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Patuxent's Role in the Development of the North American Breeding Bird Survey

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The North American Breeding Bird Survey (BBS) is a roadside survey of the breeding birds of North America. The BBS provides data from the contiguous United States, Alaska, southern and central Canada, and northern Mexico. Begun in 1966 by Chandler (Chan) S. Robbins at the U.S. Geological Survey (USGS) Patuxent Wildlife Research Center (Patuxent), and now jointly managed by Patuxent, the Canadian Wildlife Service, and the Mexican Commission for the Knowledge and Use of Biodiversity, the survey is conducted primarily in June along more than 5,000 roadside survey routes that are surveyed once each year. Volunteer observers drive the 39.4-kilometer (24.5-mile [mi]) routes, stopping approximately every 800 meters (m) (0.5 mi) to conduct fifty 3-minute point counts during which they record all the birds heard or seen within a 400-m (0.25-mi) radius of the counting location. Observers submit their data for each stop along their routes to the BBS offices in their respective countries, after which the information is made available to the public.

The BBS is unique in its temporal and geographic scale, and it is often the only source of information for geographic studies of important scientific issues such as the effects of climate change, disease, and land-use change on North American bird populations. Wildlife researchers and managers rely on the survey as the authoritative source of information on population change for more than 400 species of North American birds. It was the primary source of data for the State of the Birds Report (North American Bird Conservation Initiative, 2009), a publicly accessible summary of the "big picture" of population change and conservation of North American birds. Nevertheless, even after more than 45 years successfully providing population change data, Patuxent researchers are continuing their efforts to strengthen the BBS and similar surveys. Keeping a survey such as the BBS current in terms of field methods, data management, and analyses is a formidable task, and Patuxent has devoted substantial resources toward all of these activities throughout much of its existence. This chapter describes some of the themes and approaches to the design and analysis of roadside bird surveys that have been used at Patuxent, where the BBS and related surveys conducted by the U.S. Fish and Wildlife Service (USFWS) for mourning doves (*Zenaida macroura*) (the Call-Count Survey [CCS]; Sauer and others, 2010) and American woodcock (*Scolopax minor*) (the Singing-Ground Survey [SGS]; Sauer and others, 2008) have been the focus of research activity since the 1940s.

K.A. Smith and J. Rensel. Breeding Bird Survey volunteers, along historic intercontinental railroad grade on the Peplin Mountain, UY (Utah Breeding Bird Survey route 85251). Photo by U.S. Fish and Wildlife Service.

In this chapter, the term "Patuxent" is used in the "greater Patuxent" sense that Jim Kushlan used during his tenure as Patuxent's director—that is, the historical components that have been merged and divided over the years to become the current-day Patuxent Wildlife Research Center, as well as the colocated USFWS and other groups that once were part of entities such as the Migratory Bird Populations Station.

Background of the Breeding Bird Survey

The USFWS had a long history of bird population research before the initiation of the BBS. Roadside surveys of singing grounds of American woodcock were pioneered by Mendall and Aldous (1943), and became a standard approach

for monitoring the species. Sheldon (1953) conducted studies to address the number, duration, and protocols for a stop-based roadside woodcock survey, and Kozicky and others (1954) conducted a statistical review of the approach, recommending random route locations. Chan Robbins helped analyze and summarize woodcock and mourning dove surveys during the 1950s, and participated in the preparation of status reports used in setting harvest regulations for these species. Although Chan had a great deal of experience with alternative bird counting approaches such as atlases, breeding bird censuses, Christmas Bird Counts (CBC), and roving censuses, he realized that the roadside survey had advantages over the alternatives as an efficient and relatively consistent way of collecting data over large areas. The method also had the advantage of having undergone a substantial evolution in approach and several methodological reviews while the USFWS was implementing the woodcock and dove surveys.

The critical difference between a nongame survey and the dove and woodcock surveys was that states were willing to devote resources to ensure adequate monitoring of harvested species, but no resources were available for nongame species. Consequently, when considering how to implement a North American breeding bird survey, Chan could not rely on the existing network of State personnel to conduct the counts. Fortunately, his birding activities provided him with a unique connection to the nationwide pool of birdwatchers. Chan was a major figure in birdwatching and, through State and regional bird clubs, the National Audubon Society, and a wide array of friends and colleagues throughout the continent, he envisioned staffing a survey that would utilize volunteers in the same way that the CBC had, but that would also have the rigor of the USFWS roadside surveys. Chan described his pioneering activities in developing the BBS in several presentations and publications (for example, Robbins and others, 1986; C.S. Robbins, U.S. Geological Survey, oral commun., 2006; Robbins, 2016). The reader is referred to these sources for Chan's first-hand account of his use of the environmental awareness spawned by Rachel Carson's work to establish the need for a nationwide breeding bird survey (see also Sauer, 2008).

Tending to the Survey: Research and Management of a Complex Survey

Chan Robbins wanted the BBS to be relevant, and recognized from the start that relevance would require (1) designing a survey that would provide credible information; (2) implementing the survey efficiently in terms of the logistics of recruiting the observers and providing support in the form of information (data forms, maps) and communications (a labor-intensive task in the 1960s); (3) managing data (also very labor intensive); and (4) analyzing and effectively presenting the results. These needs are reflected in Chan's early requests for volunteers (Robbins, 1965b) and his prompt summary of the data (Robbins, 1965a). Because availability of and access to results as well as timely feedback to observers are critical aspects of a successful survey, Chan presented the summarized results on maps to facilitate the public's appreciation of the data (fig. 1; Robbins, 1965a).

