USE OF NORTH AMERICAN BREEDING BIRD SURVEY DATA TO ESTIMATE POPULATION CHANGE FOR BIRD CONSERVATION REGIONS

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Abstract: Conservation planning requires information at a variety of geographic scales, and it is often unclear whether surveys designed for other purposes will provide appropriate information for management at various scales. We evaluated the use of the North American Breeding Bird Survey (BBS) to meet information needs for conservation planning in Bird Conservation Regions (BCRs). The BBS originally was developed to provide regional estimates for states, provinces, physiographic regions, and larger areas. Many analyses have used physiographic regions within states/provinces as strata. We evaluated potential consequences of using BCRs instead of the BBS physiographic regions, testing for spatial differences in sample intensity within states and provinces. We reclassified the BBS survey routes to BCRs and conducted route regression trend (interval-specific population change) analyses for a variety of regions and time intervals. Our results were similar to those based on traditional BBS regions and suggest minimal consequences of the reclassification for the BBS sample. We summarized population change within BCRs and assessed the efficiency of the BBS in estimating population change for 421 species surveyed. As would be expected from an omnibus survey, many species appeared to be poorly monitored by the BBS, with 42% of species encountered at <1 bird/route from the survey, and 28% of trend estimates too imprecise to detect a 3%/year change over 35 years. Our results indicated that the quality of the survey for estimation of population change varied among BCRs. Population trends of species were heterogeneous over space and time, varying among BCRs for 76% of species and over time for 39% of species. Regional heterogeneity also existed in trends of species groups from the BBS. While 49% of all species in the survey had increasing populations, grassland breeding birds showed consistent declines, with only 18% of species having positive trend estimates. Bird conservation regions appear to provide reasonable strata for summary of BBS data.

JOURNAL OF WILDLIFE MANAGEMENT 67(2):372–389

Key words: monitoring, North American Bird Conservation Initiative, North American Breeding Bird Survey, surveys, trends, wildlife.

The BBS is the primary source of information on population change and relative abundance for many North American bird species. For most species, the BBS is the only source of population information. Although questions exist about the sample frame and data collection methods of the survey (e.g., Link and Sauer 1997), survey results are used in a variety of conservation activities. These include setting mourning dove (*Zenaida macroura*) harvest regulations (Sauer et al. 1994; D. D. Dolton, U.S. Fish and Wildlife Service, personal communication) and developing management plans for regional conservation initiatives such as Partners in Flight (PIF; Carter et al. 2000).

Often, management initiatives create needs for information at scales not originally considered in the development of the BBS. The North American Bird Conservation Initiative (NABCI) was developed to provide a framework for conservation of all North American birds and to integrate efforts of existing bird conservation initiatives such as the North American Waterfowl Management Plan (NAWMP), PIF, and plans for shorebird and colonial waterbirds. Each plan defined regions for management coordination and implementation. Because the original spatial scales within the plans differed, a common set of ecological units was developed for North America to impose a consistent geographic framework for management plans in NABCI. Bird Conservation Regions were developed for regional avian conservation by a team of migratory bird biologists from Canada, the United States, and Mexico with experience in strategic planning.

Several widely utilized ecoregions were considered as possible templates for the BCR framework prior to the mapping team adopting the Commission for Environmental Cooperation (CEC) ecoregions covering North America (CEC 1997). These ecoregions are comprised of a 4-level hierarchy of ecological units, with Level I

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regions being the largest and most general. The mapping team developed draft BCRs by mixing Level II–IV ecoregion boundaries to delineate regions reflecting best expert opinion about relative homogeneity of bird communities, habitats, and resource management issues. In Canada and the United States, comments on draft BCRs were solicited from over 2,000 resource managers in federal, state, and nongovernment agencies (U.S. Fish and Wildlife Service and International Association of Fish and Wildlife Agencies, unpublished memorandum). Bird conservation region boundaries were subsequently modified to reflect this input. Bird conservation regions have been endorsed by NABCI, the NAWMP, PIF, U.S. Shorebird Conservation Plan, and North American Colonial Waterbird Conservation Plan as the geographic standard for integrated bird conservation planning, delivery, and evaluation (Fig. 1). In principle, these units will replace or complement units presently used for management, such as the PIF physiographic regions, the Bystrak (1981) regions traditionally used for the BBS, and the NAWMP planning regions for Joint Ventures.

Implementing bird conservation plans within these regions will require extensive information about birds (estimates of abundance, population change, survival, and productivity), habitat availability and change, and bird-habitat interactions for each region. Unfortunately, much of this information does not presently exist, and existing surveys were not developed to support monitoring or conservation planning at the scale of BCRs. Developing methods for summary of information at the scale of BCRs is an important research need. Many surveys are presently analyzed using alternative physiographic regions as strata, making it necessary to carefully evaluate the potential consequences of adopting new strata for estimation. Estimation in sample surveys depends on the ability to calculate the probability that a sample unit will be selected (Cochran 1977). In particular, if samples in a survey were originally allocated within strata, the original strata define these probabilities of selection, and any future use of the survey data must retain these selection probabilities. Simple reallocation of sample sites to the new units could undermine the credibility of the sample, as the sites may not form a probabilistic sample under the new strata (Cochran 1977).

We evaluated the consequences of using the BCRs as strata for estimation of population change using the BBS and estimated and summarized population change from BBS data for BCRs for the intervals 1966–2000, 1966–1979, and 1980–2000. To verify consistency with earlier results, we compared analyses based on the BCR-based analysis to results based on the Bystrak (1981) strata. To provide population managers with information on the survey results within BCRs, we evaluated several aspects of survey efficiency such as precision of estimates, sample sizes, and estimated abundance in BCRs. Finally, we evaluated consistency of change by species over time and BCRs.

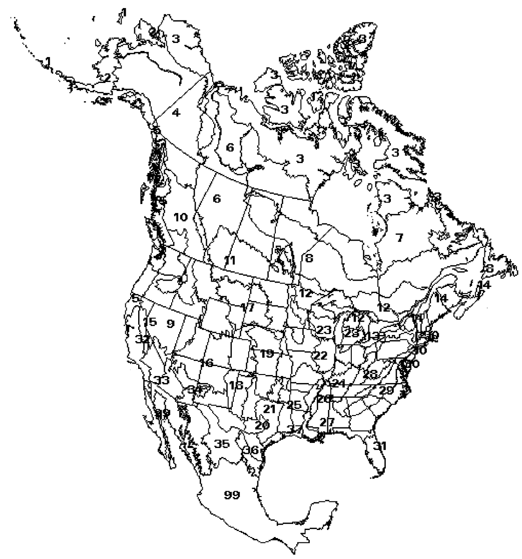

Fig. 1. Map of Bird Conservation Regions (BCR) for strata containing North American Breeding Bird Survey data. Names of each BCR are: 1 Aleutian/Bering Sea Islands, 2 Western Alaska, 3 Arctic Plains and Mountains, 4 Northwestern Interior Forest, 5 Northern Pacific Rainforest, 6 Boreal Taiga Plains, 7 Taiga Shield and Hudson Plains, 8 Boreal Softwood Shield, 9 Great Basin, 10 Northern Rockies, 11 Prairie Potholes, 12 Boreal Hardwood Transition, 13 Lower Great Lakes/St. Lawrence Plain, 14 Atlantic Northern Forest, 15 Sierra Nevada, 16 Southern Rockies/Colorado Plateau, 17 Badlands and Prairies, 18 Shortgrass Prairie, 19 Central Mixed Grass Prairie, 20 Edwards Plateau, 21 Oaks and Prairies, 22 Eastern Tallgrass Prairie, 23 Prairie Hardwood Transition, 24 Central Hardwoods, 25 West Gulf Coastal Plain/Ouachitas, 26 Mississippi Alluvial Valley, 27 Southeastern Coastal Plain, 28 Appalachian Mountains, 29 Piedmont, 30 New England/Mid-Atlantic Coast, 31 Peninsular Florida, 32 Coastal California, 33 Sonoran and Mojave Deserts, 34 Sierra Madre Occidental, 35 Chihuahuan Desert, 36 Tamaulipan Brushlands, and 37 Gulf Coastal Prairie.

METHODS

Strata and the North American Breeding Bird Survey

The BBS was initiated in 1966 in the eastern United States, and survey routes were established across the continental United States and southern Canada by 1968. New survey routes are established each year, and the BBS now includes Alaska and parts of northern Canada. The BBS is a roadside survey, conducted by volunteers in late May–early July, and coordinated by the U.S. Geological Survey and the Canadian Wildlife Service. Routes are 39.4 km long and consist of 50 evenly spaced, 3-min point counts of birds along the roadside transect. All birds heard and seen within 400 m of the point are recorded, and the sum of the counts over the 50 stops is used as the index to bird abundance along the route. The BBS database now contains >4,000 survey routes.

Because bird species assemblages and abundances tend to differ among physiographic regions, Bystrak (1981; see map in Butcher [1990] that reflects revisions in 1989 by D. Bystrak and S. Droege, USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA) developed a series of physiographic regions to be used as strata for summary of population attributes. These "Bystrak strata" were developed after the BBS began, hence sample allocations were not based on the strata but instead are quasi-systematic, with starting points randomly located within degree blocks of latitude and longitude. Originally, the number of routes placed within degree blocks varied regionally, from 4 to 8 routes/degree block in the eastern United States to 1 route/block in the western United States and southern Canada. Additional routes have been added throughout the survey area in recent years (Bystrak 1981). However, after strata were defined (ca. 1980; Bystrak 1981), additional routes were constrained not to cross stratum boundaries (D. Bystrak, USGS Patuxent Wildlife Research Center, personal communication).

When considered within states and provinces, the Bystrak strata have provided a convenient spatial structure for regional summaries. To allow estimation of population attributes at a variety of geographic scales, the BBS has been analyzed by state-stratum areas defined as the intersection of Bystrak strata and states and provinces (Geissler and Sauer 1990). These state-strata can be aggregated into states or provinces, Bystrak strata, or larger regions. They also partition the sample into units with relatively consistent route concentrations, accommodating the regional variation in number of routes/degree block. Simple aggregations of routes over space (e.g., an entire Bystrak stratum) would cause routes from different states with widely different selection probabilities to be averaged without regard to their selection probabilities, leading to biased estimates (Cochran 1977:115–149, Peterjohn et al. 1995).

