.8	0.4	1.2	3.9	3.7	4.2	0.4	R
Mountain chickadee	*Poecile gambeli*	521	−1.4	−2.1	−0.8	5.0	4.3	5.9	0.6	R
Chestnut-backed chickadee	*Poecile rufescens*	239	−1.1	−2.2	−0.1	7.6	5.7	10.5	1.0	R
Boreal chickadee	*Poecile hudsonicus*	437	0.7	−0.8	2.2	0.9	0.7	1.1	1.5	Q
Red-breasted nuthatch	*Sitta canadensis*	1,623	−0.6	−1.3	0.2	2.9	2.5	3.5	0.8	R
Brown creeper	*Certhia americana*	964	1.1	0.1	2.3	0.3	0.3	0.3	1.1	Q
Pacific wren	*Troglodytes pacificus*	315	0.1	−1.1	2.2	11.0	8.5	19.1	1.7	R
Winter wren	*Troglodytes hiemalis*	790	−0.5	−1.5	0.5	5.9	4.6	7.8	1.0	R
American dipper	*Cinclus mexicanus*	181	−0.1	−1.3	1.2	0.1	0.0	0.1	1.3	P
Golden-crowned kinglet	*Regulus satrapa*	1,030	0.2	−0.9	1.3	2.5	2.0	3.6	1.1	R
Ruby-crowned kinglet	*Regulus calendula*	1,142	0.4	−0.6	1.4	14.7	12.3	17.8	1.0	R
Mountain bluebird	*Sialia currucoides*	744	−0.6	−1.2	0.0	2.1	1.9	2.5	0.6	R
Townsend's solitaire	*Myadestes townsendi*	490	1.0	0.0	2.0	0.5	0.4	0.6	1.0	Q
Veery	*Catharus fuscescens*	1,257	−0.8	−1.3	−0.2	4.9	4.3	5.5	0.5	R

Table 3. Extended Continued.