The scope and goals of the BBS are extremely ambitious, and constant research and innovation are needed to keep pace with technological advances and maintain the credibility of the survey. Research associated with the survey has been a focus of field and statistical work at Patuxent over the past 45 years. The sections below summarize some of this research and describe how it has enhanced the value of the survey. They are organized in parallel with the essential elements of a successful survey listed above, but focus particularly on

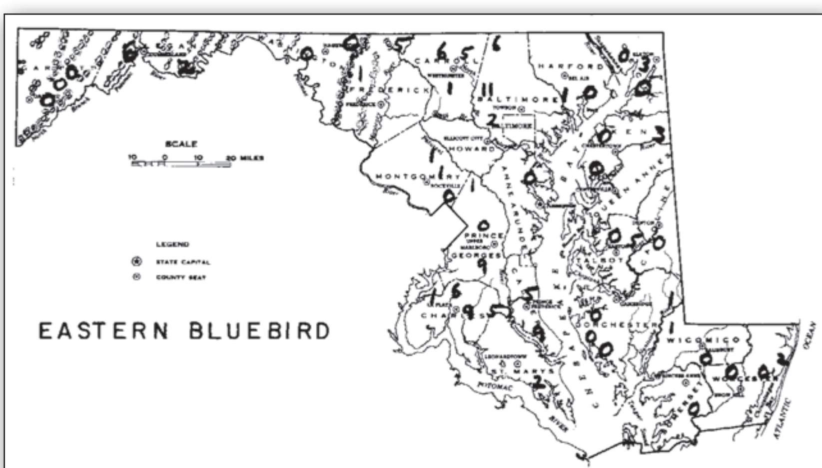


Figure 1. Eastern bluebird (*Sialia sialis*) counts for Maryland from the 1965 Breeding Bird Survey test run. (From Robbins, 1965a)

features 2 and 4 (survey implementation and communication of results), both of which are traditional functions of research that have been an important component of Patuxent for the duration of the survey.

Survey Design

Chan designed the survey to be consistent with the general approaches used by the CCS and SGS. As both of these surveys were used by management and had been tested through years of critical review and methods development, they were a good model for a logistically feasible survey that provided relevant data. Chan also conducted a variety of methodological studies in 1965 to evaluate specific aspects of the design, such as duration of counts and number of stops along the roadside routes (Robbins and others, 1986). From the start, however, Patuxent researchers criticized two important aspects of the survey. First, roadsides constitute an incomplete framework for sampling, as off-road habitats are not covered. Second, no observers count all the birds on a BBS route, and the proportion of birds missed in counting varies by species, observer, environmental conditions, date, time of day, and many other variables. Quantitative researchers at Patuxent in the 1960s were particularly critical of the BBS design, and vigorous arguments occurred about the need to conduct off-road counts and to collect additional data to control for variations in rates of bird detection (Charles Henny, U.S. Fish and Wildlife Service, oral commun., 1965). These issues have been the focus of much research at Patuxent over the past 40 years.

The question of whether the BBS needs to incorporate methods that allow estimation of rates of bird detection was, and still is, particularly controversial at Patuxent. Detectability estimation from count-based surveys has been a productive research area for Patuxent investigators, and many current and former Patuxent staff members have made important contributions in this area; all of the methods considered as possible approaches for adding detection rates to the BBS have been the subject of Patuxent studies. Patuxent alumni David Anderson and Kenneth Burnham, along with many students, have promoted line transect and capture-recapture methods for estimating detection rates of birds and other taxa.

At Patuxent, James Nichols and colleagues pioneered the use of capture-recapture and other approaches for analyzing count data to estimate species occupancy, abundance, and species richness. Andy Royle and colleagues described and implemented innovative ways of estimating detection rates from replicate surveys. William Link, William Kendall, and others addressed the question of detectability from a different perspective, considering it to be a feature of known covariates (such as the observer running the route), and modeling and controlling for these covariates in the analysis. Other quantitative ecologists, notably Ted Simons, Kenneth Pollock, and colleagues at North Carolina State University (Raleigh), have continued method development and conducted field trials to implement approaches for estimating detection rates. Finally, in his dual role as State BBS coordinator in Mississippi and Patuxent researcher, Daniel Twedt has implemented a pilot project to test the applicability of some of the field methods for estimating detectability along routes established in the Gulf Coast Network of national parks.

Most of these studies have included enthusiastic participation by field-oriented researchers and BBS coordinators, including (among many others) Patuxent biologists Chan Robbins, Deanna Dawson, Barbara Dowell, Daniel Boone, Danny Bystrak, Sam Droege, Bruce Peterjohn, Keith Pardieck, Jane Fallon, and David Ziolkowski. The volunteer BBS observers have also been more than willing to donate their time to participate in studies that use BBS routes as sample units, permitting regional analysis. This involvement of a large number of Patuxent staff members and volunteers is a model for collaborative science.

Evaluation of the consequences of the roadside nature of counts has also invoked the collaborative spirit of Patuxent staff members, most notably in a U.S. Environmental Protection Agency-funded study, in which data were collected both on survey routes and on nearby off-road routes. This study documented differences in species abundance on and off roads (Sauer and others, 2013). Another approach to addressing this question over the years has been to evaluate habitat differences between on- and off-road routes, first from aerial photographs (Keller and Scallan, 1999), then from interpreted Landsat data (National Land Cover Data [NLCD]) (Vogelmann and others, 2001) (Sauer and others, 2013; fig. 2).

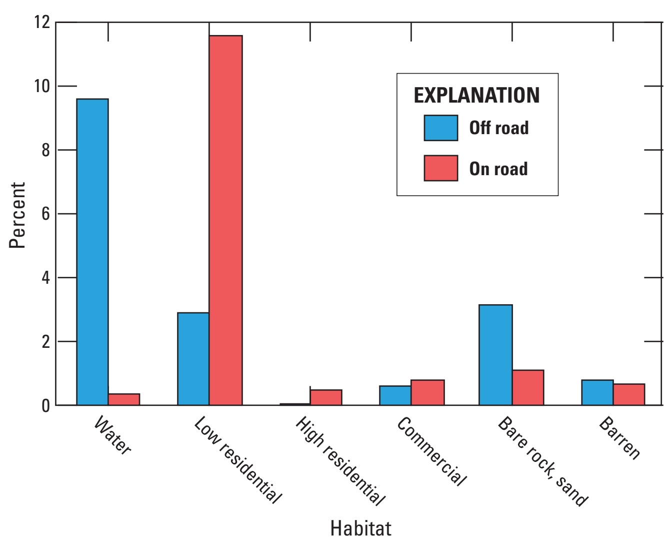


Figure 2. Percentages of six habitats near roads (at sampling sites within 400 meters [0.25 miles] of Breeding Bird Survey routes) and off roads (at sampling sites more than 400 meters from roads) in a study conducted in Maryland. (Data from Keller and Scallan, 1999; Sauer and others, 2013)

NLCD data provide excellent opportunities to evaluate habitats (fig. 3); several investigators have used them to assess whether habitats differ between on- and off-road routes (for example, Veech and others, 2012), or even to assess differences in rates of change in habitats between on- and off-road routes (Hanan, 2009). These studies have not shown major differences in habitats or rates of change in habitats between on- and off-road routes, although they have revealed that some habitats appear to be found more frequently near (for example, residential housing) or away from (for example, water) roads.

