A Retrospective Perspective: Evaluating Population Changes by Repeating Historic Bird Surveys

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Abstract

Acquiring an accurate picture of the changes in bird populations often involves a tradeoff between the time and effort required to complete the surveys and the number of years spent surveying the bird populations. An alternative approach to long-term monitoring efforts is to collect current data and contrast those with data collected earlier in a similar fashion on the same study site(s). To evaluate changes in bird populations, we repeated two extensive surveys, one in North Dakota (1967 vs. 1992-1993) and the other in the Platte River Valley of Nebraska (1979-1980 vs. 2001), where large areas of native vegetation had been converted to agriculture. We use these examples and others from the literature to illustrate the advantages and disadvantages of using historical data as a frame of reference for population changes.

Key words: bird populations, historic surveys, long-term monitoring, Nebraska, North Dakota, population changes.

Introduction

Monitoring provides important information about the changes in bird populations, as well as information to assess the consequences of management activities (Johnson 2000, Sauer 2000). An essential component of long-term monitoring is the repeated collection of data over time. Ideally, data-gathering should occur every year for many years, although, realistically, data collection over many consecutive years may not be feasible. Budget, time, and personnel constraints might limit or preclude long-term monitoring programs. In some cases, a monitoring program may have begun too late to provide useful data for conservation or management efforts or to detect incipient population changes. For example, the North American Breeding Bird Survey (BBS), which began in 1966, is the oldest large-scale, long-term monitoring program for breeding birds in North America, but the program is only 36 years old and began well after most of the major habitat changes that occurred after European settlement. Little historical information exists on large-scale changes of breeding bird populations in North America beyond that provided by the BBS (Peterjohn et al. 1995). Moreover, the BBS has provided little insight into the factors responsible for those population changes. Specifically, the BBS was not designed for small-scale, habitat-specific analyses (Sauer 2000), and the resolution of the BBS is too coarse for regional decision making (Hutto and Young 2002).

An alternative approach to understanding bird population changes is to repeat a historical survey, that is, to collect current data and contrast those with data collected earlier in a similar fashion on the same study area(s). A key component of this approach is that the historical survey provides a standard point-in-time measurement against which population changes can be assessed. A flavor of this approach is encapsulated in the following comments by Roberts (1991:180): "Monitoring is usually surveying over time: a series of surveys, repeated to detect changes. If enough is known about how any survey was done, however long ago, it can be repeated and converted into 'monitoring.'"

Historical surveys have played an important role in evaluating bird population changes in North America (*table 1*). Although historical surveys provide a rich source of baseline data, repeating these surveys can be a challenging effort. We used this approach to examine changes in breeding bird populations in two regions in the mid-continent, one in North Dakota (1967 vs. 1992-1993) and the other in the Platte River Valley of Nebraska (1979-1980 vs. 2001), where extensive areas of native vegetation have been converted to agriculture and where the BBS and other long-term monitoring programs provide only sparse coverage. We believe that others will benefit from our experiences in repeating these two historical surveys. This paper is intended to illustrate the advantages and disadvantages in repeating a historical survey (*table 2*) and some of the challenges that might arise when using this approach to

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Table 1— *Some historical North American studies that were repeated to examine changes in breeding bird populations.*

	Original survey		Repeated survey(s)		Minimum
Location	**Year(s)**	**Source(s)**	**Year(s)**	**Source(s)**	**no. years between surveys**
Cambridge, MA	1860-73, 1900-04	Brewster 1906	1940-43, 1960-64	Walcott 1974	80
State of IL	1906-1909	Forbes 1913; Forbes and Gross 1922	1956-1958	Graber and Graber 1963	50
Legal section in Woodbury County, IA	1916	Abel 1920	1926	Spiker 1927	10
			1982	Lowther 1984	66
Quaker Run Valley, Allegany State Park, NY	1930-1931	Saunders 1936	1983-1985	Baird 1990	53
Grapevine Mts., Death Valley National Monument, NV	1939-1940	Miller 1945	1971, 1973	Johnson 1974	32
Potosi Mt., Clark County, NV	1939	Miller 1946	1971	Johnson 1974	32
Clark Mt., San Bernadino County, CA	1939	Miller 1940	1973-1977, 1989	Johnson 1995	34
Northern IA	1940	Kendeigh 1941	1989	Bernstein et al. 1990	49
Fairfax County, VA	1942	Aldrich 1942	1979	Aldrich and Coffin 1980	37
Appalachian Mts., NC and TN	1944-1946	Ganier and Clebsch 1944, 1946	1996-1998	Haney et al. 2001	52
Highlands Plateau, Macon County, NC	1946-1947	Odum 1950	1959-1960, 1971-1972	Holt 1974	13
Prince Georges County, MD	1947	Stewart and Robbins 1947	1975-1976	Whitcomb et al. 1977	28
Great Smoky Mountains, TN and NC	1947-1948	Fawver 1950	1982-1983	Wilcove 1988	35
Southern WI	1952-1954	Bond 1956	1979	Ambuel and Temple 1982	27
State of ND	1967	Stewart and Kantrud 1972	1981-1982	Besser 1985 (blackbirds only)	14
			1982	Rolandelli 1986 (crows only)	15
			1990	Nelms et al. 1994 (blackbirds only)	23
			1992-1993	Igl and Johnson 1997, Igl et al. 1999	25
Jackson Hole, Grand Teton National Park, WY	1966-1968	Cody 1974	1991-1992	Cody 1992	25
Platte River Valley, NE	1979-1980	Faanes and Lingle 1995	2001	Igl and Johnson, unpubl. data	22
Southeastern AZ	1985-1986	Strong and Bock 1990	1994-1995	Hall et al. 2002	9

Table 2— *The advantages and disadvantages of repeating a historical survey.*

Advantages	Disadvantages
Study design and methodology already have been developed.	Study design and methodology may be flawed.
Study sites already have been selected.	Study sites may not be representative of area; landowners may deny access to original study sites; study site locations and boundaries may be unknown.
Historical survey collected baseline information on birds and habitats.	Important information may not have been collected in the initial study; original investigators may not have anticipated a repeated study.
Details of field methodology and study design are written in publications.	Details of field methodology and study design may not be written in publications
Original investigators, observers, and field data can provide details of sampling design and methodology.	Original investigators or observers may have passed away or may not be able to recall details concerning sampling design or methodology; original field data may no longer exist.
Can examine changes in bird populations and habitats between the two periods.	Comparisons between the two periods may not be valid; results may reflect observer differences or annual variation rather than real population changes.
Original data-gathering occurred many years or decades in the past, often before many long-term monitoring efforts began.	Data were collected for only two periods; no data were collected between the two time periods.
Can verify population changes using independent surveys (e.g., historical vs. BBS).	Populations changes may differ between independent surveys (e.g., local vs. regional); population changes in independent surveys may reflect different phenomena.

evaluate population changes. We hope that our experiences and those in the literature (*table 1*) will serve to highlight these issues. Finally, we make suggestions for present surveys that would improve the quality of future historical surveys and facilitate repeating surveys at a future date.