1993–2014 Analysis, Core Area									Augmented Area vs. Core Area			
N	Trend	2.5% CI	97.5% CI	RA	2.5% CI RA	97.5% CI RA	Half-width	Credibility score	*N*diff	CIdiff	TrendDiff	RaDiff
2,944	−0.4	−1.0	0.0	8.1	7.4	8.9	0.5	R	7	1.0	0.0	−0.7
1,349	31.2	28.6	33.9	0.4	0.4	0.5	2.6	Q	4	1.0	0.0	0.0
3,934	0.0	−0.1	0.2	27.7	26.9	28.5	0.1	R	10	1.0	0.0	−0.4
1,945	−0.1	−0.6	0.5	0.2	0.2	0.2	0.6	Q	45	1.3	−0.1	0.0
189	1.0	−0.8	2.8	0.0	0.0	0.0	1.8	P	5	1.0	0.0	0.0
296	1.9	−1.1	5.5	0.1	0.0	0.1	3.3	P	32	0.9	−1.0	0.0
1,909	−1.4	−1.8	−0.9	1.9	1.7	2.0	0.4	R	13	1.0	0.0	−0.1
222	−0.9	−2.5	0.5	0.6	0.4	0.8	1.5	Q	3	1.8	0.2	0.0
297	−1.8	−2.5	−1.0	1.1	0.9	1.3	0.7	R	18	0.9	0.4	0.1
2,524	−1.5	−1.9	−1.0	0.2	0.2	0.3	0.5	Q	98	1.0	0.0	0.0
995	1.5	0.7	2.3	2.3	2.0	2.6	0.8	R	16	1.6	0.2	0.0
240	1.3	−0.2	2.9	1.0	0.8	1.3	1.5	Q	16	1.0	0.1	0.7
3,061	0.1	−0.1	0.4	1.0	1.0	1.1	0.3	R	54	1.0	0.0	−0.1 *
2,838	1.1	0.7	1.5	0.6	0.5	0.6	0.4	Q	78	1.0	0.0	0.0
122	4.9	2.2	7.4	0.1	0.0	0.1	2.6	P	61	1.3	−0.2	0.0
202	2.3	−1.4	4.8	0.1	0.1	0.2	3.1	P	23	1.0	0.3	0.0
2,433	1.7	1.4	2.1	1.0	0.9	1.0	0.4	Q	3	1.0	0.0	0.0
2,931	−1.2	−1.5	−0.9	0.7	0.7	0.8	0.3	Q	33	1.0	0.0	−0.1
524	3.8	2.2	5.1	0.1	0.1	0.1	1.4	P	61	1.0	−0.3	0.0
112	6.1	2.6	9.2	0.0	0.0	0.0	3.3	P	12	1.1	0.6	0.0
986	−2.7	−3.4	−2.0	0.8	0.7	0.9	0.7	Q	115	1.0	0.1	0.4 *
1,099	−1.1	−1.6	−0.6	4.6	4.1	5.2	0.5	R	78	1.1	−0.2	−0.7
405	2.8	0.5	5.1	1.3	0.9	2.0	2.3	R	58	0.7	−2.2	0.8
2,165	−1.0	−1.6	−0.2	7.2	6.4	8.4	0.7	R	152	1.0	−0.2	3.5 *
1,558	−1.8	−2.3	−1.3	5.4	4.8	6.1	0.5	R	44	1.1	−0.2	−0.8
426	0.4	−0.5	1.3	5.6	4.4	7.2	0.9	R	50	1.0	0.4	−1.5
520	−0.6	−1.7	0.5	4.7	3.7	6.2	1.1	R	4	1.0	0.0	−0.5
559	−0.6	−1.7	0.9	3.9	3.2	5.0	1.3	R	16	0.9	0.4	0.7
2,280	0.1	−0.2	0.4	1.8	1.7	1.9	0.3	R	4	1.0	0.0	−0.1
893	1.0	0.5	1.5	1.0	0.9	1.1	0.5	Q	37	1.0	0.0	−0.2 *