Survey Analysis and Presentation

Several themes emerge with respect to the history of the BBS. The first is that improvements in BBS analysis commonly were made possible by advances in computational technology. Early on in the BBS program, Patuxent's computers were not adequate to conduct analyses. Enormous amounts of time were spent trying to develop methods that could be used with the available computers, and the methods that ultimately were used to summarize BBS data typically were only approximations of the desired estimation. This limitation was more

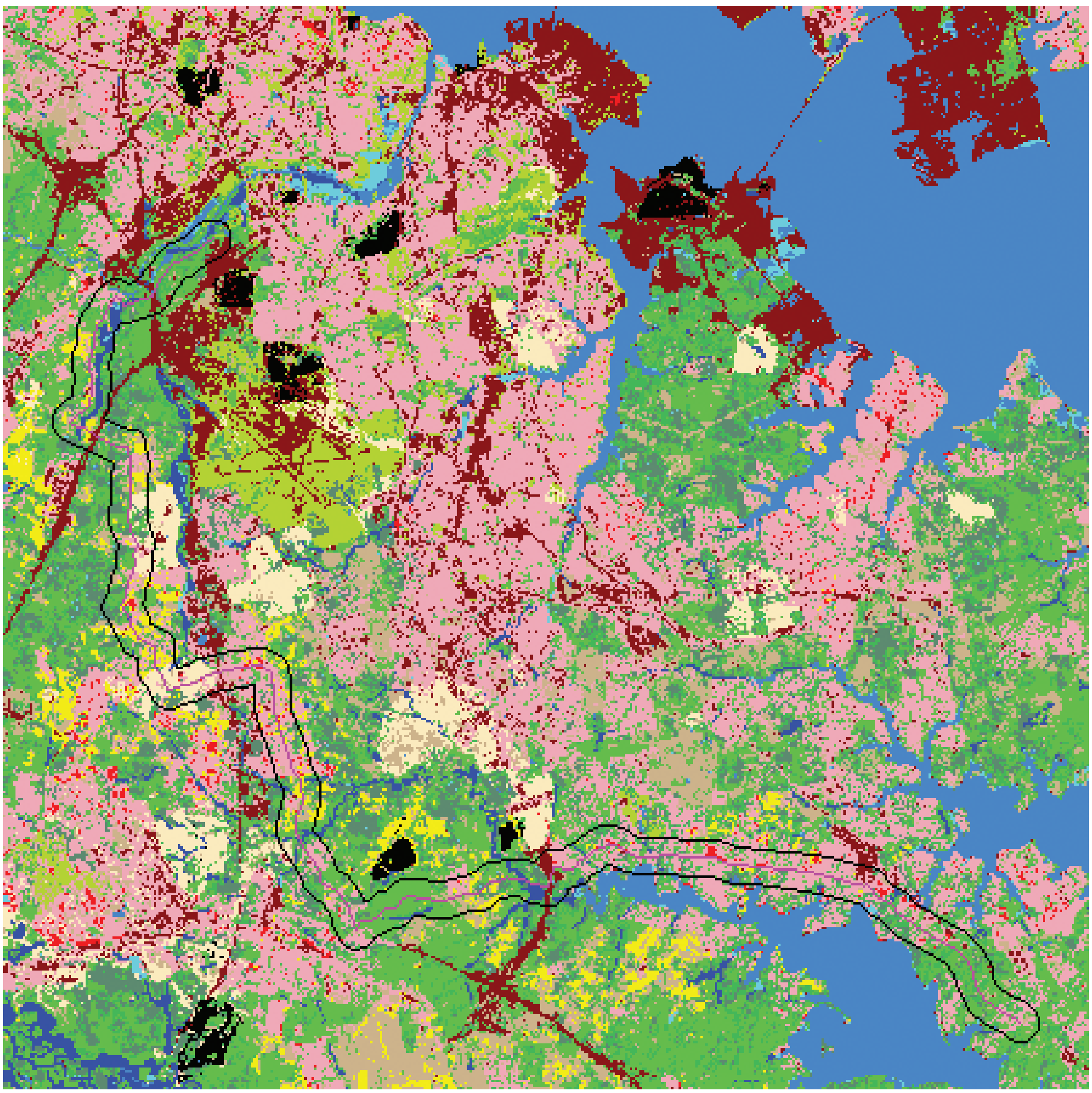


Figure 3. Severna Park, MD, Breeding Bird Survey route path (buffered at 400 meters [0.25 miles]) superimposed on National Land Cover Database (Vogelmann and others, 2001). (From U.S. Geological Survey, n.d.; map metadata accessed March 25, 2015, at http://www.mbr-pwrc.usgs.gov/bbs/trend/rtehtm13a_nlcd.html)

than just a computer issue, as new and increased computing capabilities expanded the space for and generated statistical innovation. This was clearly the case in BBS analyses.

A second theme is that innovation in methods at Patuxent has always been a collaborative effort, facilitated by the presence of mathematical statisticians, statistician/programmers, and biologists, all of whom work together to adapt existing computational resources to research needs, develop new approaches to analysis that can fully use new technology, and track emerging technologies for use in BBS analyses. This collaboration has been particularly important in terms of the deeper statistical aspects of estimation of population change, and Patuxent has been fortunate that a mathematical statistician with a focus on count surveys has been directly involved in analyzing BBS data. This involvement has paved the way to innovations such as estimating equations and hierarchical models, and has provided the expertise needed to apply the computer-intensive Bayesian statistical approaches that represent the current analysis paradigm.

The third theme is long-term participation by scientists. Consistent support for the program has led to great institutional memory and long-term stewardship of the survey. Chan Robbins has been present from the start; Danny Bystrak, Sam Droege, and Bruce Peterjohn are all former BBS coordinators working at Patuxent and are still active in the program, and collectively Paul Geissler, Bill Link, and I (John Sauer) have participated in the analysis of BBS data through 30 years. Consequently, data analysts have the great advantage of being able to talk to the people who actually designed the survey, managed the data, and conducted earlier analyses.