Case Studies

In this section, we briefly describe the North Dakota and Nebraska surveys and the sources of data that were available to us to repeat those surveys (*table 3*). Both of these historical surveys were developed and conducted by staff at Northern Prairie Wildlife Research Center, a federal research facility that has been in existence since 1965. Being a government facility, the Center has had some stability in its infrastructure, staff, and mission for over 30 yrs, which enabled us to repeat these surveys with a certain level of ease. In particular, Northern Prairie maintains an archive of electronic and paper data files for most major research efforts. Nonetheless, we were not immune from many of the challenges in repeating historical surveys.

North Dakota

In 1967, Robert E. Stewart and Harold A. Kantrud (1972) conducted an extensive survey of breeding bird populations throughout North Dakota to obtain baseline estimates of statewide breeding bird abundance and frequency of occurrence. Stewart and Kantrud divided the state into eight major strata based on biogeographical, physiographical, and ecological characteristics. From these eight strata, Stewart and Kantrud 130 sample units by random selection without replacement (*fig. 1*). Breeding bird surveys were conducted by Stewart and Kantrud on foot. Each observer surveyed breeding birds on a rectangular half (805 x 402 m; 32.37 ha) of a legal quarter-section (64.75 ha each) by following a standardized survey route. Stewart and Kantrud (1972) estimated population means and totals (*table 4*), and their standard errors, using standard methods for stratified random samples with proportional allocation (Cochran 1977). They calculated Bayesian confidence intervals (95 percent confidence limits; Box and Tiao 1973) in lieu of the usual confidence intervals, using the methods described in Johnson (1977).

In 1992 and 1993, a quarter-century after the original survey, we repeated the Stewart-Kantrud survey using the same sample units, methods, and statistical analyses (Igl and Johnson 1997, Igl et al. 1999). Our objectives were to examine changes in breeding bird populations in North Dakota, to identify habitats used by breeding birds in North Dakota, to estimate densities of breeding birds in those habitats, and to evaluate changes in their

Table 3— *Primary and secondary sources of historical data and information for the North Dakota (Stewart and Kantrud 1972) and the Nebraska (Faanes and Lingle 1995) studies.*

	Survey	
Sources of information	**North Dakota**	**Platte River Valley, Nebraska**
Primary		
Original investigator(s)	✔	✔
Original observer(s)	✔	✔
Original field data / journals	✔	
Original statistician(s)	✔	✔
Original statistical analyses	✔	✔
Historical photographs	✔	
Secondary		
Publication(s)	✔	✔
Annual report(s)	✔	✔
Archived electronic file(s)	✔	✔

Table 4— *Population estimates of breeding birds by habitat association and migration strategy in North Dakota and the Platte River Valley of Nebraska.*

	Population estimates			
	North Dakota		Platte River Valley, Nebraska	
	1967	**1992-1993**	**1979-1980**	**2001**
Habitat associations				
Wetland	6,681,000	5,057,000	767,000	798,000
Grassland	12,113,000	10,230,000	931,000	865,000
Shrubland	1,607,000	1,896,000	329,000	397,000
Open habitat with scattered trees	1,071,000	1,922,000	591,000	481,000
Open woodland or edge	2,933,000	3,870,000	2,135,000	1,354,000
Woodland	102,000	168,000	40,000	34,000
Residential or human structures	791,000	1,613,000	610,000	1,232,000
Other	204,000	271,000	10,000	112,000
Migration strategy				
Resident	357,000	894,000	296,000	209,000
Short-distance migrant	17,187,000	15,903,000	2,823,000	2,445,000
Long-distance migrant	7,956,000	9,103,000	2,294,000	2,619,000
Total	25,500,000	25,900,000	5,414,000	4,553,000

densities within habitats between 1967 and 1992-1993. In 1992-1993, we conducted surveys on 128 of the 130 quarter-sections originally surveyed in 1967 by Stewart and Kantrud (1972); landowners denied access at the other two quarter-sections. LDI and Christopher J. Johnson conducted the surveys during the recent period. Data from this survey indicated that significantly declining species were primarily grassland- and wetland-breeding birds, whereas significantly increasing species were primarily species associated with human structures and woody vegetation (*table 4*).

During the recent surveys, several sources of historical information or data were available (*table 3*), including the original field notes and data (*fig. 2*), the original statistical analyses, historical photographs (*fig. 3*), archived electronic data files, and publications (e.g., Stewart and Kantrud 1972). The original field notes of Stewart and Kantrud contained count information by habitat (i.e., information that was not in the electronic data files or publications), which allowed us to compare changes in habitat (*fig. 3*) and densities of birds within habitats (*fig. 4*) between periods. The study sites (i.e., legal quarter-sections) were based on the Federal System of Rectangular Land Survey, which divided the land into square tracts and allowed us to relocate the original study sites and boundaries. To ensure consistency in methodology between the two periods, we worked closely with Harold A. Kantrud (one of the original participants in the 1967 survey), who was still working at the Center at the time of the recent survey. DHJ was involved with the statistical analyses in both the historical and the recent surveys.

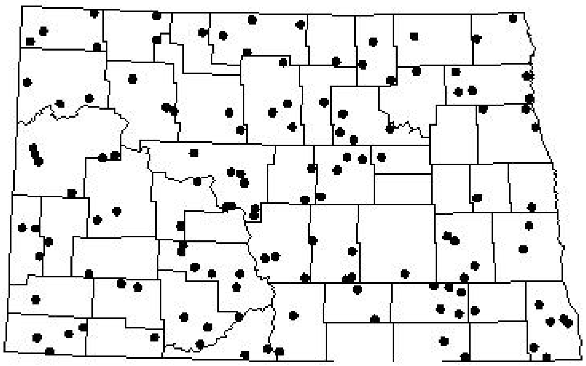

Figure 1— Distribution of 128 quarter-sections in North Dakota where bird surveys were conducted during 1967 and 1992-1993.

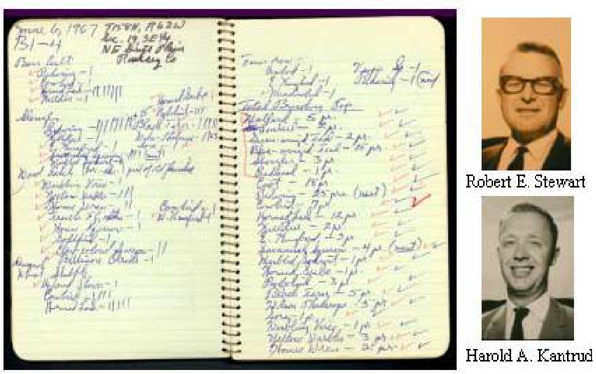

Figure 2— Original field notes of Robert E. Stewart and Harold A. Kantrud from 1967.