3,006	−1.5	−1.7	−1.2	3.5	3.3	3.7	0.2	R	4	1.0	0.0	−0.2
1,019	3.5	2.5	4.5	1.8	1.6	2.2	1.0	R	19	1.4	−0.3	0.2
2,447	1.3	1.0	1.7	5.7	5.1	6.3	0.4	R	31	1.0	0.0	−0.4
384	3.5	0.6	6.7	1.6	0.9	3.2	3.0	Q	7	1.0	0.0	−0.1
2,827	1.1	0.8	1.3	16.5	15.4	17.8	0.3	R	16	1.1	−0.2	−0.3
623	0.6	−0.7	1.9	1.7	1.3	2.3	1.3	R	132	0.8	−0.1	3.2 *
559	−0.2	−0.7	0.2	4.0	3.5	4.5	0.4	R	19	1.0	−0.1	−0.7
2,763	−0.6	−0.8	−0.5	7.2	7.0	7.4	0.1	R	15	1.0	0.0	−0.1
957	−0.1	−0.5	0.3	10.8	9.5	12.3	0.4	R	46	1.0	0.1	−2.4 *
3,682	0.0	−0.1	0.2	24.8	24.0	25.7	0.1	R	27	1.0	0.0	0.0
41	−0.1	−1.7	1.2	55.0	32.4	100.6	1.5	R	23	0.9	0.6	−41.9 *
2,279	3.0	2.5	3.5	9.0	8.3	9.8	0.5	R	165	1.0	−0.2	−0.9
2,077	−2.2	−2.6	−1.9	40.2	36.4	44.9	0.4	R	5	1.0	0.0	−3.6
2,772	−0.3	−0.7	0.0	4.7	4.4	5.1	0.4	R	127	1.0	−0.1	−0.5
800	−0.4	−1.0	0.1	10.0	8.3	12.3	0.6	R	78	1.0	−0.2	−2.4
1,310	−2.2	−3.5	−0.7	4.9	3.9	7.5	1.4	R	84	1.3	−1.8	2.7
2,585	3.0	2.4	3.8	81.7	70.4	95.3	0.7	R	61	1.0	−0.3	−9.6
3,807	−1.1	−1.3	−0.9	11.9	11.5	12.4	0.2	R	27	1.0	0.0	−1.1 *
2,090	0.8	0.5	1.2	4.8	4.5	5.1	0.4	R	107	1.0	0.0	−0.8 *
518	−1.4	−2.0	−0.8	5.9	5.0	6.9	0.6	R	3	1.0	0.0	−0.9
221	−1.6	−2.8	−0.5	6.0	4.5	8.5	1.2	R	18	0.9	0.5	1.6
314	0.6	−1.3	2.4	0.3	0.2	0.6	1.9	Q	123	0.8	0.1	0.5 *
1,546	−0.6	−1.4	0.1	3.8	3.3	4.6	0.8	R	77	1.0	0.1	−0.9
937	1.2	0.1	2.4	0.3	0.3	0.4	1.2	Q	27	1.0	−0.1	0.0
296	−0.2	−1.1	0.7	8.3	6.5	10.8	0.9	R	19	1.8	0.3	2.6
780	−0.5	−1.5	0.5	6.1	4.8	8.1	1.0	R	10	1.0	0.0	−0.2
168	0.1	−1.1	1.4	0.1	0.1	0.1	1.3	P	13	1.0	−0.2	0.0
969	0.2	−0.9	1.5	2.5	2.1	3.1	1.2	R	61	0.9	−0.1	0.0
989	0.1	−1.2	1.3	11.1	8.9	14.2	1.2	R	153	0.8	0.3	3.5
735	−0.5	−1.2	0.1	2.4	2.1	2.7	0.6	R	9	1.0	0.0	−0.2
454	1.1	0.4	1.9	0.5	0.4	0.6	0.7	Q	36	1.3	−0.1	0.0
1,254	−0.8	−1.3	−0.2	5.0	4.4	5.6	0.5	R	3	1.0	0.0	−0.1