However, whether the selection probabilities differ by stratum within states and provinces is unclear. Although the strata were developed after the initial routes were selected, the strata have existed for >20 years, and placement of newly developed routes may have been influenced by the strata locations (e.g., through avoidance of stratum crossing). Although not an issue when using the Bystrak strata, the possibility that new strata may require weighting to accommodate variation in selection probabilities is important to consider. If selection probabilities do not differ by stratum within states or provinces, then estimation for new regions can be accomplished simply by reclassifying routes into the new regions and using these new regions as strata within states/provinces without regard to the initial strata.

Allocation of BBS Routes into Bird Conservation Regions

We used a Geographic Information System (ARCINFO; Environmental Systems Research Institute [ESRI] 1998) to characterize the BCR for each route. An ARCINFO polygon coverage was developed for BCRs in North America. Geographic information exists in several forms for BBS routes. The paths of routes that were in the active survey database in 1997 in the continental United States have been digitized as part of the U.S. Geological Survey Electronic National Atlas Project (http://www.usgs.gov/atlas/, metadata at http://www.nationalatlas.gov/birdmt.html). Canadian routes also have been digitized (R. Bradshaw, Canadian Wildlife Service, personal communication). Finally, routes that are no longer surveyed, newly initiated routes, and routes in Alaska were characterized by the latitude and longitude of their starting points. We overlaid BBS route geographic data on the BCR coverage and assigned BBS routes to the BCR that either (1) contained the largest part of their length (for routes with digitized route paths), or (2) contained the starting point of the route (for routes with only starting point information). We also determined whether routes were influenced by >1 contiguous BCR, by documenting (1) whether a route path fell into >1 BCR, or (2) whether the starting point of a survey route was within 39.4 km of a BCR boundary. These "buffer" routes may not accurately characterize bird populations specific to a single BCR. Route assignments based on starting points were verified by the BBS coordinator, resulting in reclassification of 22 routes.

Analysis of Sampling Design

A primary concern in the analysis is that the new categorization of BBS routes would change the selection probabilities of routes. This would occur if routes were allocated at differing probabilities within states and provinces in conjunction with the Bystrak strata, and if use of BCR as strata changed the weightings on the routes in the analysis. We tested for this within states and provinces by conducting chi-square analyses using information from the Bystrak (1981) strata. For each state or province, we estimated expected values for the total number of routes in each Bystrak stratum assuming allocation proportional to stratum area within the state or province, aggregating areas when needed so that minimum expected values were generally >5 routes. By testing these expected values against observed number of routes, we determined whether any Bystrak stratum within the state or province had a disproportionate number of routes. Rejecting the null hypothesis of number of routes proportional to area indicated the need for caution in regrouping the BBS routes into BCR strata for analysis, unless the BCR strata are similar to the original strata and hence retain the differing sample intensity in the original strata.

Analysis of Population Change Within Strata

We estimated trends (interval-specific estimates of population change) by BCR, using the modified route regression methods described by Link and Sauer (1994). We used a poisson regression, with covariates to accommodate observer differences, to estimate a trend over the interval of interest on each survey route. We then estimated regional trends as a weighted average of the route trends, with weights of abundance, precision of estimation, and an area weight to accommodate differences in selection probabilities among regions. Poisson regression generally provides results similar to those of alternative procedures such as LOESS smooths (James et al. 1996, Link and Sauer 1997). Variances are estimated using bootstrapping of route-specific trends.

We estimated trends by stratum for all species in the BBS for 3 intervals: 1966–2000; 1966–1979, and 1980–2000. We adopted the convention of referring to the starting date of the BBS as 1966, although regional variation exists in starting dates. The BBS started in the central United States in 1967, and in the western United States and much of Canada, no routes were initiated prior to 1968.

We analyzed data from 421 species. Due to taxonomic changes, we combined some species for analysis. In particular, western grebes and Clark's grebe were combined; great blue heron includes great white heron and Wurdemann's heron; mallard includes Mexican duck; red-tailed hawk includes Harlan's hawk; yellow-bellied sapsucker complex includes data for yellow-bellied, red-breasted, red-naped, and unknown sapsuckers; northern flicker includes yellow-shafted, red-shafted, and unknown flickers; willow/alder flycatcher data are lumped; "western flycatcher" includes data for pacificslope and cordilleran flycatchers as well as unknown westerntype flycatchers; tufted titmouse includes blackcrested titmouse; yellowrumped warbler includes myrtle, Audubon's and unidentified myrtle/Audubon's warblers; and darkeyed junco includes slatecolored, whitewinged, Oregon, pinksided, grayheaded, and unidentified darkeyed juncos.

We assessed heterogeneity in trend estimates over space and time. A trend estimate is a single number that expresses an interval-specific measure of change. This high level of abstraction of the time series often is useful for management in a specific context but generally is not informative in describing spatial and temporal heterogeneity within the region (e.g., James et al. 1996). To document this heterogeneity, it is useful to estimate trends at more local geographic scales (such as BCRs) and for subintervals of time (e.g, 1966–1979 and 1980–2000), and test for differences among these estimates. We used Z-tests to evaluate whether temporal heterogeneity exists by species in trends estimated at the survey-wide scale. We used a chi-square test (Sauer and Williams 1989) to test for spatial heterogeneity among estimates for each species among BCRs in long-term (1966–2000) trends. Significant differences in trends between the time intervals or among BCRs suggest that the population has not experienced a consistent trend over time or space, and hence the long-term trend may be limited as a predictor of future population change. However, the long-term estimate is still valuable as a summary measure of change over the interval regardless of the consistency of change within the subinterval. As in other analyses (Sauer and Droege 1992), we did not provide results for regions that are poorly sampled over the survey period, such as northern Canada and Alaska. These areas comprise portions of BCRs 1–4 and 7 (Fig. 1).

Comparison with "Traditional" Analyses Based on Bystrak Regions

To document the consistency of the BCR-based analysis with earlier analyses, we conducted an analysis using the traditional Bystrak (1981) regions within states or provinces as strata. This analysis was conducted using the same procedures as the BCR analysis, but retaining the original strata definition. Analysis using the Bystrak strata does not contain information from the Open Boreal Forest, Tundra, or parts of the Closed Boreal Forest Strata, and excludes Alaska, Newfoundland, and Yukon due to sparse samples and poor coverage.

As a general measure of consistency between the analyses, we calculated *Z*-statistics based on the differences between estimated trends using BCR and Bystrak strata at the level of states and surveywide. This test is only used as a standardized measure of the consequences of the change in strata, and is not a comparison of 2 independent quantities. To assess the relative efficiency of the alternative strata, we conducted a paired *t*-test of estimated variances of surveywide trends from the 2 methods. For each species, we subtracted the variance estimated using the Bystrak stratum definition from the variance estimated using the BCR stratum definition, and tested the null hypothesis that the mean difference among species equaled zero.

Survey Efficiency of the BBS Within BCRs

Summary analyses of BBS data are complicated by large differences over space and time in both abundances of local populations and quality of survey information. The BBS often produces inefficient estimates (i.e., with large variances) based on small samples, and often these estimates are marked during analyses to indicate results that are of low quality. We analyzed population trends by BCR to determine limitations of the survey with regard to 3 deficiencies:

Sample Size.—A considerable folklore exists about what constitutes a reasonable sample size of survey routes for a BBS analysis. W. A. Link (USGS Patuxent Wildlife Research Center, personal communication) suggested using a cutoff of 14 routes as a minimum sample, based on a criterion that samples <14 are likely to have <85% confidence that the variance estimate is within 50% of the true value. Fourteen has been used as a cutoff for minimum samples in several analyses (e.g., Carter et al. 2000). Of course, any criterion is arbitrary, and often smaller samples are considered in summary analysis. We identified species seen on <14 routes and further marked species seen on <5 routes to indicate species with very small samples.

Low Abundances.—Low relative abundances traditionally have been viewed as a cause for concern in BBS analyses. Abundance is estimated as birds/survey route, and regional abundances are estimated as means on routes, averaged among routes in the state-physiographic regions, then area-weighted among regions to obtain overall means. Because counts on BBS routes are not censuses, abundance estimates from BBS routes are actually relative abundances, and caution must be used in comparative analyses of these "abundances" (Link and Sauer 1998*a*). Regression-based procedures, in which an arbitrary constant is added to counts before taking logs for analysis, are by necessity greatly influenced by low abundances, as the constant scales the data (e.g., Link and Sauer 1998*b*). Poisson regression does not have this technical deficiency, but low abundances still may reflect problems with survey results for the species. Species with very low abundances are either rare or locally distributed (a population attribute), or simply poorly observed (a count deficiency). Many low abundance species tend to be associated with habitats poorly represented along roadsides, indicating that BBS counts may reflect accidental observations of individuals. We indicated abundance as low (<1 bird/route) and very low (<0.1 birds/route).

Precision of Estimates.—Estimated variances of trends provide the most direct measure of survey efficiency. If estimates are too imprecise to allow us to make statements about population change, the survey will be of little use for management. We provided confidence intervals of trend estimates as a measure of the present survey efficiency. To provide some insights into future survey planning, we provided 2 effect-size-based estimates of survey precision. We determined whether the estimates are sufficiently precise to detect 3%/year changes over a 35-year interval (i.e., if the confidence interval associated with the estimated variance and a hypothetical estimated trend of 3%/yr overlaps zero) or if the estimates are sufficiently precise to detect a 5% change over the interval.