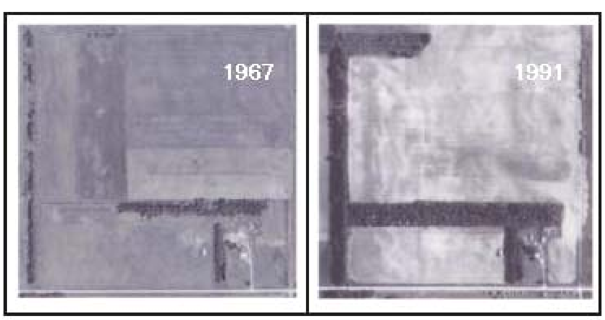

Figure 3— Increase in woody vegetation between 1967 and 1991 on an original study site surveyed by Stewart and Kantrud (1972) in Logan County, North Dakota.

Platte River Valley in Nebraska

In 1979 and 1980, Craig A. Faanes, Gary R. Lingle, and Wayne Norling conducted an extensive survey of breeding bird populations within 13 counties bordering the Platte, North Platte, and South Platte rivers in Nebraska (Faanes and Lingle 1995). The main objectives of their survey were to determine the species of breeding birds using the Platte River Valley, to estimate their population sizes, and to determine their habitat preferences.

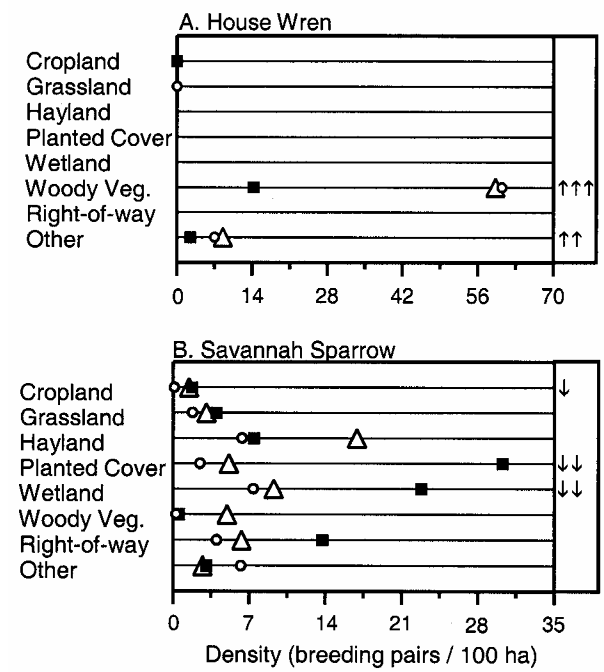

Figure 4— Habitat associations and within-habitat changes in densities of House Wren and Savannah Sparrow. Within each figure, average densities are indicated by habitat and year: a solid square indicates densities for 1967, an open circle for 1992, and an open triangle for 1993. If the species was not observed in a habitat in a given year, its density is not shown for that year. Changes in densities within habitats were indicated at the right of each graph: ↓ (decreasing) at $P < 0.10$, ↓↓ at $P < 0.05$, and ↓↓↓ at $P < 0.01$; ↑ (increasing) at $P < 0.10$, ↑↑ at $P < 0.05$, and ↑↑↑ at $P < 0.01$.

Surveys of breeding birds were conducted on randomly selected plots of habitat within each of several predetermined strata. The first level of stratification was defined by the legal boundary of each county. Within counties, the next level of stratification was the legal township. During selection of study sites, only one plot of a particular habitat type was surveyed per township. The third level of stratification was based on the predominant soil type of the region. Census plots were then randomly selected within these strata. Plot size varied according to habitat complexity. All native prairie and cropland plots were 16.2-ha, residential and riparian plots were 8.1-ha. Wooded river islands were chosen within the selected 16.2-ha plot. Shelterbelts were surveyed when they occurred on selected native prairie or cropland plots. Faanes and Lingle (1995) chose smaller plot sizes than Stewart and Kantrud (1972) because they considered smaller plots to be better suited for surveying smaller, inconspicuous species. Each plot was visited once during the 1979 season. In 1980, about 10 percent of those plots surveyed in 1979 were revisited to examine year-to-year variation. Additional plots were surveyed only in 1980. Two-hundred eighteen study sites were surveyed (*fig. 5*). Each plot was surveyed by one of two observers. Birds were counted while the observer followed a zig-zag course within each census plot. Faanes and Lingle (1995) estimated population means and totals (*table 4*), and their standard errors, using the same methods as Stewart and Kantrud (1972) described above.

In 2001, two decades after the original survey, we repeated the Faanes-Lingle survey using the same sample units, methods, and statistical analyses. The objectives of this recent survey were to examine changes in breeding bird populations in the Platte River Valley in Nebraska, to identify habitats used by breeding birds and estimate densities of breeding birds in those habitats, and to evaluate changes in their densities within habitats between 1979-1980 and 2001. In 2001, we visited 189 of the 218 study sites originally surveyed by Faanes and Lingle (1995) in 1979-1980 (*fig. 5*); landowners denied access at the other sites. Gary R. Lingle and Jennifer A. Gulbransen conducted the surveys during the recent period.

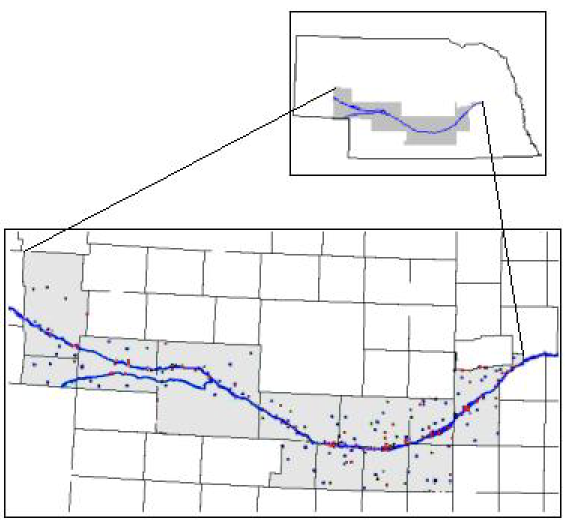

Figure 5— Distribution of 218 study sites in the Platte River Valley of Nebraska where bird surveys were conducted during 1979-1980 and 2001.

We used several sources of historical information or data to repeat the Faanes-Lingle survey (*table 2*), including the original statistical analyses, archived electronic data files, and publications (Faanes and Lingle 1995). The original field notes were missing and likely were destroyed by flooding at Northern Prairie Wildlife Research Center in 1993. The study-site descriptions of the Faanes-Lingle survey were based on the Federal System of Rectangular Land Survey, but only up to the level of a legal quarter-section. Without the original data sheets, we were unable to pinpoint the exact locations of some of the study sites, although we knew the study plots occurred within one of four quarters of a legal quarter-section. DHJ was involved with the statistical analyses in both the historical and the recent surveys.

Which Historical Surveys Should be Repeated?