Three Analytical Approaches

Analysis of BBS data is difficult because (1) the survey has a very large geographic scope; (2) survey routes vary greatly in consistency of coverage within and among regions; (3) the counting abilities of different observers, even those judged to be competent birders, can differ greatly; and (4) modeling change through time is fundamentally controversial, even without these other factors. Consequently, all serious analyses of these data attempt to address these four characteristics of BBS data analysis, and many methods have been developed to control and model this "unruly" dataset. Moreover, many investigators download BBS data and conduct summary analyses that ignore one or more of these inherent characteristics of the dataset. Evaluating these analyses and, if necessary, controlling for them has been an ongoing concern for Patuxent scientists.

BBS analysis conducted at Patuxent during the period 1966–2013 can generally be placed into one of three "paradigms," each of which takes an alternative approach to accommodating these concerns by using statistical methods and computing technologies available at the time they were used. Placed in temporal order, the paradigms are (1) fairly simple summary analyses that relied on estimating regional change between adjacent years as ratios of comparable counts on routes and portraying them as scaled changes from some base year; (2) route-regression approaches, in which route-specific trends are used as replicates for estimating change; and (3) hierarchical models that use Bayesian methods to fit log-linear models with year effects.

Base Year Methods

Base year methods were used to analyze data from roadside surveys for American woodcock and mourning dove well before the initiation of the BBS, and are described in the scientific reports that provided summary results to managers (for example, Robbins, 1960; Kiel, 1960). The methods described in these reports show the essential components of a regional analysis. Within a region, computation of estimated change between adjacent years was estimated by using routes surveyed by the same observer, and the composite change over a longer interval was determined by multiplying a series of yearly change estimates by an estimated mean count in a base year. These indexes of change from the base year described an estimated composite time series for the region. Change for groups of regions was calculated by using an area-weighted average of the indexes from the component regions (Kiel, 1960).

Early summaries of BBS data show these general ideas, but also show a variety of alternative summaries as Chan and his colleagues explored the possibilities of summarizing North American bird population change (for example, Robbins and Van Velzen, 1969, 1974). Unfortunately, analysis of BBS data, which included data from more than 500 species of North American birds collected on thousands of survey routes distributed over both the United States and southern Canada (fig. 4), proved to be very challenging. Many species were encountered only infrequently on routes, observers tended to differ greatly in quality of information, not all routes were surveyed, and the expansion of the survey into new regions resulted in data that were very unequally distributed in space and time. Analysts were greatly constrained in the types of analyses that could be conducted, and cost was typically an issue, limiting the ability to apply complicated linear models. Computing proportional changes on comparable routes from a base year was relatively simple and could be readily implemented for BBS data.

Route Regression Approaches

Geissler and Noon (1981) provide a comprehensive summary of the analysis of the BBS through the 1970s. They acknowledge the need to control for differing routes used in change estimation, but identify several statistical concerns associated with the base year approach of multiplying mean counts from some initial year by yearly changes based on

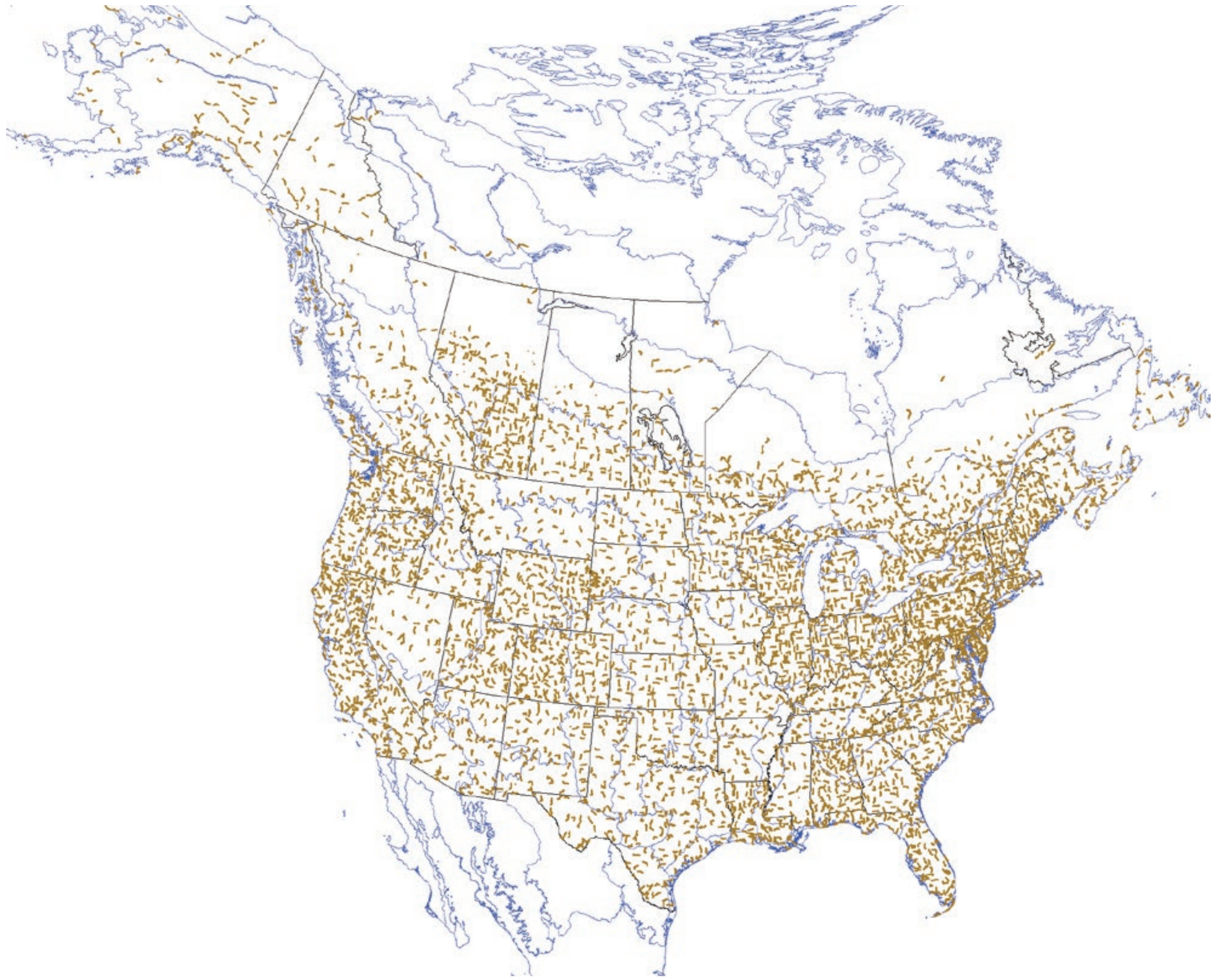


Figure 4. North American Breeding Bird Survey route locations. (From Sauer and others, 2013; note limited density of locations in northern and western regions; map metadata accessed March 25, 2015, at http://www.mbr-pwrc.usgs.gov/bbs/geographic_information/GIS_shapefiles_2013.html)

comparable routes. They instead suggest a "route regression" analysis, in which change is estimated by using regression analysis (log counts as a function of years) on individual routes, and then combined in a weighted average to form a regional composite estimate of change. The advantage of this approach is that observer differences can be controlled for in the analysis by including observer information as a covariate. Route regression methods were implemented for the survey and used in the 15-year summary of the BBS (Robbins and others, 1986), an important summary of the survey. Paul Geissler, a key figure in its development, did an admirable job of developing a robust analysis that could be applied to almost any BBS dataset.