Estimation of Relative Efficiency

We used a measure of route-specific precision that depends only on years of survey and covariate (observer) data to provide regional summaries of relative efficiency. Variances of linear-regression-trend estimates are the product of 2 parts: (1) a mean-squared error and (2) an additional component proportional to the number of years and covariates in the analysis. Geissler and Sauer (1990) suggested that this second component (the element from the $X'X^{-1}$ matrix corresponding to the slope estimate) be used as a relative measure of precision for BBS routes because it summarizes years of coverage and observer data into a single number. We will denote the inverse of this the "precision weight," as it is often used in analyses to reflect relative precision (e.g., Geissler and Sauer 1990). This number is larger for routes with fewer observers (and hence covariates) and more years of data. The largest value is obtained for an interval when the route is surveyed for all years and a single observer conducts all surveys. Over the 35 years of the BBS, only 8 survey routes were surveyed in all years by a single observer. Consequently, dividing the relative precision calculated for each route by this "best possible" relative precision provides a measure of relative efficiency of survey on routes, documenting the proportional loss of information associated with missing years and observer changes on the routes. We estimated the mean scaled relative precision by BCR, as well as the mean number of years routes were run in the region.

Summary of Species Results

Providing coherent summaries of BBS data generally is difficult. Often, a species group approach is used, in which summaries are calculated for a collection of species that share a common characteristic believed to influence their population change. Data from BBS often are summarized into 12 groups based on breeding habitat (Grassland, Wetland/Open Water, Successional/Scrub, Woodland, and Urban habitats), nest type (Cavity, Open-cup [passerines and cuckoos]), migration (Short-distance, Permanent Resident, and Neotropical), and nest location (Ground/low [passerines and cuckoos], Mid-story/Canopy [passerines]). Peterjohn and Sauer (1993) and Sauer et al. (1997) summarized lists of the species in these groups. The idea of grouping species for analysis has been criticized (Mannan et al. 1984). However, obvious associations exist between population changes of some groups and important demographic events (such as severe weather effects on short-distance migrants; Sauer et al. 1997). Further, a majority of species in some groups appear to be declining in population (such as Grassland and Scrub nesting birds; Peterjohn et al. 1999), suggesting that the groupings may have some use for management.

For each of these species groups, we calculated summaries of proportions of bird species in each BCR and surveywide for which BBS data contain sample size, abundance, and precision deficiencies. We also calculated the proportion of species with positive trends for each species group surveywide, based on the Link and Sauer (1994) procedure.

RESULTS

Tests of Homogeneity of Route Densities Among Strata Within States

Very few regions showed heterogeneity in densities of survey routes over space. The test of homogeneity was significant ($P < 0.05$) for several regions: Alaska ($\chi^2 = 109.67$, df = 3; too few routes in the tundra, too many routes in the Northern Pacific Rainforests); California ($\chi^2 = 21.18$, df = 9; too few routes in the Mohave Desert, too many routes in the Los Angeles Ranges); Newfoundland ($\chi^2 = 5.153$, df = 1); Ontario ($\chi^2 = 163.8$, df = 3; too many routes in Great Lakes Plain and the St. Lawrence River Plain, too few routes in the Closed Boreal Forest); and Quebec ($\chi^2 = 137.2$, df = 2; too many routes in the Northern Spruce-hardwoods and the St. Lawrence River Plain, too few routes in the Closed Boreal Forest). The roadless and low population areas of northern Canada and Alaska traditionally have been poorly covered by the BBS and traditionally have been excluded from BBS analyses. We excluded these regions when calculating the pooled chi-square test for the overall hypothesis of heterogeneity among all regions, which was not significant (122.7, df = 145, $P = 0.9$).

The chi-square tests provided little evidence of heterogeneity over space in densities of survey routes and suggested that replacing the existing strata with BCRs will have little effect on the analysis. The results from Alaska, Ontario, and Quebec were expected, since the northern parts of Canada and Alaska are poorly accessed by roads. Bystrak strata and BCRs partition the northern parts of Ontario and Quebec in similar ways, indicating that replacing the Bystrak strata with the BCRs should preserve the selection probabilities associated with routes in that region. In the Continental United States, only California shows significant areas of lower (Mohave Desert) and higher (Los Angeles Ranges) densities of

Table 1. Number of North American breeding bird survey routes that were classified based on route path information (Route Path), number of routes falling in buffer areas near edges of regions (Buffer Routes), and total number of routes (*n*) for each Bird Conservation Region (BCR).

BCR	Buffer Routes	Route Path	*n*
Aleutian/Bering Sea Islands	0	0	1
Western Alaska	5	0	21
Arctic Plains and Mountains	0	0	4
Northwestern Interior Forest	20	35	100
Northern Pacific Rainforest	19	134	179
Boreal Taiga Plains	13	99	106
Taiga Shield and Hudson Plains	0	9	9
Boreal Softwood Shield	7	69	74
Great Basin	31	236	256
Northern Rockies	19	234	250
Prairie Potholes	34	238	252
Boreal Hardwood Transition	21	229	235
Lower Great Lakes/St. Lawrence Plain	50	155	168
Atlantic Northern Forest	18	228	242
Sierra Nevada	8	34	36
Southern Rockies/Colorado Plateau	36	180	215
Badlands and Prairies	12	105	114
Shortgrass Prairie	15	110	117
Central Mixed Grass Prairie	19	94	99
Edwards Plateau	3	16	18
Oaks and Prairies	17	57	65
Eastern Tallgrass Prairie	33	199	223
Prairie Hardwood Transition	21	123	130
Central Hardwoods	14	118	128
West Gulf Coastal Plain/Ouachitas	14	68	83
Mississippi Alluvial Valley	19	40	50
Southeastern Coastal Plain	15	234	268
Appalachian Mountains	44	331	371
Piedmont	38	110	130
New England/MidAtlantic Coast	20	113	135
Peninsular Florida	3	57	69
Coastal California	19	97	104
Sonoran and Mojave Deserts	6	69	77
Sierra Madre Occidental	9	32	35
Chihuahuan Desert	5	40	45
Tamaulipan Brushlands	3	21	23
Gulf Coastal Prairie	13	22	34

routes. The Mohave and Sonoran Deserts stratum is maintained in BCRs, and when the test for homogeneity was calculated based on BCRs in California, the test approached significance (χ^2 = 8.2, df = 4, $P < 0.085$).

Reallocation of BBS Routes into BCR

We classified BCR locations of 4,469 BBS routes that had been surveyed at least 1 time during 1966–2000, omitting from the analysis 361 routes that had never been surveyed. Path information was available for 3,937 of these routes, and remaining routes were classified by starting-point locations. Six hundred and twenty-three routes were close to or crossed BCR boundaries. We found that number of routes classified, number with digitized route path data, and number of routes near BCR boundaries varied greatly among strata, reflecting the regional patterns of BBS route densities (Table 1). Among BCRs (excluding strata with <10 routes) a mean 16.4% of routes either crossed BCR boundaries or were within the buffers (range 4.3–38.2%). A mean 84.7% of routes were classified based on digitized route paths (range 0–97.4%) within the BCRs.

Population Change Estimates Based on BCR and Bystrak Strata

When we calculated surveywide trend estimates using the BCR regions, our results were very similar to those calculated using the Bystrak strata. With the exception of green-winged teal (*Anas crecca*), none of the estimates were significantly different, as shown by our *Z*-tests, and we found no consistent differences based on the paired *t*-test results between estimates based on BCRs and those based on Bystrak strata (mean difference of trend based on Bystrak strata and trend based on BCR = 0.13, SE = 0.089, $t = 1.50$, df = 420, $P = 0.13$). Variances based on BCRs were not consistently different from those based on Bystrak strata (mean difference = 0.89, SE = 2.421, $t = 0.37$, df = 420, $P = 0.71$). However, we found a small but significant increase in the number of survey routes used in the analysis with BCRs (mean increase = 7.55, SE = 0.508, $t = 14.87$, df = 420, $P < 0.001$), resulting primarily from more routes entering the analysis in strata in western Canada. The Bystrak stratum analysis excluded some routes from the closed and open Boreal Forest strata (e.g., the state-strata were not included due to sparse coverage), but these routes were included in the BCR analysis.

As with the surveywide estimates, no pattern of consistent differences occurred among estimates at the state or province level. Trend estimates at state or province and surveywide scales for individual species for these 3 analyses are available in our data archive (http://www.mbr-pwrc.usgs.gov). We presented our analysis of survey adequacy based on the BCR results. We concluded that the change in strata had little effect on estimated trends at the surveywide level.

Survey Adequacy

We summarized survey adequacy for all species by BCR (Table 2), and for the entire survey area by species group (Table 3). These summaries are of population trend analyses conducted for the region of interest, then summarized by group and

Table 2. Summary of survey attributes by Bird Conservation Region (BCR) for all species. Proportion of species are presented for low abundances (LA, <1 bird/route), very low abundance (VLA, <0.1 bird/route), Imprecise estimates (IE, 95% confidence interval [CI] includes 3%/yr change), very imprecise (VIE, 95% CI includes 5%/yr change), temporal variation in trend (TT, significant [$P < 0.05$] difference in interval trends), small sample size (SS, No. of routes < 14), very small sample size (VSS, No. of routes < 5), and number of species detected in the stratum (*n*).