Historical surveys are an attractive data source for evaluating bird population changes because the study design, field methodology, and study sites already have been determined and because the initial data-gathering may have occurred many years or decades in the past, before most long-term monitoring efforts (e.g., BBS) were initiated. In theory, most historical surveys should be repeatable. A key consideration is whether the historical survey is worth repeating, which should be evaluated on a case-by-case basis. Determining whether a historical survey is suitable for repeating requires consideration of a number of factors: Are the exact locations of the study sites known or documented? Can access to enough of the original study sites be obtained? Is the field methodology written down? Are the original investigators or observers still alive? Do the original field notes or completed data forms still exist? Are there archived electronic data files? Is the original study design adequate to accomplish the stated objectives of the repeat survey? Has sufficient time elapsed for changes in bird populations or habitats to have occurred? Are habitats sufficiently similar to the original habitats to permit meaningful comparisons?

A well-planned study design with well-documented field methodologies is critical for any monitoring or research effort, whether short-term or long-term. In many ways, the advantages of repeating a historical survey are also the drawbacks of repeating a historical survey (*table 2*). When repeating a historical survey, one must recognize that both the study design and methodology are constrained by the study design and methodology of the original survey. Poorly planned or poorly documented historical studies preclude repeating at a future date. Moreover, the design of the original survey may be inadequate to detect changes (Elzinga et al. 1998). In some cases, important information may not have been collected or documented during the historical survey, because the original investigators were not anticipating that the study would be repeated. Well-planned studies with detailed documentation of methods and study site locations help ensure the repeatability of a survey, even if future repetition was not anticipated by the original investigators. Some historical surveys (e.g., Stewart and Kantrud

1972, Faanes and Lingle 1995) were specifically designed to provide a baseline to evaluate changes in habitats and birds populations at a future date, which facilitates repeating at a later date.

Sources of Historical Data and Information

When compiling sources of data from a historical study, it is important to remember that "... only a part of what was observed in the past was remembered by those who observed it; only a part of what was remembered was recorded; only a part of what was recorded has survived; only a part of what has survived has come to the historian's attention ..." (Gottschalk 1956: 45). In historical studies, there are two main sources of data or information: primary and secondary (Touliatos and Compton 1988). Primary sources include the original study design or proposal, recollections of the original investigator(s), original field data, original statistician(s) and analyses, historical photographs, and field data and journals. Secondary sources include records or accounts that are one or two steps removed from the original source, such as electronic files, publications, annual reports, newspaper articles, abstracts from meetings, etc. Data that have passed through several levels may bear little resemblance to the original version; thus, using more primary sources of historical data or information will allow more types of questions to be addressed when the historical survey is repeated.

In this age of advanced technologies—including satellite imagery, global positioning systems, geographical information systems, and personal computers—it is difficult to appreciate the obstacles that early field biologists had to endure to conduct bird surveys, often armed with little more than a field notebook, a pencil, a compass, a pair of binoculars, and perhaps a map or aerial photograph. One of the most valuable sources of historical data or information is the original field notes and data (*fig. 2*), which not only indicate what types of data were collected and in what fashion, but also include information that may not have been addressed in publications or included in electronic data files. For example, the methods described in Stewart and Kantrud (1967) do not mention that bird data were collected separately for each habitat type within each study site. These data also were not included in the archived electronic data files. Having the original field data allowed us to evaluate changes in habitat composition within the original study sites (*fig. 3*) and changes in breeding bird densities among habitats (*fig. 4*). Similarly, Johnson (1974) consulted Alden H. Miller's field notes to determine details of abundances of some species that were not published in Miller (1945). Hall et al. (2002), however, were unable to compare their data to those from one of the three original years (Strong and Bock 1990) because the historical data files from that year were missing.

Besides written documentation and publications, individuals associated with the original survey can provide valuable information on the methodology and standards used during the original survey. These people include the original principal investigators, observers, and any others (e.g., statisticians) involved with the historical survey or development of the study design. For example, during the repeats of the North Dakota and Nebraska studies, we worked closely with the original investigators and observers to ensure consistency of methodology between the historical surveys and the recent surveys. Furthermore, DHJ was involved with the statistical analyses in both the historical and the recent surveys in the North Dakota and the Nebraska studies. Richard R. Bond's original field notes were lost, but Ambuel and Temple (1982) were able to consult Bond for details of the study design and methodology (e.g., survey dates) that were not included in Bond (1956). Graber and Graber (1963) used correspondence, journals, and the original field notes of Alfred O. Gross to determine the survey technique used by Forbes (1913) and Forbes and Gross (1922). Consultations, however, may result in low levels of return; Gurevitch et al. (2001) cautioned that requests for missing data or information might be very time-consuming and often results in low levels of return.

Consistency vs. Optimality of Field Methodology

A variety of methods have been used to survey birds. One of the most important considerations for any monitoring system is that the system needs to be repeatable; in turn, repeatability demands that standardized methods be used (Johnson 2000). Field methodology must be precisely documented, understood by the participants beforehand, and adhered to closely. Consistency of field methodology and effort among years is critical to maintaining the comparability of any survey (e.g., Ralph et al. 1995). All methods of sampling bird populations have their shortcomings and constraints, and biases are inherent in all data-gathering procedures (Ralph and Scott 1981). In that respect, historical surveys are no different; for field methodology, consistency is more important than optimality.

A major obstacle to repeating a historical survey is the inconsistent or incomplete fashion in which investigators describe details of their study design, methodology, study sites, and statistical analyses within reports or publications. The finest—and often some of the most important—details of sampling design and methodology usually are not included in publications. In a recent review on meta-analysis, Gurevitch et al. (2001) expressed concern about the difficulties arising from the incomplete reporting in primary literature, despite attention to statistical rigor in the editorial policies of most ecological journals. The overall result is the loss of valuable information needed to repeat a survey. For example, Kendeigh (1941) did not record the methodology or the time spent delineating territories and nest searching, so Bernstein et al. (1990) attempted to emulate Kendeigh's study by censusing at different times of the day, using a combination of strip census with spot mapping, and searching for all nests within the study plot.

One should not alter the methods or study design excessively or the changes will influence comparisons between past and future results. For example, Ambuel and Temple's (1982) survey methods, survey dates, and area of coverage did not duplicate those of Bond (1956). In particular, Ambuel and Temple began their surveys two weeks earlier than Bond had, included forest edge habitats that were excluded by Bond, and covered a greater area within each forest than Bond. Ambuel and Temple acknowledged that larger study sites have a higher probability of including uncommon species. Wilcove (1988) surveyed birds using the methods provided by Fawver (1950), but he increased the number of visits per site. Wilcove recognized that the increased sampling effort may have influenced the interpretation of the results.

Repeating a historical survey can be done at various levels of intensity, depending on the objectives to be accomplished and the resources available. In some situations, surveying all of the species or visiting all of the original sites may not be necessary or practical, based on the objectives of the study. For example, Nelms et al. (1994) visited a subset of the original Stewart and Kantrud (1972) study sites in 1981-82 in a portion of North Dakota to estimate population sizes and examine changes in populations of three species of blackbirds that depredate sunflower crops. Rolandelli (1986) surveyed American Crows (*Corvus brachyrhynchos*) on a subset of the Stewart and Kantrud study sites in 1983 to evaluate crow distribution and abundance in North Dakota.