Table 3. Continued.

		1993–2014 Analysis, Augmented Area								
Common name	**Scientific name**	***N***	**Trend**	**2.5% CI**	**97.5% CI**	**RA**	**2.5% CI RA**	**97.5% CI RA**	**Half-width**	**Credibility score**
Swainson's thrush	*Catharus ustulatus*	1,242	−0.1	−0.7	0.5	44.4	38.0	53.8	0.6	R
Hermit thrush	*Catharus guttatus*	1,560	0.3	−0.5	1.1	11.7	10.0	14.3	0.8	R
American robin	*Turdus migratorius*	3,944	0.1	−0.1	0.2	31.0	29.9	32.0	0.1	R
Varied thrush	*Ixoreus naevius*	366	−1.1	−2.2	−0.2	17.8	13.7	23.3	1.0	R
Gray catbird	*Dumetella carolinensis*	2,582	0.2	0.0	0.4	2.2	2.2	2.3	0.2	R
European starling	*Sturnus vulgaris*	3,770	−1.1	−1.3	−0.9	35.7	34.0	37.6	0.2	R
Cedar waxwing	*Bombycilla cedrorum*	2,517	0.3	−0.3	0.8	5.2	4.8	5.7	0.6	R
Ovenbird	*Seiurus aurocapilla*	1,721	−0.1	−0.5	0.3	11.3	10.2	12.6	0.4	R
Northern waterthrush	*Parkesia noveboracensis*	994	0.1	−0.9	1.1	4.6	3.8	5.5	1.0	R
Black-and-white warbler	*Mniotilta varia*	1,547	−0.9	−1.7	−0.2	2.1	1.9	2.5	0.7	R
Tennessee warbler	*Oreothlypis peregrina*	583	1.3	−1.3	4.4	21.9	13.3	41.7	2.8	R
Orange-crowned warbler	*Oreothlypis celata*	800	−0.6	−1.7	0.3	9.0	7.5	11.0	1.0	R
Nashville warbler	*Oreothlypis ruficapilla*	1,000	0.0	−0.8	0.9	12.6	10.1	15.9	0.9	R
MacGillivray's warbler	*Geothlypis tolmiei*	574	−0.7	−1.4	0.0	4.3	3.5	5.5	0.7	R
Mourning warbler	*Geothlypis philadelphia*	800	−1.0	−2.0	−0.1	5.6	4.5	7.2	1.0	R
Common yellowthroat	*Geothlypis trichas*	3,466	−0.8	−1.0	−0.6	6.7	6.4	7.0	0.2	R
American redstart	*Setophaga ruticilla*	1,764	0.0	−0.7	0.7	4.1	3.5	4.7	0.7	R
Cape May warbler	*Setophaga tigrina*	395	1.6	−1.6	5.4	1.0	0.6	2.0	3.5	Q
Magnolia warbler	*Setophaga magnolia*	856	0.9	0.0	1.9	11.6	9.4	14.4	0.9	R
Bay-breasted warbler	*Setophaga castanea*	332	1.1	−1.8	3.7	1.3	0.9	2.3	2.7	R
Blackburnian warbler	*Setophaga fusca*	685	0.4	−0.4	1.2	1.8	1.5	2.2	0.8	R
Yellow warbler	*Setophaga petechia*	3,087	0.0	−0.4	0.4	6.7	6.2	7.3	0.4	R
Blackpoll warbler	*Setophaga striata*	254	−5.2	−7.8	−3.1	4.0	2.8	6.8	2.3	R
Palm warbler	*Setophaga palmarum*	229	3.5	0.8	7.1	1.0	0.6	1.7	3.2	Q
Yellow-rumped warbler	*Setophaga coronata*	1,653	0.7	−0.1	1.6	19.6	16.7	23.6	0.9	R
Townsend's warbler	*Setophaga townsendi*	294	1.1	0.2	2.0	9.1	6.7	13.0	0.9	R