Stratum	LA	VLA	IE	VIE	TT	SS	VSS	*n*
Northern Pacific Rainforest	0.52	0.19	0.54	0.35	0.23	0.29	0.11	179
Boreal Taiga Plains	0.55	0.13	0.77	0.58	0.25	0.34	0.09	183
Boreal Softwood Shield	0.47	0.06	0.81	0.59	0.16	0.44	0.19	124
Great Basin	0.53	0.10	0.57	0.36	0.20	0.17	0.08	226
Northern Rockies	0.57	0.16	0.70	0.44	0.23	0.24	0.06	221
Prairie Potholes	0.56	0.22	0.62	0.40	0.35	0.24	0.06	198
Boreal Hardwood Transition	0.51	0.17	0.47	0.29	0.38	0.15	0.04	187
Lower Great Lakes/St. Lawrence Plain	0.60	0.25	0.53	0.39	0.35	0.22	0.08	178
Atlantic Northern Forest	0.53	0.18	0.47	0.26	0.43	0.11	0.02	171
Sierra Nevada	0.49	0.14	0.81	0.58	0.11	0.51	0.21	151
Southern Rockies/Colorado Plateau	0.58	0.19	0.75	0.55	0.21	0.29	0.09	197
Badlands and Prairies	0.56	0.13	0.67	0.48	0.36	0.29	0.10	166
Shortgrass Prairie	0.67	0.20	0.76	0.58	0.28	0.47	0.20	152
Central Mixed Grass Prairie	0.57	0.15	0.65	0.45	0.30	0.40	0.14	164
Edwards Plateau	0.40	0.10	0.82	0.64	0.20	0.56	0.20	105
Oaks and Prairies	0.57	0.24	0.68	0.53	0.30	0.42	0.16	142
Eastern Tallgrass Prairie	0.53	0.20	0.40	0.27	0.35	0.18	0.03	141
Prairie Hardwood Transition	0.54	0.27	0.50	0.31	0.33	0.29	0.11	177
Central Hardwoods	0.44	0.12	0.33	0.23	0.41	0.17	0.08	130
West Gulf Coastal Plain/Ouachitas	0.49	0.12	0.49	0.29	0.35	0.20	0.05	118
Mississippi Alluvial Valley	0.42	0.09	0.68	0.45	0.23	0.35	0.14	117
Southeastern Coastal Plain	0.54	0.20	0.50	0.36	0.34	0.23	0.08	157
Appalachian Mountains	0.49	0.23	0.36	0.21	0.40	0.12	0.06	164
Piedmont	0.51	0.18	0.42	0.28	0.36	0.20	0.08	131
New England/Mid-Atlantic Coast	0.53	0.15	0.45	0.24	0.34	0.22	0.07	173
Peninsular Florida	0.44	0.18	0.66	0.53	0.23	0.32	0.16	116
Coastal California	0.57	0.19	0.68	0.47	0.10	0.38	0.11	197
Sonoran and Mojave Deserts	0.63	0.25	0.84	0.72	0.21	0.58	0.27	134
Sierra Madre Occidental	0.37	0.12	0.89	0.53	0.23	0.50	0.16	149
Chihuahuan Desert	0.48	0.11	0.87	0.66	0.22	0.55	0.34	136
Tamaulipan Brushlands	0.40	0.13	0.81	0.61	0.22	0.48	0.24	104
Gulf Coastal Prairie	0.42	0.10	0.91	0.80	0.17	0.60	0.30	139
Surveywide	0.42	0.05	0.28	0.14	0.35	0.00	0.00	418

region. The data for individual species by BCR and for the entire survey area are available from our data archive (http://www.mbr-pwrc.usgs.gov). Please note that these results are presented in a descriptive fashion; we generally do not provide statistical tests of differences among the strata and species groups since we do not state a priori hypotheses about differences among groups. Specific comparisons can easily be conducted using binomial tests or chi-square tests for differences (Sauer and Williams 1989).

Abundances.—Proportion of species (Table 2) with low abundance (<1 bird/route) averaged 0.42 among BCRs and ranged from 0.67 (Shortgrass Prairie) to 0.37 (Sierra Madre Occidental). Among species groups (Table 3), the proportions ranged from 0.64 (Wetland Breeding) to 0.20 (Urban Breeding). Very low relative abundances (birds/route < 0.1) occurred for an average pro-

Table 3. Summary of North American breeding bird survey attributes by species group for the entire survey area. Proportion of species are presented for low abundances (LA, <1 bird/route), very low abundance (VLA, <0.1 bird/route), Imprecise estimates (IE, 95% CI includes 3%/yr change), very imprecise (VIE, 95% CI includes 5%/yr change), and number of species (*n*). Note that all species used in this analysis were found on >14 routes at the scale of the entire survey.

Species group	LA	VLA	IE	VIE	*n*
Grassland Breeding	0.32	0.04	0.25	0.11	28
Wetland Breeding	0.64	0.06	0.50	0.26	86
Successional or Scrub Breeding	0.23	0.01	0.20	0.05	87
Woodland Breeding	0.44	0.07	0.16	0.08	128
Urban Breeding	0.20	0.00	0.20	0.13	15
Cavity Nesting	0.48	0.12	0.22	0.10	58
Open-cup Nesting	0.24	0.00	0.16	0.07	182
Short Distance Migrant	0.30	0.05	0.22	0.09	102
Permanent Resident	0.48	0.08	0.29	0.11	93
Neotropical Migrant	0.31	0.01	0.14	0.07	137
Ground or Low Nesting	0.23	0.01	0.13	0.04	112
Mid-story or Canopy Nesting	0.23	0.00	0.15	0.09	124
All Species	0.42	0.05	0.28	0.14	420

portion of 0.05 of species among BCRs, ranging from 0.27 of species in the Prairie Hardwood Transition to 0.06 of the Boreal Softwood shield. Among species groups, the proportions ranged from 0.12 of Cavity Nesters to 0 of the Canopy Nesting and Urban species. Estimated at the scale of the entire survey area, 40% of species had low abundances and 5% had very low abundances.

Precision.—Proportions of species (Table 2) with trend estimates too imprecise to detect a 3%/year change over 35 years averaged 0.64 among BCRs and ranged from 0.91 (Gulf Coastal Prairie) to 0.33 (Central Hardwoods). Among species groups (Table 3), the proportions ranged from 0.50 (Wetland Breeding) to 0.13 (Ground Nesting). Very imprecise trend estimates (unable to detect a 5%/year change over the interval) occurred for an average proportion of 0.45 of species among BCRs, ranging from 0.80 in the Gulf Coastal Prairie to 0.21 in the Appalachian Mountains. Among species groups, the proportions ranged from 0.26 of Wetland Breeding birds to 0.04 of Ground Nesting species. Estimated for all species at the scale of the entire survey area, 28% of species had imprecise trend estimates and 14% had very imprecise estimates.

Sample Sizes.—Proportion of species with small sample sizes (encountered on <14 routes) averaged 0.33 among BCRs and ranged from 0.60 (Gulf Coastal Prairie) to 0.11 (Atlantic Northern Forest; Table 2).

Regional Efficiency of Survey

We presented scaled relative efficiency by states and provinces within BCRs (Table 4). To interpret these values, consider the overall patterns of efficiency on the scale of individual routes. Plotting both the scaled relative precision for a route surveyed by a single observer with varied number of years versus number of years surveyed (the curve that ends at 1) shows loss of information associated with missing years. Plotting the actual average relative precision of BBS routes run for various numbers of years versus number of survey years documents the additional loss of information associated with observer changes on analyses (Fig 2). The observed scaled relative precisions generally are much lower than the best possible, and the mean scaled relative precision for routes run 35 years was 51%. Scaled relative efficiencies in Table 4 are scaled relative to the most efficient route possible. To rescale them to the mean efficiency of a route run for 35 years but containing observer

(continued on page 382)

Table 4. Mean scaled relative efficiency by state and province within Bird Conservation Region (BCR), along with mean number of years and number of routes analyzed in the region.

BCR	State or province	Relative efficiency	Mean no. years	Mean no. routes
Western Alaska	Alaska	1.97	7.06	13
Total		1.97	7.06	13
Arctic Plains and Mountains	Alaska	0.34	7.00	3
Total		0.34	7.00	3
Northwestern Interior Forest	Alaska	0.84	7.94	44
Northwestern Interior Forest	British Columbia	0.14	5.50	2
Northwestern Interior Forest	Yukon	2.61	7.74	16
Total		1.28	7.82	62
Northern Pacific Rainforest	Alaska	1.66	8.04	24
Northern Pacific Rainforest	British Columbia	7.53	11.83	26
Northern Pacific Rainforest	California	10.80	17.53	28
Northern Pacific Rainforest	Oregon	9.82	13.57	46
Northern Pacific Rainforest	Washington	8.37	14.68	27
Total		8.05	13.22	151
Boreal Taiga Plains	Alberta	4.75	9.40	35
Boreal Taiga Plains	British Columbia	0.97	8.00	3
Boreal Taiga Plains		0.16	6.00	4
Boreal Taiga Plains	Manitoba	6.52	12.07	14
Boreal Taiga Plains	Saskatchewan	6.88	8.73	13
Total		5.08	9.53	69
Taiga Shield and Hudson Plains		0.41	7.50	2
Taiga Shield and Hudson Plains	Newfoundland	0.17	4.33	3
Total		0.27	5.00	5
Boreal Softwood Shield	Manitoba	7.39	13.00	4
Boreal Softwood Shield	Newfoundland	0.48	4.19	15
Boreal Softwood Shield	Ontario	4.73	10.15	12
Boreal Softwood Shield	Quebec	1.67	6.00	8
Total		2.74	6.85	39
Great Basin	British Columbia	6.68	13.09	22
Great Basin	California	8.54	17.76	20
Great Basin	Idaho	7.41	14.57	33
Great Basin	Nevada	1.70	9.56	29
Great Basin	Oregon	7.69	13.12	49
Great Basin	Utah	3.82	11.08	24
Great Basin	Washington	4.14	12.42	52
Total		5.65	12.88	229
Northern Rockies	Alberta	3.75	11.21	12
Northern Rockies	British Columbia	9.27	12.08	32
Northern Rockies	Colorado	2.98	14.60	5
Northern Rockies	Idaho	3.92	11.22	25
Northern Rockies	Montana	5.28	15.97	34
Northern Rockies	Oregon	2.12	11.13	23
Northern Rockies	Utah	0.79	6.50	4
Northern Rockies	Washington	2.93	10.09	10
Northern Rockies	Wyoming	2.15	11.13	62
Total		4.10	12.02	207
Prairie Potholes	Alberta	6.49	11.21	51

Table 4. continued.