The route regression method, with several modifications, was used as the primary BBS analysis method from 1986 to 2008. Like the base year method, route regression analyses could be implemented with relatively limited computer resources. It was a robust approach in that it could be implemented for almost any dataset, no matter how unbalanced with respect to patterns of years when routes were surveyed. Unfortunately, this adaptability had a cost in terms of limited capability for inference, and aspects such as the precision weightings that were criticized as being extemporaneous (Sauer and Link, 2011). With this complicated weighted average, no overall model could form a framework for estimation; variances needed to be calculated through bootstrapping, a tedious nonparametric procedure. Route regression produced a summary of interval-specific trend, but many people wanted more information—at least a graph showing population indices by year. Sauer and Geissler (1990) suggested an approach for estimating composite yearly indices of abundance that summarized the pattern around the trend line, but estimating variances of these annual indices was not possible.

Paul Geissler weathered a great deal of criticism before the route regression method was accepted, and it underwent periodic review and modification throughout the time of its

use. Concerns about estimation of change on routes done by using simple regression on log counts was addressed in 1994, when Link and Sauer (1994) suggested using estimating equations to estimate trend on routes. However, the limited nature of the trend summaries, and the advent of methods that permitted comprehensive summaries with variances from the data, ultimately led to the replacement in 2008 of the route regression method with a hierarchical model.

Hierarchical Models

In 2002, Link and Sauer (2002) suggested the use of a log-linear hierarchical model for analysis of BBS data. Hierarchical models are a flexible means of modeling complex, multiscale longitudinal surveys such as the BBS. Attributes can be estimated at different scales (for example, routes, strata, continent-wide); the repeated nature of counts within survey routes can be modeled; nuisance factors such as differences in counting ability among observers and observer start-up effects can be controlled for; and year effects can be treated as random and estimated even when some years are poorly sampled (again, a common issue in the BBS). Most important, the model can be fit by using Markov chain Monte Carlo, an extremely computer-intensive method that became accessible to the scientific community when the software program WinBUGS (Lunn and others, 2000) was released in 1989. These methods require a Bayesian approach to statistics, in which all quantities are random and, rather than providing estimates of unknown fixed parameters, the goal of inference is to estimate the distributions of unknown (but variable) quantities of interest. Bayesian methods have an appealing conceptual simplicity and avoid the nuanced discussions that commonly afflict standard (non-Bayesian, or “Frequentist”) statistical inference; they also have the great practical advantage of providing the only way to develop a comprehensive statistical framework for estimating population change from BBS data.

Bill Link became interested in these methods when he was developing approaches for summarizing collections of species trends (that is, how many species are increasing in population), and it became evident that Bayesian methods were a natural approach for estimating BBS and other data. He gradually became an important proponent of the use of these methods in ecological statistics (for example, Link and Barker, 2010).

Sauer and Link (2011) published a comprehensive comparative analysis of population change using these hierarchical models in 2011, and routinely continue to provide hierarchical model results to users. One great advantage of hierarchical models is their extreme flexibility. They provide a basis for an infinite number of elaborations, and users can associate attributes with population relative abundance and change at any scale of interest. They also can include submodels to accommodate observational components such as detectability.

Maps of Breeding Bird Survey Data

The benefits of the visual display of BBS data have long been obvious. Chan Robbins (1965a) made simple maps by writing numbers of birds encountered on routes in Maryland from the 1965 test survey (fig. 1); Danny Bystrak qualitatively estimated contour lines for maps in a summary of the BBS’s first 15 years (Robbins and others, 1986) and other publications. By 1995, Patuxent was producing contour maps from surfaces based on Kriging and other surface modeling procedures (Sauer and others, 1995). Currently (2016), inverse-distance maps of both trend and abundance are made for more than 420 bird species (fig. 5). More sophisticated approaches such as hierarchical models have been implemented for selected species, but are not routinely applied to BBS data (Thogmartin and others, 2004).