Some of the original methods or objectives of the historical survey can be modified or augmented in future surveys without compromising comparisons between the two periods. For example, in 1967, Stewart and Kantrud (1972) based the number of breeding pairs of the Brown-headed Cowbird (*Molothrus ater*) on the number of males seen per sample unit. Recognizing the potential impact of female cowbirds on their hosts, we surveyed both male and female cowbirds in 1992 and 1993. This minor adjustment in methodology allowed us to make comparisons between our data and those from the historical survey (Igl and Johnson 1997) as well as those from concurrent or recent studies that are based on counts of females (e.g., Johnson and Igl 1995), without compromising the quality of the data. In addition, we were able to calculate statewide population estimates and their confidence limits for male and female cowbirds in the two recent years (Igl and Johnson, in prep.), which has never been done for this species over an extensive area. Nelms et al. (1994) followed Stewart and Kantrud's survey methods, but allowed for a higher acceptable sustained wind speed during their censuses of three blackbird species, because Besser and Brady (1984) had found no effect of winds up to 56 km per hour on the ability of observers to detect blackbirds. Although Forbes (1913) and Forbes and Gross (1922) originally surveyed bird populations in all seasons of the year, Graber and Graber (1963) limited their survey to the winter and summer seasons because annual bird populations during the two migratory seasons were too variable to provide meaningful comparisons between the historical and recent surveys.

Biases in Field Methodology: Past and Present

Biases associated with the methodology of historical bird surveys often are not quantified. For example, Stewart and Kantrud (1972) admitted that they did not quantify the biases associated with their survey methodology, but recognized that both negative and positive biases may be present. Our recent survey (Igl and Johnson 1997) was conducted as similarly as possible to the methods used in the historical survey (*table 3*). Although standardization in methodology is essential, it will not eliminate biases from a study. Moreover, it is unreasonable to assume that all biases in field methodologies can be controlled or eliminated. Undoubtedly, biases related to differences in observers, years, weather, sampling time, etc. will be present in the historical and recent surveys, but variations associated with methodology in the two periods should be relatively consistent among years.

Any discussion of bias in avian surveys will include a discussion of observer bias. Undoubtedly, observers vary in their abilities to conduct bird surveys (Faanes and Bystrak 1981, Sauer et al. 1994). Moreover, an observer's abilities often change with time and experience. In any monitoring system, however, it is best to use the same observer for as many years as possible. If it is necessary to change observers, training will minimize the disruption in the monitoring scheme and lessen the variation among observers between periods (Kepler and Scott 1981, Hanowski and Niemi 1995).

During long-term monitoring efforts, new observers eventually will replace earlier observers. This statement is especially true for studies that involve repeating historical surveys. The longer the interval between the original survey and the future survey, the less likely the original observers or investigators will be available to repeat the survey. In many cases, the original observers may no longer be alive or might lack the physical abilities, interest, or time to repeat the survey in the future. In rare cases, the original observers might be available to survey several decades after the historical survey. For example, during our repeat of Faanes and Lingle's (1995) survey in the Platte River Valley of Nebraska in 2001, one of the original observers, Gary R. Lingle, participated in the bird surveys, 22 years after the historical survey. John W. Aldrich participated in a survey of breeding birds in a mature eastern deciduous forest in Virginia in 1942 (Aldrich 1942) and again 37 years later (Aldrich and Coffin 1980). Martin L. Cody (1992) repeated his 1966-68 (Cody 1974) study 25 years after the original survey.

Relocating Original Study Sites

Critical to the success of repeating any bird survey, be it annual or historical, is relocating the original study sites and boundaries. Many studies cannot be repeated exactly because the original study site locations were poorly documented, could not be relocated, or had unknown boundaries. Historical studies that involve one (e.g., Abel 1920) or a few study sites (e.g., Odum 1950) usually provide details on the locations or boundaries of study sites in publications, but often the exact study site locations are not given within a publication because their descriptions are either too lengthy or numerous to include (e.g., Stewart and Kantrud 1972) or are deemed unimportant for the publication by the principal investigators or the journal editors. Besides publications, data sources for study site locations and boundaries include the detailed study proposals, original field notes, maps, electronic data files, and the original investigators. For example, Wilcove (1988) relocated most but not all of Fawver's (1950) study sites using directions in Fawver's dissertation, old maps, and information provided by Fawver and long-term residents in the area. In some cases, the location of the study site might be known, but the exact boundaries of the study site might not be obvious. For example, Bernstein et al. (1990) could not locate the exact boundaries of Kendeigh's (1941) study area, although the general location of the study area (a small, undisturbed prairie remnant) was known. In other cases, the boundaries of the study sites may no longer exist. For example, Holt (1974) found that the exact boundaries of one of Eugene P. Odum's (1950) study sites had been obliterated. Hall et al. (2002) could not relocate nine of 132 point-count stations originally surveyed by Strong and Bock (1990).

For monitoring purposes, it is probably best to use the same study sites as those used in the original survey (Johnson 2000). Using the same study sites increases the efficiency of the study in measuring change, both in bird populations and habitat conditions. A system with some old and some new locations might offer somewhat better statistical properties (Johnson 2000) but may not be optimal when repeating a historical survey. For example, Walcott's (1974) study site in 1940-43 and 1960-64 was about 50 m from William Brewster's (1906) original study site. Graber and Graber (1963) did not duplicate exactly the census route of Forbes (1913) and Forbes and Gross (1922) but instead selected survey routes that were representative for the area. In some situations, some or all of the original study sites may no longer be accessible, especially those on privately owned land. For example, private land owners denied access to two (1.5 percent) of the original 130 study sites in our North Dakota study and 29 (13 percent) of the original 218 study sites in our Nebraska study.

Old maps and aerial photographs can be useful in locating original study sites. Historical photographs also can be useful in evaluating historical conditions and mapping and monitoring landscape features (e.g., land use) or major habitat changes between two study periods. We evaluated changes in habitats on the original study sites of Stewart and Kantrud (1972) by contrasting recent aerial photographs with aerial photographs from the late 1960s (*fig. 3*). Bernstein et al. (1990) used recent and historical aerial photographs to document woody succession into a prairie remnant since Kendeigh (1941) conducted his survey in 1940.

Sample Sizes

To this point, we have not addressed the issue of sample size. Ultimately, statistical power in monitoring bird population changes depends on surveying numerous sites (Verner 1985, Johnson 2000). In planning to repeat a historical study, however, the sample size is less readily adjusted because it is constrained by the number of study sites of the historical survey. For example, several historical surveys in *table 1* involved only a single study site in a small area (e.g., Kendeigh 1941), whereas others involved several hundred study sites over an extensive area (e.g., Faanes and Lingle 1995). Because of the advantages of large sample sizes and the limitations of small sample sizes, we emphasize the importance in defining objectives before repeating a historical survey (e.g., Johnson 2000).