BCR	State or province	Relative efficiency	Mean no. years	Mean no. routes
Prairie Potholes	Iowa	5.83	21.60	10
Prairie Potholes	Manitoba	5.97	14.23	25
Prairie Potholes	Minnesota	7.43	15.44	24
Prairie Potholes	Montana	8.26	17.80	10
Prairie Potholes	Nebraska	6.99	22.00	4
Prairie Potholes	North Dakota	10.99	19.97	32
Prairie Potholes	Saskatchewan	7.85	9.91	43
Prairie Potholes	South Dakota	10.18	16.89	18
Total		7.84	14.38	217
Boreal Hardwood Transition	Manitoba	7.27	10.67	5
Boreal Hardwood Transition	Michigan	5.47	14.70	44
Boreal Hardwood Transition	Minnesota	14.24	16.82	32
Boreal Hardwood Transition	Ontario	11.26	13.57	48
Boreal Hardwood Transition	Quebec	3.85	11.03	35
Boreal Hardwood Transition	Wisconsin	16.82	23.97	28
Total		9.79	15.29	192
Lower Great Lakes/ St. Lawrence Plain	New York	17.06	24.45	52
Lower Great Lakes/ St. Lawrence Plain	Ohio	9.43	17.40	15
Lower Great Lakes/ St. Lawrence Plain	Ontario	7.49	14.87	58
Lower Great Lakes/ St. Lawrence Plain	Pennsylvania	7.81	18.00	10
Lower Great Lakes/ St. Lawrence Plain	Quebec	18.79	17.73	13
Lower Great Lakes/ St. Lawrence Plain	Vermont	3.67	18.50	6
Total		11.74	18.86	154
Atlantic Northern Forest	Connecticut	5.12	11.00	2
Atlantic Northern Forest	Maine	6.44	14.80	59
Atlantic Northern Forest	Massachusetts	15.80	24.63	8
Atlantic Northern Forest	New Brunswick	14.99	18.29	31
Atlantic Northern Forest	New Hampshire	18.47	29.30	20
Atlantic Northern Forest	New York	15.78	18.58	25
Atlantic Northern Forest	Nova Scotia	12.70	17.66	30
Atlantic Northern Forest	Prince Edward Island	4.36	23.50	4
Atlantic Northern Forest	Quebec	5.37	10.40	28
Atlantic Northern Forest	Vermont	8.86	22.32	19
Total		10.90	17.82	226
Sierra Nevada	California	7.77	14.38	29
Southern Rockies/ Colorado Plateau	Arizona	1.55	6.48	15
Southern Rockies/ Colorado Plateau	Colorado	2.40	8.39	71
Southern Rockies/ Colorado Plateau	New Mexico	5.81	12.09	29
Southern Rockies/ Colorado Plateau	Utah	1.18	7.52	56
Southern Rockies/ Colorado Plateau	Wyoming	4.96	11.71	7
Total		2.60	8.63	178
Badlands and Prairies	Montana	8.46	17.35	20

Table 4. continued.

BCR	State or province	Relative efficiency	Mean no. years	Mean no. routes
Badlands and Prairies	North Dakota	12.02	18.21	13
Badlands and Prairies	South Dakota	9.12	13.35	40
Badlands and Prairies	Wyoming	2.77	12.18	32
Total		7.42	14.35	105
Shortgrass Prairie	Colorado	5.33	10.83	43
Shortgrass Prairie	Kansas	7.28	18.33	3
Shortgrass Prairie	Nebraska	4.68	16.50	8
Shortgrass Prairie	New Mexico	7.49	12.56	16
Shortgrass Prairie	Oklahoma	2.31	15.20	5
Shortgrass Prairie	Texas	14.33	12.59	18
Shortgrass Prairie	Wyoming	4.02	15.80	5
Total		7.12	12.54	98
Central Mixed Grass Prairie	Kansas	16.13	26.78	23
Central Mixed Grass Prairie	Nebraska	7.84	17.19	26
Central Mixed Grass Prairie	Oklahoma	18.10	18.09	23
Central Mixed Grass Prairie	Texas	4.62	11.83	16
Total		12.11	18.80	88
Edwards Plateau	Texas	7.56	17.56	18
Oaks and Prairies	Oklahoma	9.60	21.50	14
Oaks and Prairies	Texas	12.65	18.38	46
Total		11.94	19.08	60
Eastern Tallgrass Prairie	Illinois	14.27	23.17	69
Eastern Tallgrass Prairie	Indiana	11.34	19.35	20
Eastern Tallgrass Prairie	Iowa	15.46	24.88	26
Eastern Tallgrass Prairie	Kansas	20.90	29.62	13
Eastern Tallgrass Prairie	Michigan	0.73	8.50	2
Eastern Tallgrass Prairie	Minnesota	16.41	13.40	5
Eastern Tallgrass Prairie	Missouri	6.90	16.14	29
Eastern Tallgrass Prairie	Nebraska	16.86	27.33	6
Eastern Tallgrass Prairie	Ohio	11.52	18.69	35
Eastern Tallgrass Prairie	Oklahoma	8.11	18.33	6
Eastern Tallgrass Prairie	Wisconsin	23.73	18.00	1
Total		12.95	21.28	212
Prairie Hardwood Transition	Illinois	5.38	23.50	2
Prairie Hardwood Transition	Indiana	6.63	16.22	9
Prairie Hardwood Transition	Iowa	5.93	29.00	1
Prairie Hardwood Transition	Michigan	12.05	18.38	36
Prairie Hardwood Transition	Minnesota	15.87	17.78	17
Prairie Hardwood Transition	Wisconsin	16.77	23.84	57
Total		14.23	20.84	122
Central Hardwoods	Alabama	10.32	17.50	5
Central Hardwoods	Arkansas	12.43	24.00	8
Central Hardwoods	Illinois	23.65	20.55	11
Central Hardwoods	Indiana	17.44	21.06	17
Central Hardwoods	Kentucky	18.74	22.34	32
Central Hardwoods	Missouri	5.49	17.41	29
Central Hardwoods	Ohio	63.09	35.00	1
Central Hardwoods	Oklahoma	13.46	21.00	2
Central Hardwoods	Tennessee	22.87	32.07	15
Total		15.83	21.98	120

Table 4. continued.

BCR	State or province	Relative efficiency	Mean no. years	Mean no. routes
West Gulf Coastal Plain/Ouachitas	Arkansas	13.49	26.06	18
West Gulf Coastal Plain/Ouachitas	Louisiana	5.44	11.77	22
West Gulf Coastal Plain/Ouachitas	Oklahoma	11.70	13.62	13
West Gulf Coastal Plain/Ouachitas	Texas	7.41	16.38	21
Total		9.06	16.88	74
Mississippi Alluvial Valley	Arkansas	12.22	24.73	11
Mississippi Alluvial Valley	Kentucky	24.99	23.00	1
Mississippi Alluvial Valley	Louisiana	4.36	12.09	20
Mississippi Alluvial Valley	Mississippi	3.65	12.56	9
Mississippi Alluvial Valley	Missouri	23.51	30.00	2
Mississippi Alluvial Valley	Tennessee	14.23	33.00	2
Total		7.89	16.92	45
Southeastern Coastal Plain	Alabama	14.48	17.74	55
Southeastern Coastal Plain	Florida	7.18	17.84	35
Southeastern Coastal Plain	Georgia	8.69	19.10	41
Southeastern Coastal Plain	Kentucky	32.77	30.50	2
Southeastern Coastal Plain	Louisiana	7.21	16.67	3
Southeastern Coastal Plain	Mississippi	6.42	16.03	30
Southeastern Coastal Plain	North Carolina	6.73	11.28	35
Southeastern Coastal Plain	South Carolina	19.07	17.61	18
Southeastern Coastal Plain	Tennessee	13.61	31.40	10
Southeastern Coastal Plain	Virginia	6.39	15.56	15
Total		10.22	17.23	244
Appalachian Mountains	Alabama	13.18	16.76	23
Appalachian Mountains	Connecticut	30.91	25.50	2
Appalachian Mountains	Georgia	15.55	22.33	6
Appalachian Mountains	Kentucky	1.66	10.57	13
Appalachian Mountains	Maryland	17.37	19.86	14
Appalachian Mountains	New Jersey	9.23	20.43	7
Appalachian Mountains	New York	15.70	23.69	32
Appalachian Mountains	North Carolina	1.58	9.63	14
Appalachian Mountains	Ohio	6.50	14.87	30
Appalachian Mountains	Pennsylvania	13.24	20.56	97
Appalachian Mountains	Tennessee	15.06	21.35	23
Appalachian Mountains	Virginia	13.64	15.06	32
Appalachian Mountains	West Virginia	11.79	16.07	56
Total		12.13	18.04	349
Piedmont	Alabama	5.32	27.50	2
Piedmont	Georgia	8.32	19.95	20
Piedmont	Maryland	33.45	26.94	17
Piedmont	New Jersey	30.64	23.75	4
Piedmont	North Carolina	7.20	14.14	19
Piedmont	Pennsylvania	6.11	13.76	16
Piedmont	South Carolina	4.31	12.83	12
Piedmont	Virginia	10.71	19.12	24
Total		12.38	18.39	114

Table 4. continued.