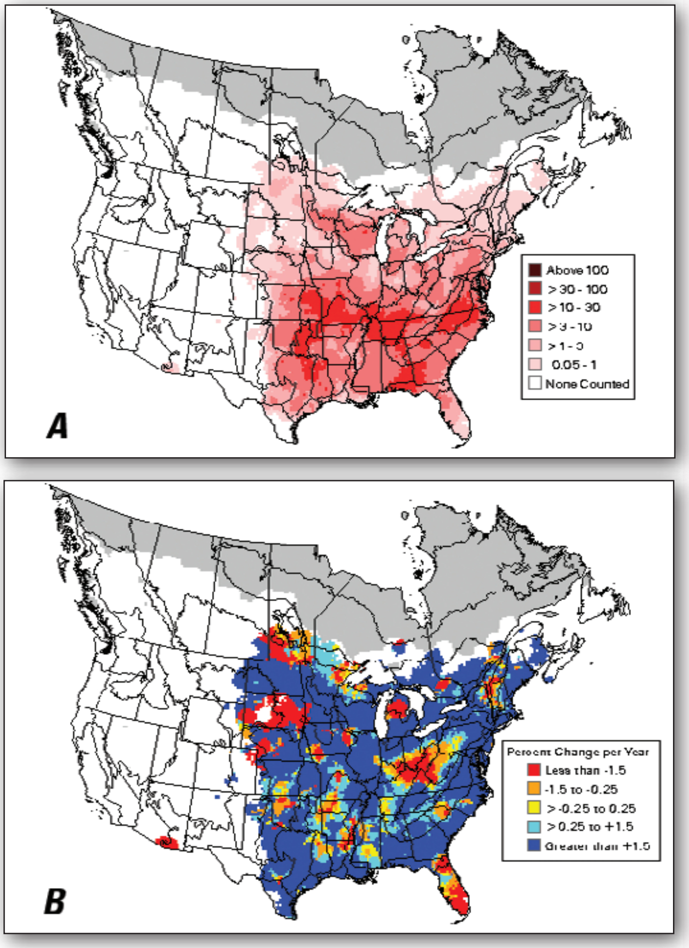


Figure 5. *A*, Relative abundance (summer distribution), 2006–10, and *B*, population change (trend) of Eastern bluebirds (*Sialia sialis*) in the 1966–2010 Breeding Bird Survey (BBS) analysis. (From Sauer and others, 2011; accessed February 16, 2011, at *A*, http://www.mbr-pwrc.usgs.gov/bbs/ra2010/ra7660.htm and *B*, http://mbr-pwrc.usgs.gov/bbs/tr2010/tr07660.htm; gray areas are regions outside the BBS area)

Internet-Based Summaries

In 1997, Patuxent began providing comprehensive summaries of BBS data to users on the World Wide Web (WWW) (Sauer and others, 1997). Jim Hines and I had been developing a stand-alone, PC (personal computer) -based program for summary and display of population trends, annual indices, and abundance and trend maps that we called program VUBBS. The material we had been producing was easily converted to the HyperText Markup Language (html) format that is still (2016) a primary means of displaying WWW content on browsers. Many of the results were prepackaged; we conducted the analysis, reviewed the results for consistency and correctness, and then provided interactive lists from which users could select species data for display. Because the results are served from a computer at Patuxent, we had great flexibility to develop new summaries by means of Perl scripts and other programs that allowed users to run programs on Patuxent’s computers. In this way, users could estimate population trends interactively for any species using predefined regions. These online summary results are revised annually, are available to any user, and have proven to be effective tools for bird conservation (figs. 6 and 7).

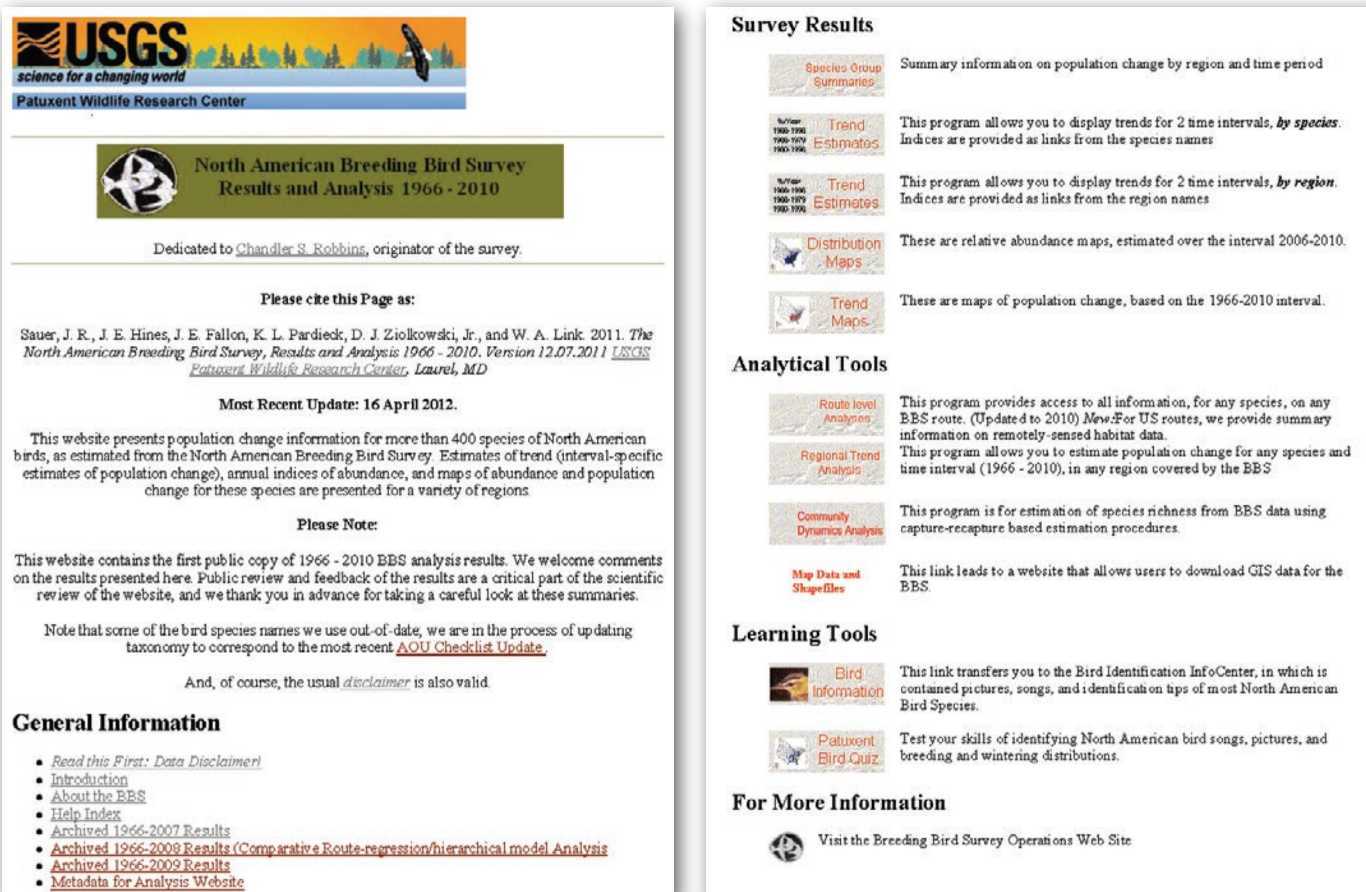
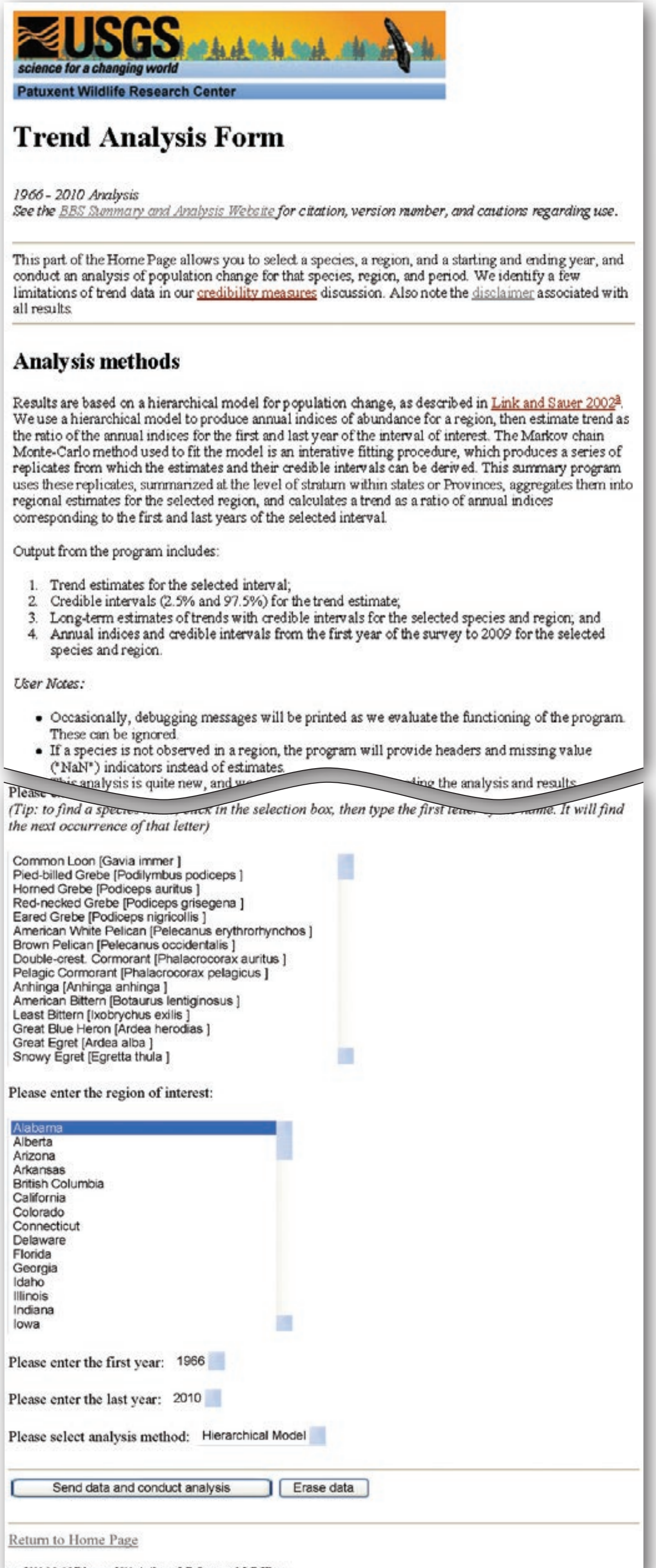