Black-throated green warbler	*Setophaga virens*	911	0.9	0.3	1.5	3.1	2.8	3.6	0.6	R
Wilson's warbler	*Cardellina pusilla*	952	−0.3	−1.3	0.8	6.2	5.0	8.0	1.1	R
Chipping sparrow	*Spizella passerina*	3,408	−0.2	−0.6	0.3	11.1	10.2	12.2	0.4	R
Clay-colored sparrow	*Spizella pallida*	756	−0.9	−1.4	−0.5	12.2	10.7	14.2	0.4	R
Brewer's sparrow	*Spizella breweri*	598	−1.7	−2.8	−0.6	17.4	13.5	23.1	1.1	R
Savannah sparrow	*Passerculus sandwichensis*	2,129	−1.2	−1.7	−0.7	18.0	15.8	20.9	0.5	R
Le Conte's sparrow	*Ammodramus leconteii*	335	−2.3	−4.1	−0.3	1.3	0.9	1.9	1.9	R
Fox sparrow	*Passerella iliaca*	523	0.7	−0.5	1.8	14.5	10.9	20.0	1.1	R
Song sparrow	*Melospiza melodia*	3,011	−1.0	−1.2	−0.8	10.8	10.3	11.2	0.2	R
Lincoln's sparrow	*Melospiza lincolnii*	894	−0.3	−1.3	0.7	7.9	6.3	10.5	1.0	R
Swamp sparrow	*Melospiza georgiana*	1,063	1.1	0.2	1.9	2.6	2.2	3.2	0.8	R
White-throated sparrow	*Zonotrichia albicollis*	980	−1.1	−1.7	−0.6	38.8	33.8	44.4	0.6	R
White-crowned sparrow	*Zonotrichia leucophrys*	547	−1.0	−2.5	0.8	29.2	21.1	49.1	1.6	R
Dark-eyed junco	*Junco hyemalis*	1,537	−0.5	−1.3	0.3	22.4	19.3	26.6	0.8	R
Western tanager	*Piranga ludoviciana*	856	1.1	0.5	1.7	7.1	6.1	8.5	0.6	R
Rose-breasted grosbeak	*Pheucticus ludovicianus*	1,517	−0.6	−1.0	−0.2	2.0	1.8	2.2	0.4	R
Bobolink	*Dolichonyx oryzivorus*	1,348	−0.7	−1.2	−0.2	5.2	4.7	5.8	0.5	R
Red-winged blackbird	*Agelaius phoeniceus*	3,946	−0.8	−1.0	−0.6	52.1	49.7	54.5	0.2	R
Rusty blackbird	*Euphagus carolinus*	204	−1.8	−4.5	0.9	0.3	0.2	0.5	2.7	Q
Common grackle	*Quiscalus quiscula*	3,097	−1.7	−1.9	−1.4	25.6	24.5	26.7	0.2	R
Brown-headed cowbird	*Molothrus ater*	3,938	−0.6	−0.8	−0.3	11.6	11.1	12.2	0.2	R
Pine grosbeak	*Pinicola enucleator*	271	−0.8	−2.8	1.3	0.5	0.3	0.7	2.1	Q
Purple finch	*Haemorhous purpureus*	1,232	−1.2	−2.0	−0.5	1.3	1.1	1.5	0.8	R
Red crossbill	*Loxia curvirostra*	685	0.7	−1.6	3.4	4.1	2.9	6.3	2.5	R
White-winged crossbill	*Loxia leucoptera*	447	4.1	−6.1	10.7	16.9	7.6	59.8	8.4	P
Pine siskin	*Spinus pinus*	1,261	−5.1	−6.8	−3.7	7.9	6.2	10.8	1.6	R
American goldfinch	*Spinus tristis*	3,037	0.1	−0.1	0.3	6.7	6.4	7.0	0.2	R
Evening grosbeak	*Coccothraustes vespertinus*	849	−6.2	−7.6	−4.8	1.5	1.1	1.9	1.4	R
House sparrow	*Passer domesticus*	3,328	−3.4	−3.6	−3.2	25.5	24.1	27.1	0.2	R