BCR	State or province	Relative efficiency	Mean no. years	Mean no. routes
New England/ Mid-Atlantic Coast	Connecticut	18.48	25.29	14
New England/ Mid-Atlantic Coast	Delaware	7.05	21.69	13
New England/ Mid-Atlantic Coast	Maine	51.97	30.00	2
New England/ Mid-Atlantic Coast	Maryland	23.73	25.78	36
New England/ Mid-Atlantic Coast	Massachusetts	12.60	20.63	19
New England/ Mid-Atlantic Coast	New Hampshire	19.57	33.00	4
New England/ Mid-Atlantic Coast	New Jersey	4.31	14.24	25
New England/ Mid-Atlantic Coast	New York	9.42	18.13	8
New England/ Mid-Atlantic Coast	Rhode Island	1.88	13.33	5
New England/ Mid-Atlantic Coast	Virginia	4.88	17.25	4
Total		14.14	21.36	130
Peninsular Florida	Florida	6.55	14.28	59
Coastal California	California	7.31	16.84	100
Sonoran and Mojave Deserts	Arizona	1.76	8.50	22
Sonoran and Mojave Deserts	California	8.94	13.65	34
Sonoran and Mojave Deserts	Nevada	1.90	10.00	6
Total		5.71	11.39	62
Sierra Madre Occidental	Arizona	4.78	9.93	28
Sierra Madre Occidental	New Mexico	1.04	8.25	4
Total		4.31	9.74	32
Chihuahuan Desert	New Mexico	4.08	11.95	19
Chihuahuan Desert	Texas	3.85	13.71	21
Total		3.96	12.83	40
Tamaulipan Brushlands	Texas	8.95	14.35	22
Gulf Coastal Prairie	Louisiana	1.05	9.81	15
Gulf Coastal Prairie	Texas	6.02	13.89	17
Total		3.69	11.97	32

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changes (i.e., the highest point in the lower curve in Fig. 2), multiply them by 1.948, the ratio of the mean efficiency to the most efficient. This rescaling indicates the efficiency of the region relative to the average (rather than the best) route surveyed for 35 years. The mean scaled relative efficiency was 7.5%. Bird conservation regions tended to differ widely in mean efficiency, with a maximum of 22.9 in the Central Hardwoods and a minimum of 0.34 in the Arctic Plains and Mountains. Within BCRs, estimates among states and provinces also varied greatly, reflecting the geographic extent of many of the BCRs. For example, within the

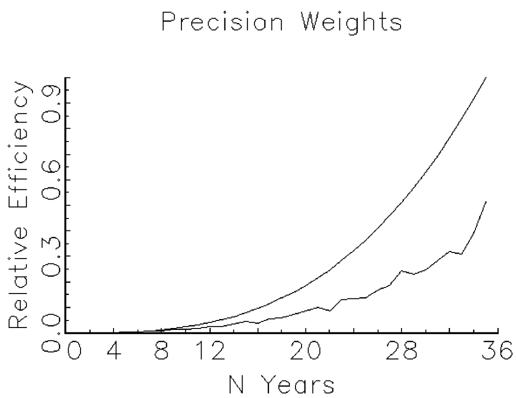

Fig. 2. Scaled relative efficiency of North American breeding bird survey (BBS) routes as a consequence of number of years of survey. The higher curve shows the relative efficiency of routes surveyed by a single observer, scaled so that a single observer route with 35 years of data is given an efficiency of 1.0. The lower curve represents the actual efficiencies of BBS routes surveyed for varying numbers of years, and is also scaled to single observer route with 34 years of data. It is below the single observer route curve because most BBS routes have been surveyed by several observers over the survey interval, and hence are less efficient than single-observer routes.

Appalachian Mountain BCR, efficiency varied from 1.6 (North Carolina) to 30.91 (Connecticut).

Mean number of years of survey also varied greatly among BCRs and among states or provinces within BCRs (Table 4). Overall, routes were run a mean of 14.8 years, with the maximum for BCRs as 20.8 years in the Prairie Hardwood Transition and a minimim of 5.0 years in the Taiga Shield and Hudson Plains.

Analysis of Population Change

Spatial Heterogeneity in Trend.—A large proportion of species showed spatial heterogeneity in population trend (Table 5). The percentages were consistently high, though varied, among species groups, ranging from 72% (Grassland) to 100% (Urban) for nesting habitat species groups, and average 76% for all species. Individual species results are presented in our data archive (http://www.mbr-pwrc.usgs.gov).

Temporal Heterogeneity in Trend.—Species also tended to show temporal variation in trend over the 1966–2000 period (Table 5). Overall, 39% of species showed significant temporal differences in estimated trends, and this percentage varied from 28% (Permanent Resident) to 73% (Urban) among the breeding habitat species groups.

Patterns of Population Change.—Proportions of species with positive trends varied over both BCRs (Table 6) and species groups (Table 7). We present results by BCR for 2 species groups, Grassland-breeding birds and Neotropical migrant bird species (Table 6). Grassland-breeding birds vary greatly both in number of species present and trends over BCRs and have between zero and 51% of species with increasing populations. Within BCRs, Neotropical migrants varied from 23 to 75% of species with increasing trends.

For species groups summarized over the entire survey area, groups with significant ($P < 0.05$) differences from 50% include Grassland breeding birds (18%), Scrub-breeding species (33%), Neotropical migrant (41%), Ground or Low Nesting species (33%), and Cavity nesters (59%). Overall, 49% of all species had increasing populations (Table 7). Several of the estimates differed significantly from 50% ($P < 0.05$; Table 7), but within each of the group categories, the proportions differed only among breeding habitat groups ($P < 0.03$, chi-square tests; Sauer and Williams 1989). Estimates did not differ within other species groups (within the groups nest sites, migration status, and nest location, all $P > 0.10$).

Individual Species Patterns.—The species population changes estimated in our analysis generally are consistent with earlier published works on population changes in birds (Peterjohn et al. 1995, Sauer et al. 1997, Peterjohn and Sauer 1999), although a few exceptions occur. For example, green-winged teal have an extreme estimated population increase, which is the conse-

Table 5. Spatial and temporal heterogeneity in trends, expressed as the proportion of species in each species group in which trends differed significantly ($P < 0.05$) over space (among within-region estimates) or time (surveywide), along with sample sizes (n) for the Bird Conservation Region (BCR) analysis (no. of species occurring in >1 BCR on at least 5 survey routes). Sample sizes for the temporal analysis are provided on Table 3.

Species group	Spatial proportion	n	Temporal proportion
Grassland Breeding	0.72	28	0.36
Wetland Breeding	0.74	85	0.29
Successional or Scrub Breeding	0.71	84	0.30
Woodland Breeding	0.83	126	0.35
Urban Breeding	1.00	14	0.73
Cavity Nesting	0.84	57	0.26
Open-cup Nesting	0.75	177	0.39
Short Distance Migrant	0.84	100	0.37
Permanent Resident	0.74	86	0.28
Neotropical Migrant	0.79	136	0.44
Ground or Low Nesting	0.74	110	0.39
Mid-story or Canopy Nesting	0.85	118	0.39
All Species	0.76	406	0.39

Table 6. Precision-adjusted estimates of proportion of species with positive trend estimates for all species, Grassland-breeding birds, and Neotropical migrant birds. For each group, the proportion of species with increasing populations (Prop) is presented, with associated *P*-values for a test of the null hypothesis that Prop = 0.5, and sample sizes (*n*).

	All Species			Grassland			Migrants		
Bird Conservation Region	Prop	*P*	*n*	Prop	*P*	*n*	Prop	*P*	*n*
Northern Pacific Rainforest	0.33	0.003	122				0.23	0.002	40
Boreal Taiga Plains	0.50	0.917	122	0.24	0.180	8	0.50	0.976	40
Boreal Softwood Shield	0.33	0.217	71				0.44	0.858	30
Great Basin	0.52	0.942	184	0.31	0.561	12	0.44	0.712	55
Northern Rockies	0.63	0.472	163				0.61	0.336	54
Prairie Potholes	0.66	0.217	144	0.37	0.330	23	0.70	0.200	44
Boreal Hardwood Transition	0.45	0.895	144	0.27	0.333	12	0.34	0.003	61
Lower Great Lakes/St. Lawrence Plain	0.58	0.002	123	0.06	0.001	9	0.65	0.263	52
Atlantic Northern Forest	0.49	0.572	136	0.27	0.001	7	0.40	0.033	57
Sierra Nevada	0.39	0.567	75				0.38	0.468	26
Southern Rockies/Colorado Plateau	0.41	0.682	131	0.19	0.324	7	0.37	0.683	48
Badlands and Prairies	0.54	0.841	108	0.17	0.092	19	0.52	0.911	40
Shortgrass Prairie	0.57	0.558	81	0.00	<0.001	15	0.56	0.815	29
Central Mixed Grass Prairie	0.47	0.770	99	0.25	0.022	13	0.34	0.298	40
Edwards Plateau	0.23	0.003	46				0.29	0.176	20
Oaks and Prairies	0.45	0.203	82	0.10	0.215	5	0.37	0.033	30
Eastern Tallgrass Prairie	0.51	0.778	108	0.04	0.001	12	0.38	0.009	47
Prairie Hardwood Transition	0.54	0.071	119	0.11	<0.001	13	0.53	0.510	45
Central Hardwoods	0.46	0.115	107				0.38	0.002	52
West Gulf Coastal Plain/Ouachitas	0.39	0.001	93				0.23	0.009	43
Mississippi Alluvial Valley	0.41	0.026	77				0.25	0.001	31
Southeastern Coastal Plain	0.51	0.974	114				0.47	0.901	45
Appalachian Mountains	0.45	0.026	126	0.11	<0.001	7	0.37	0.001	61
Piedmont	0.58	0.006	101	<0.01	<0.001	5	0.61	0.115	46
New England/MidAtlantic Coast	0.46	0.139	133	0.09	<0.001	6	0.28	<0.001	57
Peninsular Florida	0.35	0.443	75				0.37	0.213	16
Coastal California	0.50	0.957	122	0.51	0.963	6	0.24	0.208	37
Sonoran and Mojave Deserts	0.49	0.983	55				0.75	0.395	16
Sierra Madre Occidental	0.36	0.541	75				0.24	0.213	26
Chihuahuan Desert	0.54	0.839	61				0.64	0.628	21
Tamaulipan Brushlands	0.46	0.911	54				0.57	0.848	14
Gulf Coastal Prairie	0.53	0.899	55				0.56	0.826	12
Surveywide	0.49	0.964	401	0.18	0.007	27	0.42	0.004	135

quence of several extreme counts. Removal of 3 of these observations results in a trend estimate of 3.47%/year ($P = 0.04$, $n = 299$), a number consistent with earlier estimates (Sauer et al. 1997).

Information for each species includes the abundance and precision categorizations summarized in Tables 3 and 5, as implemented for the long-term (1966–2000) analysis. We do not include the summary estimates for the interval trends, since abundances generally are similar among intervals, and sample sizes and *P*-values for test of the null hypothesis of no change for the estimates are presented on our internet site (http://www.mbr-pwrc.usgs.gov).