Figure 6. Screen capture of the home page of the North American Breeding Bird Survey results and analysis Web site, 1966–2010. (From Sauer and others, 2011)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Trend Analysis Form

1966 - 2010 Analysis
See the BBS Summary and Analysis Website for citation, version number, and cautions regarding use.

This part of the Home Page allows you to select a species, a region, and a starting and ending year, and conduct an analysis of population change for that species, region, and period. We identify a few limitations of trend data in our credibility measures discussion. Also note the disclaimer associated with all results.

Analysis methods

Results are based on a hierarchical model for population change, as described in Link and Sauer 2002[a]. We use a hierarchical model to produce annual indices of abundance for a region, then estimate trend as the ratio of the annual indices for the first and last year of the interval of interest. The Markov chain Monte-Carlo method used to fit the model is an interative fitting procedure, which produces a series of replicates from which the estimates and their credible intervals can be derived. This summary program uses these replicates, summarized at the level of stratum within states or Provinces, aggregates them into regional estimates for the selected region, and calculates a trend as a ratio of annual indices corresponding to the first and last years of the selected interval.

Output from the program includes:

1. Trend estimates for the selected interval;
2. Credible intervals (2.5% and 97.5%) for the trend estimate;
3. Long-term estimates of trends with credible intervals for the selected species and region; and
4. Annual indices and credible intervals from the first year of the survey to 2009 for the selected species and region.

User Notes:

- Occasionally, debugging messages will be printed as we evaluate the functioning of the program. These can be ignored.
- If a species is not observed in a region, the program will provide headers and missing value ("NaN") indicators instead of estimates.
- This analysis is quite new, and we ... ding the analysis and results

Please ...
(Tip: to find a species ... click in the selection box, then type the first letter ... name. It will find the next occurrence of that letter)

Common Loon [Gavia immer]
Pied-billed Grebe [Podilymbus podiceps]
Horned Grebe [Podiceps auritus]
Red-necked Grebe [Podiceps grisegena]
Eared Grebe [Podiceps nigricollis]
American White Pelican [Pelecanus erythrorhynchos]
Brown Pelican [Pelecanus occidentalis]
Double-crest. Cormorant [Phalacrocorax auritus]
Pelagic Cormorant [Phalacrocorax pelagicus]
Anhinga [Anhinga anhinga]
American Bittern [Botaurus lentiginosus]
Least Bittern [Ixobrychus exilis]
Great Blue Heron [Ardea herodias]
Great Egret [Ardea alba]
Snowy Egret [Egretta thula]

Please enter the region of interest:

Alabama
Alberta
Arizona
Arkansas
British Columbia
California
Colorado
Connecticut
Delaware
Florida
Georgia
Idaho
Illinois
Indiana
Iowa