Survey Dates

As with study site locations, the exact dates and times of individual counts at a historical study site rarely are included in publications, but rather authors typically only include the start and end dates for the entire survey. Data sources for survey dates and times include both the original field notes and electronic data files. Because breeding bird populations can change dramatically over the course of the breeding season, counts in subsequent years should be conducted on or near the date of the original count. For example, in repeating the North Dakota and Nebraska surveys, we matched the date that a study site was surveyed as closely as feasible to the date that it was originally surveyed by using the information recorded in the original field notes or electronic data files. For the repeat of the Stewart and Kantrud (1972) study, the overall absolute difference between the dates of 1967 surveys and the 1992 and 1993 surveys averaged 2.5 days.

Habitat-Specific Analysis

Although the BBS has been effective in documenting long-term patterns of population change in breeding birds, the BBS does not provide comparable data on habitat changes. Hutto and Young (2002) argued that describing patterns of habitat use will make a much more effective program than one based on monitoring long-term population trends alone. Evaluating changes in bird populations is most useful if comparable habitat information is available for both the historic and recent surveys. For example, the inclusion of habitat data with our bird count data allowed us to evaluate changes in habitat composition within the original study sites (*fig. 3*) and changes in breeding bird densities among habitats (*fig. 4*).

Two Points in Time: Interpretation and Statistical Concerns

The primary objective of most long-term monitoring efforts is to detect changes in bird populations over time. One caveat to repeating historical surveys is that the data cover only two (sometimes more) points in time during a long period, whereas populations of birds may show tremendous short-term variability (Lowther 1984, Wilcove 1988, Igl and Johnson 1999). Skeptics of repeating historical surveys have questioned the validity of determining long-term changes by using data from only two periods separated by several decades, owing to the perceived shortcomings in the analytical techniques (e.g., Askins et al. 1990). Yet, there is nothing inappropriate in addressing questions of differences between two periods. Moreover, the data collected during historical surveys often are the same as or similar to those collected during long-term monitoring efforts.

Repeating a historical survey does pose some statistical concerns. Obviously, two points do not provide much information on a species' population trend. The changes between the two periods may reflect only normal year-to-year variation in a population rather than a consistent pattern. For example, conditions in the recent year might be different from those in the historical year. We suggest two remedies to this problem. First, one can repeat a historical survey twice, and thereby assess annual variation. This approach was taken by Igl and Johnson (1997), who repeated Stewart and Kantrud's (1972) historical survey in two years (1992 and 1993) rather than one. (Alternatively, as in the Platte River study, the historical survey had been partially repeated in two separate years.) Igl and Johnson (1997) claimed that a significant change had occurred only if the difference between 1967 and 1992 values and the difference between 1967 and 1993 were both significant ($P < 0.10$) *and* if both differences were in the same direction.

If multiple repeats of a survey cannot be done, an ad hoc and approximate remedy may be useful if comparable information from a monitoring program, such as the BBS, is available. If, for example, the BBS value provides a reasonably consistent index to the population that is being censused in the repeated survey, then the coefficients of variation of the BBS values and the true population numbers will be roughly equal. That is, if a population increases, say, 15 percent from one year to the next, an index to that population should increase about 15 percent during that same time frame. Accordingly, one could compare the relative magnitude of change between a historic survey and its repeat to the analogous variation in the time series of an index. If the changes are comparable, there is no evidence that the difference is unusually large and therefore reflects a real change between the historic and current times. If the difference between historic and repeated values is substantially greater than the variation in an index, there is reason to believe that true population values have changed.

Shorter intervals between the historical survey and subsequent surveys might enhance the ability to detect short-term changes but, as mentioned above, also increase the time and resources required to repeat the historical survey. The survey in 1947 by Stewart and Aldrich (1949) has been repeated every five years since 1948 (Hall 1984), which reflects a compromise between annual surveys and surveys separated by several decades.

Supplement to Long-Term Monitoring Programs

Repeating historical surveys should be viewed as a supplement to, rather than a substitute for, long-term, large-scale surveys. Some species or regions are poorly sampled by long-term monitoring efforts such as the BBS. Historical surveys can provide a valuable–and often overlooked–source of baseline data on breeding bird populations in such areas. Several studies have attempted to verify population trends from the BBS with data from independent, long-term surveys (e.g., breeding bird atlases: Robbins et al. 1989; checklists: Temple and Cary 1990; Christmas Bird Counts: Hagan 1993; migration counts: Dunn and Hussell 1995). Historical surveys can be used similarly. Parallel trends derived from studying the same populations in different ways may provide corroborating evidence and strengthen the assessment of population trends of the BBS. A secondary objective in repeating the North Dakota and Nebraska studies was to compare patterns in breeding bird population changes with trends from the BBS for the same periods (*table 5*). In the North Dakota study, we found similar patterns of long-term population change evident in our data and those from the BBS. This concordance illustrates that both these independently derived measures of population change likely were recording similar phenomena. We found less concordance with the Nebraska study (*table 5*), possibly because the two measures of population change covered different areas (i.e., Platte River Valley vs. statewide).

Conclusions

Historical surveys provide an important source of baseline data for examining changes in bird populations, provided that researchers are aware of the limitations and challenges in using these data. Although historical surveys have been used widely in the literature to evaluate long-term population changes (*table 1*), there are a number of issues that pose serious impediments to repeating historic surveys. These issues are not unique to repeating historical surveys but represent limitations that apply to other studies as well.

Gurevitch et al. (2001) listed four components of data collection: data extraction and recording, data entry, data proofing, and data storage. The most serious impediments to repeating historic surveys are associated with data storage. These range from methodological limitations (e.g., the failure of the original investigators to document study site locations and field methodologies) to those concerned with the lack of standards in data storage and archiving. Gurevitch et al. (2001) further listed two levels of data from a study: 1) metadata, which includes background information for subsequent analyses and interpretation and details of methodologies, and 2) response data, which are the numerical and categorical data quantifying the responses of the species or the system. Repeating a historical survey requires that both data types were accurately and completely recorded and archived during the original survey. Clearly, all studies benefit from foresight, advance planning, and good organization.

Finally, it is important to recognize that all present surveys are potential "future" historic surveys. As mentioned earlier, one of the most important considerations for any study is repeatability. If present surveys are to serve as historical surveys in the future, then investigators must: 1) be precise and thorough in providing details of their methodologies, study site locations, and study design, and 2) implement procedures to archive electronic and paper data files. Providing detailed guidelines and methodologies in publications and archiving data will improve the repeatability of any study and ensure consistency in data collection, whether within the same year, the following year, or 100 years later.

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Literature Cited

Abel, A. R. 1920. **An intensive ornithological survey of a typical square mile of cultivated prairie.** Proceedings of the Iowa Academy of Science 27: 385-393.

Aldrich, J. W. 1942. **Report on the breeding bird population of an oak-tulip woodland in northeastern Virginia.** Unpublished report submitted to the U.S. Fish and Wildlife Service, Washington, DC.

