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Combining Data from the Christmas Bird Count and the Breeding Bird Survey to Determine the Continental Status and Trends of North America Birds

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Both the Breeding Bird Survey (BBS) and the Christmas Bird Count (CBC) have been used for several decades to determine the status and trends of birds in North America. We propose new methods for assessing and comparing the reliability of these two surveys for estimating continental bird trends. In addition, we propose a new method for combining BBS and CBC continental trends to produce a combined continental trend for any species with useful trend information from both surveys.

METHODS

Breeding Bird Survey (BBS)

The BBS, administered by the U.S. Geological Survey; <http://www.pwrc.usgs.gov/BBS/>, is the primary source of status and trend information for North American birds during the breeding season. The BBS is a roadside survey that includes 50 3-minute stops one-half mile apart, at which experienced individuals count all birds seen and heard. Surveys are done between late May and early July beginning 30 minutes before dawn. Surveys have been done on more than 4,000 routes; about 3,000 routes are done each year. Data are aggregated by BCR and by state. The survey began in 1965, so our analyses begin with that year.

Audubon Christmas Bird Count (CBC)

The CBC (<http://www.audubon.org/bird/cbc/>) is the primary source of status and trend information for North American birds in early winter. Each individual CBC occurs within a 15-mile diameter circle on a single day within two weeks of Christmas. Participants join groups that survey subunits of the circle during the course of the day using a variety of transportation methods (mostly on foot, in a car, or watching at a feeder). Just over 2,000 circles are surveyed each year. Like the BBS, data are aggregated by BCR and by state. The first CBC was done in 1900. We begin our analysis of CBC trends with the winter of 1965-66 for comparison with the BBS (which began in 1965) and because earlier CBC data are less comparable to current CBC data due to changes in methods and intensity of effort.

Trend analysis methods

BBS trends and annual indices are estimated using the route-regression methods described by Geissler and Sauer (1990). In this analysis, trend is estimated first, and annual indices of abundance are used to assess higher levels of pattern in the context of the trend.

Route trends are estimated as multiplicative trends using the estimating equations estimator described by Link and Sauer (1994). Observer effects are incorporated in the model to prevent bias associated with increases in observer quality over time (Sauer et al. 1994). Regional trends are found as weighted averages of route trends. Regardless of variability in the counts on the route, missing counts (from years when the route was not surveyed) and observer changes (that modify the quality of the data) both tend to make route data less reliable. Consequently, it is necessary to weight the route trends by a measure of the consistency of counting on the route. This weight is proportional to number of years run and number of observer changes, but because it does not contain the mean standard error (MSE) of the count data it provides no information on variation in counts. We also weight route trend estimates by mean route counts (Geissler and Sauer 1990) and by areas of the BCRs within states. Combination of entire strata is not conducted because of geographic variation in sampling intensity within the strata. Bootstrapping is used to estimate variances of trends.

CBC trends and annual indices are derived from a hierarchical model that treats CBC counts as overdispersed Poisson random variables, with means described by a loglinear regression with random effects (Link and Sauer 2002, Link et al. 2006). The model includes a stratum-specific effect of effort (party-hours) and overdispersion effects allowing for lack of fit to the Poisson model. The model is hierarchical in that most of the effects are treated as random variables, including circle, year, overdispersion, and effort effects. We fit hierarchical models using Bayesian methods, specifically Markov chain Monte Carlo techniques (Gilks et al. 1996, Link and Sauer 2002). We used program WinBUGS (Spiegelhalter et al. 1999) to estimate the variability around the parameters and indices, creating 95% credible intervals that are analogous to confidence intervals derived from other statistical approaches.

Almost all scientific analyses of CBC data have assumed that reported bird numbers increase with increased effort. Because of that assumption, CBCs have collected information about effort for years. The most used estimate of effort is party-hours: the amount of time spent counting birds by a group of observers (Butcher 1990). Early CBC analyses assumed that counts increased linearly with effort; Butcher and McCulloch (1990) introduced a nonlinear model that allowed for counts to be independent of effort or for there to be diminishing returns at higher levels of effort. That model has been revised (Link and Sauer 1999a, 1999b, Link et al. 2006). We use their loglinear model that allows the relationship of count and effort to vary among BCRs (or other strata such as states).

Route-regression and hierarchical models have been shown to produce similar trend estimates in studies to date (Sauer et al. in press). Thus, comparing BBS trends using route regression with CBC trends using a hierarchical model should not produce any bias. BBS trends using the hierarchical models are expected to be available soon.