[a] The "Trail's" flycatcher and "Western" flycatcher analyses result from the lumping of data from currently recognized species with overlapping ranges that were not recognized as distinct species when the BBS survey began.

Table 3. Extended Continued.

1993–2014 Analysis, Core Area									Augmented Area vs. Core Area			
N	Trend	2.5% CI	97.5% CI	RA	2.5% CI RA	97.5% CI RA	Half-width	Credibility score	*N*diff	CIdiff	TrendDiff	RaDiff
1,092	−0.7	−1.4	−0.2	28.7	24.3	35.1	0.6	R	150	1.0	0.7	15.8 *
1,418	0.0	−0.8	0.8	9.4	7.9	11.5	0.8	R	142	1.0	0.3	2.3
3,774	0.1	−0.1	0.2	32.2	31.2	33.3	0.1	R	170	1.2	0.0	−1.2
244	−3.5	−4.7	−2.3	5.2	3.9	7.3	1.2	R	122	0.8	2.5 *	12.6 *
2,575	0.2	0.0	0.4	2.3	2.2	2.4	0.2	R	7	1.0	0.0	0.0
3,750	−1.1	−1.4	−1.0	36.6	34.8	38.5	0.2	R	20	1.0	0.0	−0.9
2,496	0.3	−0.3	0.8	5.6	5.2	6.2	0.5	R	21	1.0	0.0	−0.4
1,706	−0.1	−0.5	0.3	11.5	10.3	12.9	0.4	R	15	1.0	0.0	−0.2
850	1.1	0.1	2.3	2.3	1.8	2.9	1.1	R	144	0.9	−1.0	2.3 *
1,516	−0.8	−1.6	−0.2	2.0	1.8	2.4	0.7	R	31	1.1	−0.1	0.1
531	0.7	−1.4	2.7	11.2	7.9	16.8	2.0	R	52	1.4	0.7	10.7
665	−0.9	−1.8	0.0	3.4	2.8	4.2	0.9	R	135	1.1	0.3	5.6 *
996	0.0	−0.8	0.9	13.0	10.5	16.5	0.9	R	4	1.0	0.0	−0.4
558	−0.7	−1.4	0.0	5.1	4.2	6.5	0.7	R	16	1.0	0.0	−0.8
780	−0.9	−1.9	0.1	5.6	4.5	7.3	1.0	R	20	1.0	−0.1	0.0
3,388	−0.9	−1.1	−0.7	7.6	7.3	8.0	0.2	R	78	1.0	0.1	−1.0 *
1,727	0.1	−0.5	0.8	4.3	3.8	5.1	0.6	R	37	1.1	−0.1	−0.2
384	0.7	−2.0	4.5	0.7	0.5	1.2	3.2	Q	11	1.1	0.8	0.3
827	1.1	0.2	2.1	11.6	9.4	14.6	1.0	R	29	1.0	−0.2	0.0
325	0.8	−2.1	3.4	1.6	1.0	2.8	2.8	R	7	1.0	0.3	−0.2
683	0.4	−0.4	1.2	1.9	1.6	2.3	0.8	R	2	1.0	0.0	−0.1
2,923	−0.4	−0.7	−0.1	6.2	5.8	6.8	0.3	R	164	1.5	0.4	0.5
131	−4.3	−11.7	3.8	0.7	0.3	4.0	7.8	P	123	0.3	−0.9	3.3
210	2.6	0.0	5.3	0.5	0.3	0.8	2.7	Q	19	1.2	1.0	0.5
1,501	0.3	−0.4	0.9	10.2	9.0	11.7	0.6	R	152	1.3	0.5	9.3 *
234	−0.2	−1.0	0.5	9.6	6.9	13.8	0.8	R	60	1.2	1.3	−0.5
890	0.9	0.3	1.5	3.0	2.6	3.5	0.6	R	21	1.0	0.0	0.1
790	−1.5	−2.3	−0.6	1.6	1.4	2.0	0.8	R	162	1.2	1.2	4.6 *
3,326	−0.2	−0.5	0.0	10.8	10.2	11.6	0.3	R	82	1.7	0.1	0.2
752	−0.9	−1.4	−0.5	13.1	11.5	15.3	0.4	R	4	1.0	0.0	−1.0
595	−1.7	−2.8	−0.6	19.9	15.4	26.6	1.1	R	3	1.0	0.0	−2.5
1,986	−1.4	−1.8	−1.1	17.5	15.6	19.6	0.4	R	143	1.4	0.2	0.6
332	−2.7	−4.6	−0.8	1.3	1.0	2.0	1.9	R	3	1.0	0.4	−0.1
362	−1.0	−4.6	1.6	1.4	1.1	2.5	3.1	Q	161	0.4	1.6	13.0 *
2,953	−1.0	−1.2	−0.9	13.3	12.7	13.9	0.2	R	58	1.2	0.0	−2.5 *
749	−0.8	−1.8	0.4	5.9	4.7	8.5	1.1	R	145	0.9	0.5	2.0
1,032	1.5	0.7	2.3	2.2	1.9	2.7	0.8	R	31	1.1	−0.4	0.4
934	−0.9	−1.3	−0.4	40.0	35.1	45.8	0.5	R	46	1.2	−0.3	−1.2
419	−0.1	−1.8	1.7	4.3	3.3	7.5	1.8	R	128	0.9	−0.9	24.9 *
1,386	−0.8	−1.4	0.0	9.7	8.5	11.3	0.7	R	151	1.1	0.2	12.7 *
838	1.4	1.0	1.8	7.3	6.4	8.4	0.4	R	18	1.6	−0.2	−0.2
1,511	−0.6	−1.0	−0.2	2.2	2.0	2.4	0.4	R	6	1.0	0.0	−0.2
1,346	−0.7	−1.2	−0.2	5.3	4.8	5.9	0.5	R	2	1.0	0.0	−0.1
3,911	−0.8	−1.0	−0.6	60.4	57.6	63.2	0.2	R	35	1.0	0.0	−8.2 *
127	−3.7	−6.8	0.7	0.1	0.0	0.2	3.8	P	77	0.7	1.9	0.2 *
3,086	−1.7	−1.9	−1.4	27.5	26.3	28.7	0.2	R	11	1.0	0.0	−1.9
3,934	−0.6	−0.8	−0.3	12.2	11.7	12.7	0.2	R	4	1.0	0.0	−0.5
167	−0.4	−3.8	3.4	0.1	0.1	0.5	3.6	Q	104	0.6	−0.5	0.3
1,191	−1.1	−1.9	−0.5	1.4	1.3	1.6	0.7	R	41	1.1	0.0	−0.2
649	0.1	−2.0	2.8	4.6	3.3	6.7	2.4	R	36	1.0	0.6	−0.5
322	2.6	−4.9	9.2	4.5	2.0	24.7	7.1	P	125	1.2	1.4	12.3
1,158	−5.2	−6.7	−3.7	7.8	6.0	11.0	1.5	R	103	1.0	0.1	0.1
3,019	0.1	−0.2	0.3	6.8	6.5	7.1	0.2	R	18	1.0	0.0	−0.1
844	−6.2	−7.6	−4.8	1.5	1.2	2.0	1.4	R	5	1.0	0.0	0.0
3,314	−3.4	−3.6	−3.2	25.8	24.4	27.4	0.2	R	14	1.0	0.0	−0.3