Aldrich, J. W. and R.W. Coffin. 1980. **Breeding bird populations from forest to suburbia after thirty-seven years.** American Birds 34: 3-7.

Table 5— *Populations changes of some breeding birds in North Dakota (1967 vs 1992-1993) and the Platte River Valley in Nebraska (1979-1980 vs 2001) compared to those from the North American Breeding Bird Survey for North Dakota and Nebraska. Declines and increases are statistically significant; populations that are not statistically significant are indicated by no change.*

	North Dakota		Platte River Valley in Nebraska	
Species	**Repeat survey (1967 vs. 1992-1993)**	**BBS (1967 to 1993)**	**Repeat survey (1979-1980 vs. 2001)**	**BBS (1980 to 2000)**
Canada Goose (*Branta canadensis*)	No change	Increase	No change	No change
Blue-winged Teal (*Anas discors*)	Decline	Decline	No change	No change
Swainson's Hawk (*Buteo swainsoni*)	Increase	Increase	No change	Decline
American Coot (*Fulica americana*)	Decline	Decline	No change	No change
Mourning Dove (*Zenaida macroura*)	No change	Increase	No change	Decline
Western Kingbird (*Tyrannus verticalis*)	Increase	Increase	No change	Decline
Eastern Kingbird (*Tyrannus tyrannus*)	Increase	Increase	No change	Decline
American Crow (*Corvus brachyrhynchos*)	No change	No change	Increase	No change
Horned Lark (*Eremophila alpestris*)	No change	No change	No change	No change
Black-capped Chickadee (*Parus atricapillus*)	Increase	No change	No change	No change
House Wren (*Troglodytes aedon*)	Increase	Increase	No change	No change
American Robin (*Turdus migratorius*)	Increase	Increase	No change	No change
Gray Catbird (*Dumetella carolinensis*)	No change	No change	Increase	No change
Chipping Sparrow (*Spizella passerina*)	Increase	Increase	No change	No change
Dickcissel (*Spiza americana*)	No change	No change	No change	No change
Red-winged Blackbird (*Agelaius phoeniceus*)	Decline	Decline	No change	Increase
House Sparrow (*Passer domesticus*)	Increase	Increase	No change	Decline

Ambuel, B. and S. A. Temple. 1982. **Songbird populations in southern Wisconsin: 1954 and 1979.** Journal of Field Ornithology 53: 149-158.

Askins, R. A., J. F. Lynch, and R. Greenberg. 1990. **Population declines in migratory birds in the eastern North America.** Current Ornithology 7: 1-57.

Baird, T. H. 1990. **Changes in breeding bird populations between 1930 and 1985 in the Quaker Run Valley of Allegany State Park, New York.** New York State Museum, Bulletin No. 477.

Bernstein, N. P., K. K. Baker, and S. R. Wilmot. 1990. **Changes in a prairie bird population from 1940 to 1989.** Journal of the Iowa Academy of Science 97: 115-120.

Besser, J. F. 1985. **Changes in breeding blackbird numbers in North Dakota from 1967 to 1981-2.** Prairie Naturalist 17: 133-142.

Besser, J. F. and D. J. Brady. 1984. **Censusing breeding Red-winged Blackbirds in North Dakota.** Wilson Bulletin 96: 83-90.

Bond, R. R. 1956. **Ecological distribution of breeding birds in the upland forest communities of southern Wisconsin.** Ecological Monographs 27: 351-384.

Box, G. E. P. and G. C. Tiao. 1973. **Bayesian inference in statistical analysis.** Reading, MA: Addison-Wesley.

Brewster, W. 1906. **The birds of the Cambridge region of Massachusetts.** Memoirs of the Nuttall Ornithological Society No. 4.

Cochran, W. G. 1977. **Sampling techniques, 3rd edition.** New York: John Wiley and Sons.

Cody, M. L. 1974. **Competition and the structure of bird communities.** Monograph on Population Biology. Princeton, NJ: Princeton University Press.

Cody, M. L. 1992. **Population densities and community structure of birds in Jackson Hole: a reassessment after 25 years.** In: G. E. Plumb and H. J. Harlow, editors. Sixteenth Annual Report. National Park Service Research Center and University of Wyoming.

Dunn, E. H. and D. J. T. Hussell. 1995. **Using migration counts to monitor landbird populations: Review and evaluation of current status.** Current Ornithology 12: 43-88.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. **Measuring and monitoring plant populations.** Bureau of Land Management Technical Reference 1730-1.

Faanes, C. A. and D. Bystrak. 1981. **The role of observer bias in the North American Breeding Bird Survey.** In: C. J. Ralph and J. M. Scott, editors. Estimating numbers of terrestrial birds. Studies in Avian Biology 6: 353-359.

Faanes, C. A. and G. R. Lingle. 1995. **Breeding birds of the Platte River Valley of Nebraska.** U.S. Geological Survey, Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/distr/birds/platte/platte.htm (Version 02SEP99).

Fawver, B. J. 1950. **An analysis of the ecological distribution of breeding bird populations in eastern North America.** Champaign: University of Illinois; 199 p. Ph.D. dissertation.

Forbes, S. A. 1913. **The midsummer bird life of Illinois: a statistical study.** Illinois Laboratory of Natural History Bulletin 9: 373-385.

Forbes, S. A. and A. O. Gross. 1922. **The numbers and local distribution in summer of Illinois land birds of the open country.** Illinois Natural History Survey Bulletin 14: 187-218.

Ganier, A. F. and A. Clebsch. 1944. **Summer birds of the Unicoi Mountains.** Migrant 15: 61-65.

Ganier, A. F. and A. Clebsch. 1946. **Breeding birds of the Unicoi Mountains.** Migrant 17: 53-59.

Gottschalk, L. 1956. **Understanding history.** New York: Alfred Knopf.

Graber, R. R. and J. W. Graber. 1963. **A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958.** Illinois Natural History Survey Bulletin 28: 383-528.

Gurevitch, J., P. S. Curtis, and M. H. Jones. 2001. **Meta-analysis in ecology.** Advances in Ecological Research 32: 199-247.

Hagan, J. M., III. 1993. **Decline of the Rufous-sided Towhee in the eastern United States.** Auk 110: 863-874.

Hall, G. A. 1984. **Population decline of Neotropical migrants in an Appalachian forest.** American Birds 38: 14-18.

Hall, L. S., M. L. Morrison, L. L. Christoferson, J. Martin, C. E. Bock, and T. R. Strong. 2002. **Bird populations in riparian areas of southeastern Arizona in 1985-86 and 1994-95.** Western North American Naturalist 62: 370-376.

Haney, J. C., D. S. Lee, and M. Wilbert. 2001. **A half-century comparison of breeding birds in the southern Appalachians.** Condor 103: 268-277.

Hanowski, J. M. and G. J. Niemi. 1995. **Experimental design considerations for establishing an off-road, habitat-specific bird monitoring program using point-counts.** In: C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Forest Service, U.S. Department of Agriculture; 145-150.