DISCUSSION

Our analysis of BBS data is not designed to directly address the general question of the validity of the BBS. Flaws in the BBS design are well documented, and inevitably complicate any analysis. Detectability of birds is not explicitly estimated as part of the survey, and any estimation of population change from counts requires model-based adjustments for covariates known to affect detectability (e.g., observer differences; Geissler and Sauer 1990, Sauer et al. 1994, Kendall et al. 1996, Link and Sauer 1998*b*), as well as additional assumptions about consistency of detectability over time and space. The BBS sample frame also is deficient, in that survey routes are restricted to roadsides. Any analysis of BBS data should begin with a frank assessment of the possible consequences of these assumptions on analysis, and our descriptions of efficiency of individual species and grouped results are conditional on these overall (and often unstated) assumptions. None of the analyses presented here directly address these fundamental issues for BBS analysis. Review

Table 7. Precision-adjusted estimates of proportion of species with positive trend estimates for 12 species groups and for all species. For each group, the proportion of species with increasing populations (Prop) is presented, with associated variances (Var), *P*-values associated with the test of the null hypothesis that the proportion is 0.5, and sample sizes (*n*).

Species group	Prop	*n*	Var	*P*
Breeding Habitat				
Grassland Breeding	0.18	27	<0.01	<0.01
Wetland Breeding	0.68	75	0.03	0.26
Successional or Scrub Breeding	0.33	86	<0.01	<0.01
Woodland Breeding	0.54	119	0.01	0.71
Urban Breeding	0.25	15	0.06	0.30
Nest Type				
Cavity Nesting	0.59	51	<0.00	0.05
Open-cup Nesting	0.39	182	0.05	0.63
Migration				
Short Distance Migrant	0.45	97	0.12	0.88
Permanent Resident	0.51	86	0.03	0.96
Neotropical Migrant	0.41	135	<0.01	<0.01
Nest Location				
Ground or Low Nesting	0.33	111	<0.01	<0.01
Mid-story or Canopy Nesting	0.53	124	0.14	0.93
All Species	0.49	394	0.03	0.93

of historical information from the survey only provides indirect evidence of the consequences of these flaws (Sauer et al. 1994, Kendall et al. 1996), and we encourage experiments to evaluate the deficiencies in the present BBS design.

Instead, our analysis documents that, conditional on the current sampling frame of roadside habitats, BCRs could be used as strata for analysis. Physiographic regions were not part of the original sample allocation procedures for the survey, and therefore exist for convenience. They are accommodated in the design only to the extent that new routes are not allowed to cross the stratum boundaries. However, intensity of samples does vary when considering multi-state regions. Strata, as defined in terms of physiographic regions within states or provinces, play an important role in partitioning the survey into regional aggregations that contain the same density of routes (Geissler and Sauer 1990). At more local scales, our results suggest that with a few exceptions no differences exist in selection probabilities for routes within states and provinces, and BCRs can be used in place of the traditional Bystrak physiographic regions. When differing route densities occur among Bystrak strata within a region (such as in California, Quebec, and Ontario), BCRs appear to maintain these areas with disproportionate numbers of routes. Consequently, replacement of the traditional Bystrak strata with BCRs appears to be acceptable with regard to sampling, and BCRs within states and provinces can be used as strata for BBS analyses.

Although the use of Bystrak Regions or BCRs within states and provinces may not cause significant differences in results, many issues associated with strata remain unresolved. For example, we noted that some small areas were aggregated in our analysis to increase expected values, and that these areas may require further study. For example, the Coastal Flatwoods in Alabama may have disproportionately large numbers of routes, but was merged with the Upper Coastal Plain for analysis. The Los Angeles Range in California also may have an excess number of survey routes relative to the area surveyed. A series of nonrandomly located survey routes in the BBS also are conducted in National Parks, National Forests, waterbodies, and other natural areas. These routes generally are not used in BBS analyses and were not used in this analysis, but could be put in a separate stratum for analysis.

Classification of routes near BCR boundaries is somewhat controversial, since many routes do cross the boundaries and any resulting classification is arbitrary. In our reclassification, we noted routes near boundaries so future analyses could revisit our classifications or directly assess the consequences using data from several BCRs. However, boundaries of many BCRs do not reflect ecotones easily modeled by a single boundary line. Hence, routes near BCR edges may be more heterogeneous than routes toward the BCR center. We suggest that analysis of habitats associated with BBS routes near BCR boundaries would provide the best means for resolving the BCR associations of routes shared by several BCRs.

We also note that geographic information is incomplete for many of the survey routes (Table 1). Reasonable analysis of most survey data requires use of geographic information, and in particular conservation planning in BCRs is likely to involve use of remotely sensed habitat data in combination with bird survey data (e.g., Flather and Sauer 1996). Maintenance and further development of geographic information from the BBS will greatly enhance the capability of the survey to contribute information for conservation planning.

Efficiency of the BBS Sample Within BCRs

Our analysis of survey efficiency using BCR strata is conditional on the assumption that observer differences form the primary source of differences in detectability among routes, and that these differences can be adequately accommodated through use of observer covariates (Geissler and Sauer 1990). The BBS is an omnibus survey, in that over 421 species are encountered along the survey routes. As such, the BBS trades off efficiency in estimation for any particular species in favor of allowing less efficient estimation for many species. Also, the roadside sample frame and point-count survey method trade convenience of access and methods for statistical rigor. As noted above, a series of (presently) untestable assumptions must be made regarding the detectability of birds in point counts and validity of the roadside sample frame in any BBS analysis. Observable covariates that influence proportion of birds detected can be incorporated into analyses (e.g., James et al. 1996, Link and Sauer 1998*b*), but unobservable factors that influence detectability cannot be modeled in analyses without additional information.

Another consequence of the omnibus nature of the BBS is that quality of information is equivocal for many species. In all BCRs, many species are encountered on BBS routes at small sample sizes and at low relative abundances. The exact consequences of small samples and low abundances are difficult to determine, but they clearly indicate the need for caution in some uses of the data. Regression-based trend estimation methods and power analyses (e.g., Geissler and Sauer 1990, Gibbs and Melvin 1997) require additions of constants to the data, and these analyses are greatly influenced by very small counts. Generalized linear models do not have this technical limitation, but still retain distributional assumptions that must be considered. Small sample sizes result in poor estimates of trend and variance. In many cases, these measures of inefficiency are a consequence of the survey design. For example, small samples of wetland species most likely are a consequence of the roadside sample frame (Robbins et al. 1986, Sauer and Droege 1990).

Many investigators conduct power analysis to evaluate needed sample sizes for individual species and to assess the exact ability of the survey to detect prespecified changes. While we acknowledge the need for quantitative guidelines for adding samples to the survey, we chose not to assess power of the BBS to detect population changes. Methods for assessing power and needed sample sizes often make very restrictive assumptions about population change and rely on simple analytical methods such as simple linear regression. Instead of providing very general recommendations based on many assumptions, we followed a more conservative approach of documenting whether the existing survey met standards of efficiency based on effect sizes of 3 and 5%/year. These results provide general guidance for the prospects of future surveys. For those who wish to conduct analysis of samples sizes, estimated variances of trends can be used as pilot data to predict needed sample numbers.

Spatial and Temporal Heterogeneity in Population Change Estimates

We document extensive variation in population change over time and space. This result is consistent with other analyses of BBS data (Robbins et al. 1986, 1989; Sauer and Droege 1992; Böhning-Gaese et al. 1994; James et al. 1996). Route regression-based trend estimates have been shown to be similar to those based on alternative methods, such as LOESS smooths (e.g., James et al. 1996, Link and Sauer 1997). Hence, the heterogeneity does not invalidate trend estimates as a measure of interval-specific population change. However, the temporal heterogeneity does undermine the credibility of the predictive value of the interval-specific change estimate. The trend estimates presented by analyses of BBS data must be viewed as simple, interval-specific estimates of change that do not necessarily provide long-term descriptors of the time series dynamics. This aspect of BBS analyses has been a source of controversy about analysis of BBS data over the years, since interval-specific change estimates are used both to document short-term patterns of change and also to predict the future dynamics of the system (e.g. Robbins et al. 1989).

The extensive temporal and spatial heterogeneity we documented suggests that "trend" analyses from the BBS are most appropriately viewed as a summary tool for specific intervals, not a summary of a long-term, consistent change in the population, as is implicit in the standard time-series definition of trend (Degum and Degum 1988). Understanding how all time-series components interact in the estimation of short-term change (e.g., Link and Sauer 1998*b*) and documenting spatial and temporal pattern in populations has proven to be a challenging part of interpreting bird population change. Unfortunately, the BBS is not designed to allow analysis of causal factors in population change, and the post-hoc hypothesis testing to which survey results are subjected does not generally lead to unequivocal results (e.g., Robbins et al. 1989, Peterjohn et al. 1995).

Summary Analyses of Population Change

The regional and species-specific heterogeneity in population change are reflected in the summary estimates of population change from BCRs and at the scale of the entire survey. Some taxa are known to be collectively experiencing population declines, and these patterns are well described in our analysis. Grassland Breeding birds in particular are experiencing declines both within BCRs and overall. However, for other taxa such as Neotropical migrant birds, significant differences exist among BCRs, with some BCRs showing few increasing species, but others showing a large proportion of increasing species. Note that these estimates of proportion of increasing species tend to be imprecise (i.e., not different from 0.5). However, the analysis does tend to show disproportionate numbers of declining species for several groups, including Grassland Breeding, Scrub Breeding, Neotropical migrant, and Ground- or Low-Nesting species. Only Cavity-Nesting species had a disproportionate number of increasing species. Overall, 49% of species had increasing populations. As with individual species patterns, heterogeneity over space can complicate interpretation of these estimates of proportion of increasing species. However, our analysis indicates that BCRs appear to be a reasonable scale for summary of BBS data.