We note that our analysis of "new" areas and species is in the context of species currently analyzed in the Sauer et al. (2014) website. However, BBS data for all species has always been freely available for all to use, and many investigators use BBS data for a variety of analyses of species and regions not contained in Sauer et al. (2014). The analyses presented here provide a path forward for expanding the comprehensive, continent-scale analysis of BBS data provided in Sauer et al. (2014). Sauer and Link (2011) provided a basis for implementing hierarchical models in yearly summaries of the BBS (Sauer et al. 2014); therefore, this work provides a basis for adding in additional regions and species for future BBS analysis. In our view, the augmented survey-area analysis is a useful innovation for summary of BBS data. It permits the incorporation of new regions and species into the survey and, even with the obvious limitations of data from largely roadless areas with a low density of coverage, helps to fulfill the original vision of the BBS as a continental-scale survey. It provides a means for routine summary of Alaska results, and provides results for Alaskan and other boreal species within the context of the full survey area. Further, the analysis approach also can form the basis for incorporation of additional strata in Mexico when sufficient data accrue from survey expansion efforts in Mexico.

As with all BBS analyses, alternative approaches exist to both spatial structuring and the statistical models used in this analysis. Our analysis differs from Sauer et al. (2014) analyses in that more hierarchical structure is employed in the model (for slope and stratum effects), and we chose a minimum sample size of species occurring on $\geq$3 routes in a stratum for inclusion of the stratum in the analysis. We chose to impose more hierarchical structure to accommodate the expected lack of precision in the new strata; the hierarchical structure allowed better estimation for strata with small sample sizes. Smith et al. (2014) used a model similar to that of Sauer et al. (2014), although they let the variances of the route/observer effects vary among strata. A variety of alternative models provide generally similar results from BBS analyses; choosing among models with complex hierarchical structures is difficult (Link and Sauer 2016). To refine our view of appropriate hierarchical structure for future BBS analysis, we will be applying cross-validation procedures developed in Link and Sauer (2016); limited implementation of cross-validation procedures suggest that a model not including separate variances of route-observer effects outperforms a model containing these effects.

Supplemental Material

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Table S1. Species we considered for analysis of population change. These species have been detected on BBS routes but were not analyzed in Sauer et al. (2014). We group the species into 3 categories: 1) species that meet the criterion we used for inclusion in additional analysis (observed on at least 3 BBS routes in a single stratum); 2) species with $\geq$3 observations on routes, but not meeting the inclusion criterion of $\geq$3 routes in a single stratum; and 3) species found on $<$3 BBS routes. Species names follow Chesser et al. (2014).

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Table S2. Population change estimates for 176 species encountered on BBS routes in Alaska. Analysis is based on log-linear hierarchical models; trend is defined as the change in annual indexes over a specified time period (Sauer et al. 2013). For each species, we present sample size (number of routes, *N*), trend estimate (% change/yr, 1993–2014), 2.5% and 97.5% credible intervals (CI) for trend, relative abundance (RA, defined as the annual index in the midyear of the interval) and 2.5% and 97.5% CIs for relative abundance, half-width of the CIs for trend, and a credibility score (R = reasonably monitored, Q = questionably monitored [estimates have $\geq$1 deficiency]), and P = poorly monitored (Sauer et al. 2014). Values $<$0.1 are indicated as 0.0. Species not included in previous BBS analyses are indicated with "8" in column "New."

Found at DOI: http://dx.doi.org/10.3996/102015-JFWM-109.S2 (28 KB XLSX).

Reference S1. Droege S, Sauer JR. 1989. North American Breeding Bird Survey annual summary 1988. U.S. Fish and Wildlife Service, Biological Report 89:1–16.

Found at DOI: http://dx.doi.org/10.3996/102015-JFWM-109.S3 (1306 KB PDF).

Reference S2. Robbins CS, Bystrak D, Geissler PH. 1986. The Breeding Bird Survey: Its first fifteen years, 1965–1979. U.S. Fish and Wildlife Service, Resource Publication 157.

Found at DOI: http://dx.doi.org/10.3996/102015-JFWM-109.S4 (10757 KB PDF).

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