Please enter the first year: 1966

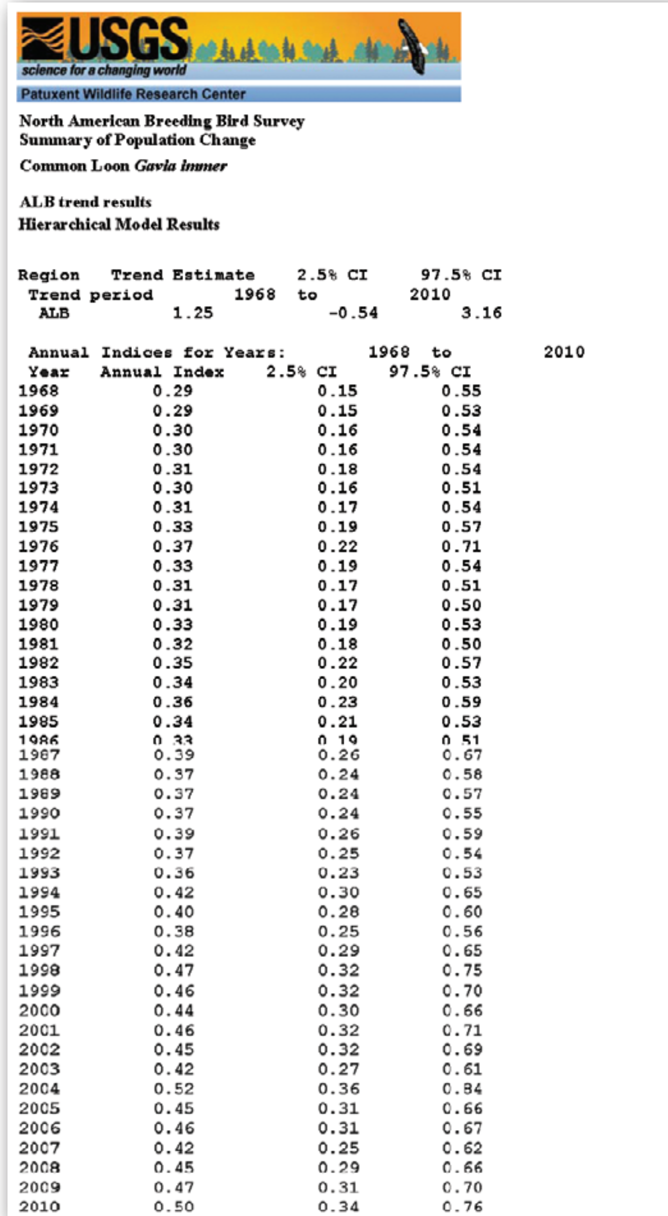
Please enter the last year: 2010

Please select analysis method: Hierarchical Model

Send data and conduct analysis | Erase data

Return to Home Page

ver 2011.0.0, 16 February 2011, Authors: J. R. Sauer and J. E. Hines.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North American Breeding Bird Survey
Summary of Population Change
Common Loon *Gavia immer*

ALB trend results
Hierarchical Model Results

Region	Trend Estimate	2.5% CI	97.5% CI
Trend period	1968	to	2010
ALB	1.25	-0.54	3.16

Annual Indices for Years: 1968 to 2010

Year	Annual Index	2.5% CI	97.5% CI
1968	0.29	0.15	0.55
1969	0.29	0.15	0.53
1970	0.30	0.16	0.54
1971	0.30	0.16	0.54
1972	0.31	0.18	0.54
1973	0.30	0.16	0.51
1974	0.31	0.17	0.54
1975	0.33	0.19	0.57
1976	0.37	0.22	0.71
1977	0.33	0.19	0.54
1978	0.31	0.17	0.51
1979	0.31	0.17	0.50
1980	0.33	0.19	0.53
1981	0.32	0.18	0.50
1982	0.35	0.22	0.57
1983	0.34	0.20	0.53
1984	0.36	0.23	0.59
1985	0.34	0.21	0.53
1986	0.33	0.19	0.51
1987	0.39	0.26	0.67
1988	0.37	0.24	0.58
1989	0.37	0.24	0.57
1990	0.37	0.24	0.55
1991	0.39	0.26	0.59
1992	0.37	0.25	0.54
1993	0.36	0.23	0.53
1994	0.42	0.30	0.65
1995	0.40	0.28	0.60
1996	0.38	0.25	0.56
1997	0.42	0.29	0.65
1998	0.47	0.32	0.75
1999	0.46	0.32	0.70
2000	0.44	0.30	0.66
2001	0.46	0.32	0.71
2002	0.45	0.32	0.69
2003	0.42	0.27	0.61
2004	0.52	0.36	0.84
2005	0.45	0.31	0.66
2006	0.46	0.31	0.67
2007	0.42	0.25	0.62
2008	0.45	0.29	0.66
2009	0.47	0.31	0.70
2010	0.50	0.34	0.76

Figure 7. Screen capture of Web site showing an example of the results obtained by using the interactive program for summarizing population change from North American Breeding Bird Survey data (http://www.mbr-pwrc.usgs.gov/bbs/trend/tf11.html, accessed February 16, 2011). The program is shown in the left and center columns; the right column shows a results summary for Common Loons (*Gavia immer*) in Alberta, Canada.

A "Living" Survey (Past, Present, and Future)

The BBS, like any survey, can never be considered a finished product, but must be subject to modification to incorporate new ideas and address newly discovered (or even long-term) deficiencies. Patuxent researchers have focused on improving the analysis of this important survey, conducting field studies on the process of counting birds (for example, Keller and Fuller, 1995), and evaluating the consequences of detectability and roadside survey constraints. In addition, Patuxent has made the survey and analyses increasingly accessible to the scientific community through computer programs and technical support. Many researchers use BBS data, and their analyses often generate new ideas and raise (or quell) concerns about the survey. Making the survey analytical results and tools available facilitates that work. The interactive analysis program on the Breeding Bird Survey Web site (http://www.mbr-pwrc.usgs.gov/bbs/bbs.html, accessed February 16, 2011), for example, allows users to select data by region and period for analysis. This interaction between the organization that conducts the survey and the community that uses the survey data is critical for the long-term sustainability of the survey, as it maintains a focus on ascertaining and meeting user needs.

Patuxent has long taken a leadership role in summarizing this important survey. The key to the survey's success is constant revision and research input into the "routine" yearly summaries of the data. Another key component of this success is the mutual respect and collaborative research skills of the BBS staff members, ranging from ornithologists, who inform the analysis with natural history and taxonomic information; to computer programmers, who provide the programming skills and Internet expertise to allow implementation of analysis and summary programs; to mathematical statisticians, who authoritatively navigate the increasingly complicated methods now employed for BBS data analysis. Although administrators may, at times, underestimate the value of statistical analysis in ecological research and relegate statisticians to a supporting role, such a philosophy could undermine the success of a complex and evolving survey such as the BBS. BBS researchers have been fortunate over the years that Patuxent's administrators have recognized that the effective running and maintenance of the survey requires a collaborative partnership.

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Female killdeer guarding eggs at Patuxent Research Refuge, Laurel, MD, 2007. Photo by Matthew C. Perry, U.S. Geological Survey.