Holt, J. P. 1974. **Bird populations in the hemlock sere on the Highlands Plateau, North Carolina.** Wilson Bulletin 86: 397-406.

Hutto, R. L. and J. S. Young. 2002. **Regional landbird monitoring: perspectives from the northern Rocky Mountains.** Wildlife Society Bulletin 30: 738-750.

Igl, L. D. and D. H. Johnson. 1997. **Changes in breeding bird populations in North Dakota: 1967 to 1992-93.** Auk 114: 74-92.

Igl, L. D. and D. H. Johnson. 1999. **Le Conte's Sparrows breeding in Conservation Reserve Program fields: Precipitation and patterns of population change.** Studies in Avian Biology 19: 178-186.

Igl, L. D., D. H. Johnson, and H. A. Kantrud. 1999. **Uncommon breeding birds in North Dakota: population estimates and frequencies of occurrence.** Canadian Field-Naturalist 113: 646-651.

Johnson, D. H. 1977. **Some Bayesian statistical techniques useful in estimating frequency and density.** Special Scientific Report–Wildlife No. 203. Washington, DC: Fish and Wildlife Service, U.S. Department of the Interior.

Johnson, D. H. 2000. **Statistical considerations in monitoring birds over large areas.** In: R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, editors. Strategies of bird conservation: the Partners in Flight planning process. Forest Service Proceedings RMRS-P-16. U.S. Department of Agriculture; 115-120.

Johnson, D. H. and L. D. Igl. 1995. **Contributions of the Conservation Reserve Program to populations of breeding birds in North Dakota.** Wilson Bulletin 107: 709-718.

Johnson, N. K. 1965. **The breeding avifaunas of the Sheep and Spring ranges in southern Nevada.** Condor 67: 93-124.

Johnson, N. K. 1974. **Montane avifaunas of southern Nevada: historical change in species composition.** Condor 76: 334-337.

Johnson, N. K. 1995. **Seven avifaunal censuses spanning one-half century on an island of white firs (*Abies concolor*) in the Mojave Desert.** Southwestern Naturalist 40: 76-85.

Kendeigh, S. C. 1941. **Birds of a prairie community.** Condor 43: 165-174.

Kepler, C. B. and J. M. Scott. 1981. **Reducing bird count variability by training observers.** In: C. J. Ralph and J. M. Scott, editors. Estimating numbers of terrestrial birds. Studies in Avian Biology 6: 366-371.

Lowther, P. E. 1984. **Repeat of a 1916 bird census in northwestern Iowa.** Proceedings of the Iowa Academy of Science 91: 87-91.

Miller, A. H. 1940. **A transition zone island in the Mojave Desert.** Condor 42: 1161-163.

Miller, A. H. 1945. **Birds of the yellow pine association of Potosi Mountain, southern Nevada.** Condor 47: 130-131.

Miller, A. H. 1946. **Vertebrate inhabitants of the pion association in the Death Valley region**. Ecology 27: 54-60.

Nelms, C. O., W. J. Bleier, D. L. Otis, D. L., and G. M. Linz. 1994. **Population estimates of breeding blackbirds in North Dakota, 1967, 1981-1982, and 1990.** American Midland Naturalist 132: 256-263.

Odum, E. P. 1950. **Bird populations of the Highlands (North Carolina) Plateau in relation to plant succession and avian invasion.** Ecology 31: 587-605.

Peterjohn, B. G., J. R. Sauer, and C. S. Robbins. 1995. **Population trends from the North American Breeding Bird Survey.** In: T. E. Martin and D. M. Finch, editors. Ecology and management of Neotropical migratory birds: A synthesis and review of critical issues. New York: Oxford University Press; 3-39.

Ralph, C. J. and J. M. Scott, editors. 1981. **Estimating numbers of terrestrial birds.** Studies in Avian Biology 6.

Ralph, C. J., S. Droege, and J. R. Sauer. 1995. **Managing and monitoring birds using point counts: Standards and applications.** In: C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Forest Service. U.S. Department of Agriculture; 161-168.

Robbins, C. S., S. Droege, and J. R. Sauer. 1989. **Monitoring bird populations with Breeding Bird Survey and atlas data.** Annales Zoologici Fennici 26: 297-304.

Roberts, K. A. 1991. **Field monitoring: confessions of an addict.** In: F. B. Goldsmith, editor. Monitoring for conservation and ecology. London: Chapman and Hall; 179-211

Rolandelli, J. E. 1986. **An index to the population status of the American Crow in North Dakota.** Fargo, ND: North Dakota State University; 51 p. M.S. Thesis.

Sauer, J. R. 2000. **Combining information from monitoring programs: complications associated with indices and geographic scale.** In: R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles, editors. Strategies of bird conservation: The Partners in Flight planning process. Forest Service Proceedings RMRS-P-16; 124-126. U.S. Department of Agriculture.

Sauer, J. R., B. G. Peterjohn, and W. A. Link. 1994. **Observer differences in the North American Breeding Bird Survey.** Auk 111: 50-62.

Saunders, A. A. 1936. **Ecology of the birds of Quaker Run Valley, Allegany State Park, New York.** New York State Museum Handbook No. 16; 174 p.

Spiker, C. J. 1927. **A second intensive ornithological survey of a typical square mile of cultivated prairie, after a ten-year interval.** Proceedings of the Iowa Academy of Science 34: 323-326.

Stewart, R. E. and J. M. Aldrich. 1949. **Breeding bird populations in the spruce region of the central Appalachians.** Ecology 30: 75-82.

Stewart, R. E. and H. A. Kantrud. 1972. **Population estimates of breeding birds in North Dakota.** Auk 89: 766-788.

Stewart, R. E. and C. S. Robbins. 1947. **Virgin central hardwood deciduous forest.** Audubon Field Notes 1: 211-212.

Strong, T. R. and C. E. Bock. 1990. **Bird species distribution patterns in riparian habitats in southeastern Arizona.** Condor 92: 866-885.

Temple, S. A. and J. R. Cary. 1990. **Using checklist records to reveal trends in bird populations.** In: J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. Washington, DC: U.S. Fish and Wildlife Service Biological Report 90(1): 98-104.

Touliatos, J. and N. H. Compton. 1988. **Research methods in human ecology/home economics.** Ames, Iowa: Iowa State University Press.

Verner, J. 1985. **Assessment of counting techniques.** Current Ornithology 2: 247-302.

Walcott, C. F. 1974. **Changes in bird life in Cambridge, Massachusetts from 1860 to 1964.** Auk 91: 151-160.

Whitcomb, B. L., R. F. Whitcomb, and D. Bystrak. 1977. **Long-term turnover and effects of selective logging on the avifauna of forest fragments.** American Birds 31: 17-23.

Wilcove, D. S. 1988. **Changes in the avifauna of the Great Smoky Mountains 1947-1983.** Wilson Bulletin 100: 256-271.