MANAGEMENT IMPLICATIONS

The role of monitoring data in conservation has evolved from the historic use of merely documenting population trends to a much more focused, region specific role of assessing population status in the context of management actions. Management at the landscape scale involves development of models that relate bird populations to regional habitat data, and then uses the models to assess the possible consequences of alternative management actions on regional bird populations. The surveys provide the means of documenting the actual management consequences, allowing us to update our understanding of how management influences bird populations (e.g., Ruth et al. in press, Williams et al. 2002). As the only existing source of population information for many bird species, BBS data often are used both as dependent variables in development and validation of these models, and as the primary source of population status information for many species. Our results indicate that the BBS can be used to estimate population change at the scale of BCRs, at which landscape-level management of birds is likely to be focused. However, the BBS often provides small samples or imprecise results within BCRs. This lack of precision is not unusual for a survey that provides information on >400 species, but it has the potential to severely limit the use of the BBS for management of bird populations.

Imprecise estimates make responses to management unlikely to be detected by the survey, and, hence, survey results will not provide useful information for management. Small sample sizes also limit the use of the survey data as dependent variables for modeling exercises. Our analysis (and the associated datasets available from our websites) documents these limitations of the BBS at the scale of physiographic strata, and managers can use the information to assess the value of the BBS for species of special interest in their BCR. Unfortunately, improving the utility of the BBS will likely prove difficult within the constraints of its present design.

It is tempting to view additional samples as a solution to the lack of precision and small sample sizes. However, simply adding survey routes to the BBS is unlikely to create needed samples sizes for most species of management interest, as many of these species tend to occur in habitats not well-monitored by the BBS. While most BCRs contain fairly large numbers of BBS routes, many species are still not well sampled. For these undersampled species, special surveys that are appropriately stratified to sample the habitats of interest may be a reasonable alternative to the BBS.

The omnibus nature of the BBS inevitably leads to large differences in the precision of estimates among species. Furthermore, the relatively imprecise estimates at the scale of BCRs are likely to limit the use of BBS data in conservation planning and estimation of composite change for certain groups of species, such as Neotropical migrant birds. Summaries of population change must accommodate the relative imprecision of species, as simple averages of estimated trends are often misleading when the component estimates vary greatly in quality (Link and Sauer 1995, Sauer and Link 2002). In addition our summary methods, hierarchical model-based approaches provide new opportunities for accommodating the imprecision in summary analysis of groups of species (Sauer and Link 2002). As it is unlikely that all species in a BCR will be effectively surveyed, managers need to adopt statistical procedures that use available information most efficiently.

The BBS design has obvious limitations associated with the absence of detectability estimation and the roadside sampling frame. These limitations are partially compensated for in analyses of population change by use of observer covariates and other adjustments to accommodate differences in detectability. However these adjustments can be controversial and tend to undermine the credibility of analyses (Link and Sauer 1998*b*). Use of the BBS in modern conservation activities puts greater demands on the information, and provides valuable insights into needed improvements in the survey (e.g., Bibby et al. 2000). As with all surveys, BBS methods and analyses must adapt to methodological innovations and present management needs. Our review of the efficiency of the survey at the geographic scale of BCRs provides information about the survey as presently implemented. However, managers also should consider design changes in the BBS that would overcome the deficiencies associated with the roadside nature of the counts and the lack of detectability estimation.

ACKNOWLEDGMENTS

The BBS is based on the efforts of thousands of volunteers who generously contribute their time to both conduct the survey and submit and edit their results. Their skills are the key element in making the survey a success, and we gratefully acknowledge their efforts. K. Pardieck provided BBS data, route information, and many helpful comments on the analysis and manuscript. We thank W. A. Link, J. D. Nichols, J. A. Royle, and anonymous reviewers for helpful comments on the manuscript and discussion.

LITERATURE CITED

BIBBY, C. J., N. D. BURGESS, D. A. HILL, AND S. H. MUSTOE. 2000. Bird census techniques, second edition. Academic Press, London, United Kingdom.

BÖHNING-GAESE, K., M. L. TAPER, AND J. H. BROWN. 1994. Avian community dynamics are discordant in space and time. Oikos 70:121–126.

BUTCHER, G. S. 1990. Audubon Christmas bird counts. Pages 5–13 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service Biological Report 90(1).

BYSTRAK, D. 1981. The North American breeding bird survey. Pages 34–41 *in* C. J. Ralph and J. M. Scott, editors. Estimating numbers of terrestrial birds. Studies in Avian Biology No. 6, Cooper Ornithological Society, Lawrence, Kansas, USA.

CARTER M. F., W. C. HUNTER, D. N. PASHLEY, AND K. V. ROSENBERG. 2000. Setting conservation priorities for landbirds in the United States: the partners in flight approach. Auk 117:541–548.

COCHRAN, W. G. 1977. Sampling techniques, third edition. Wiley, New York, New York, USA.

COMMISSION FOR ENVIRONMENTAL COOPERATION (CEC). 1997. Ecological regions of North America: toward a common perspective. CEC, Montreal, Canada.

DEGUM, C., AND E. B. DEGUM. 1988. Trend. Pages 321–324 *in* S. Kotz and N. L. Johnson, editors. Encyclopedia of statistical sciences, volume 9. John Wiley & Son, New York, New York, USA.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE (ESRI). 1998. Understanding GIS: the ARC/INFO method. ESRI, Redlands, Calfornia, USA.

FLATHER, C. H., AND J. R. SAUER. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory songbirds. Ecology 77:28–35.

GEISSLER, P. H., AND J. R. SAUER. 1990. Topics in route regression analysis. Pages 54–57 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service Biological Report 90(1).

GIBBS, J. P., AND S. M. MELVIN. 1997. Power to detect trends in waterbird abundance with call-response surveys. Journal of Wildlife Management 61:1262–1267.

JAMES, F. C., C. E. MCCULLOCH, AND D. A. WIEDENFELD. 1996. New approaches to the analysis of population trends in land birds. Ecology 77:13–27.

KENDALL, W. L., B. G. PETERJOHN, AND J. R. SAUER. 1996. First-time observer effects in the North American breeding bird survey. Auk 113:823–829.

LINK, W. A., AND J. R. SAUER. 1994. Estimating equations estimates of trends. Bird Populations 2:23–32.

———, AND ———. 1995. Estimation of empirical mixing distributions in summary analyses. Biometrics 51:810–821.

———, AND ———. 1997. New approaches to the analysis of population trends in land birds: a comment on statistical methods. Ecology 78:2632–2634.

———, AND ———. 1998*a*. Estimating relative abundance from count data. Austrian Journal of Statistics 27:83–97.

———, AND ———. 1998*b*. Estimating population change from count data: application to the North American breeding bird survey. Ecological Applications 8:258–268.

MANNAN, R. W., M. L. MORRISON, AND E. C. MENSLOW. 1984. Comment: the use of guilds in forest bird management. Wildlife Society Bulletin 12:426–430.

PETERJOHN, B. G., AND J. R. SAUER. 1993. North American breeding bird survey annual summary 1990–1991. Bird Populations 1:52–67.

———, AND ———. 1999. Population status of North American grassland birds from the North American breeding bird survey, 1966–1996. Studies in Avian Biology 19:27–44.

———, ———, AND C. S. ROBBINS. 1995. The North American breeding bird survey and population trends of neotropical migrant birds. Pages 3–39 *in* T. E. Martin and D. Finch, editors. Neotropical migrant birds. Cambridge University Press, New York, New York, USA.

ROBBINS, C. S., D. BYSTRAK, AND P. H. GEISSLER. 1986. The breeding bird survey: its first fifteen years, 1965–1979. U.S. Fish and Wildlife Service Resource Publication 157.

———, J. R. SAUER, R. S. GREENBERG, AND S. DROEGE. 1989. Population declines in North American birds that migrate to the neotropics. Proceedings of the National Academy of Science, Washington, D.C., USA. 86:7658–7662.

RUTH, J. M., D. R. PETIT, J. R. SAUER, M. D. SAMUEL, F. A. JOHNSON, M. D. FORNWALL, C. E. KORSCHGEN, AND J. P. BENNETT. **In press**. Science for avian conservation: priorities for the new millennium. Auk. **UPDATE?**

SAUER, J. R., D. D. DOLTON, AND S. DROEGE. 1994. Mourning dove population trend estimates from call-count and North American breeding bird surveys. Journal of Wildlife Management 58:506–515.

———, AND S. DROEGE. 1990. Wood duck population trends from the North American breeding bird survey. Pages 159–165 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, editors. Proceedings of the 1988 North American Wood Duck Symposium, St. Louis, Missouri, USA.

———, AND ———. 1992. Geographic patterns of population trends of neotropical migrants in North America. Pages 26–42 *in* J. M. Hagan III and D. W. Johnson, editors. Ecology and conservation of neotropical migrant landbirds. Smithsonian Institution Press, Washington, D.C., USA.

———, J. E. HINES, G. GOUGH, I. THOMAS, AND B. G. PETERJOHN. 1997. The North American breeding bird survey results and analysis. Version 96.4. Patuxent Wildlife Research Center, Laurel, Maryland, USA, http://www.mbr-pwrc.usgs.gov/bbs/bbs.html.

———, AND W. A. LINK. 2002. Hierarchical modeling of population stability and species group attributes from survey data. Ecology 83:1743–1751.

———, G. W. PENDLETON, AND B. G. PETERJOHN. 1996. Evaluating causes of population change in North American insectivorous songbirds. Conservation Biology 10:465–478. **COULD NOT FIND–DELETE?**

———, B. G. PETERJOHN, AND W. A. LINK. 1994. Observer differences in the North American breeding bird survey. Auk 111:50–62.

———, AND B. K. WILLIAMS. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. Journal of Wildlife Management 53:137–142.

WILLIAMS, B. K., J. D. NICHOLS, AND M. J. CONROY. 2002. Analysis and management of animal populations. Academic Press, New York, New York, USA.

Received 4 November 2001.
Accepted 21 January 2003.
Associate Editor: Kelly.