Trend categories

We adopted population trend thresholds from Partners in Flight (Panjabi et al. 2005). An average annual change of -2.28% leads to a 50% decline over a 30-year period, so we considered any species with declines of this magnitude or greater to be suffering the most severe declines. For trends from the BBS or CBC alone, the trend had to be statistically significant ($p < 0.05$ for BBS; 95% credible intervals not including zero for CBC) to be placed in this category. An average annual decline of -0.54% produces a 15% decline over a 30-year period. Thus, any decrease between -2.28% and -0.54% is considered moderately declining, but not severely. An average annual increase of $+0.47\%$ leads to a 15% increase over a 30-year period. Thus, any trend between -0.54% and $+0.47\%$ is considered stable, and any trend greater than $+0.47\%$ is considered increasing. An average annual increase of $+1.36\%$ creates a 50% population increase over 30 years, so any trend greater than that is considered to be large and any trend between $+0.47\%$ and $+1.36\%$ per year is considered moderate.

Reliability of population trend data from surveys

The BBS and CBC are omnibus surveys designed to determine status and trends for a large number of species over a large geographic scale. As a result, the reliability of BBS- and CBC-derived trends varies greatly among species. An estimate of reliability is valuable for two major reasons: 1) to determine if the trend data should be considered at all, and 2) if trend information is available from more than one source, to determine which source might be more reliable. In this report, we estimate trend reliability using four factors:

- i. number of BBS routes or CBC circles that recorded the species at least twice in 39 years,
- ii. average abundance of the species on the routes or circles included in the analysis,
- iii. precision of the trend estimate, and
- iv. proportion of the breeding range covered by the BBS or winter range covered by the CBC

For each of these four factors, we assigned a score of x or 0 to 3. We gave a score of 'x' to values considered so low that the trend should not be used; scores of 0-3 are all considered to be acceptable. For sample size (number of BBS routes or CBC circles with the species), the thresholds are:

x = fewer than 5 routes or circles

1 = 5 – 13 routes or circles

2 = 14 – 49 routes or circles

3 = 50+ routes or circles

For average abundance, the thresholds are:

x = 0.01 birds or less per route or circle

1 = between 0.01 and 0.1

2 = between 0.1 and 1.0

3 = equal to or greater than 1.0 birds per route or circle

For precision, the thresholds are:

0 = unable to detect a decline of 10% per year or less

1 = able to detect a decline of 6-10% per year

2 = able to detect a decline of 2-6% per year

3 = able to detect a decline that is 2% or less

For coverage, the thresholds are:

0 = less than 1% of the breeding or wintering range

1 = between 1% and 33.3% of the breeding or wintering range

2 = between 33.3% and 66.6% of the breeding or wintering range

3 = more than 66.6% of the breeding or wintering range

If the score for sample size or abundance is x, then the trend is not reported. Trends with a 0 score for range coverage or precision are reported as long as sample size and abundance scores are both greater than x. We feel that these trends can be informative even if they do not represent a major proportion of the range or are very imprecise.

The reliability scores and ranks used in this paper are built upon the credibility scores used by the BBS for a number of years (Sauer et al. 2005). We have added: 1) an additional level of ranking for each factor, 2) total scores, 3) scores for coverage, and 4) scores for trend differences between BBS and CBC. BBS reliability scores include consideration of trend differences between earlier and later periods; ours do not. In addition, we have changed some of the thresholds currently used by Sauer et al. (2005).

Geographic units of study: Bird conservation regions (BCRs) and states

Bird Conservation Regions (BCRs) have been adopted as the primary planning units by the North American Bird Conservation Initiative (NABCI; Figure 1; U.S. NABCI Committee 2000; <http://www.nabci-us.org/bcrs.html>); as a result, most relevant statistics on bird populations are aggregated by BCRs, making BCRs by far the most practical geographic template for bird conservation statistics. In addition, state wildlife agencies have major responsibilities for bird conservation; Audubon and other conservation NGOs have state offices. Thus, it is vital to produce status and trend information state by state.

Percent of range covered by surveys

The CBC covers all the BCRs in the United States and Canada excluding Hawaii and the boreal and Arctic BCRs 1, 2, 3, 4, 6, 7, & 8; BBS coverage is very similar (Figure 2). Breeding and wintering ranges in the Western Hemisphere were derived from the NatureServe map information available online (Ridgely et al. 2005). Breeding ranges were compared with the coverage of the BBS, and winter ranges were compared with the coverage of the CBC to determine the percentage of the breeding or wintering range covered by each survey.

Combined trend scores

If a species is encountered on both the BBS and CBC, the best estimate of its overall trend may be a combination of the estimated trends from the two databases. To calculate a composite trend estimate we first weighted each trend estimate by the proportion of the species' range included in the survey (breeding range for BBS, winter range for CBC), then we lowered the weighting for either BBS or CBC if it scored in a lower reliability category for sample size, abundance, or precision relative to the other survey.

For abundance, we reduced the weighting for either BBS or CBC by 10% if its reliability score was one category lower and by 20% if the reliability score was two categories lower.

For sample size, we reduced the weighting for either BBS or CBC only if the sample size category was different. If the category was different, then we reduced the weighting by 10% if the sample size of one survey was 10-20% of sample size of the other, by 20% if one was 5-10% of the other, by 30% if one was 2-5% of the other, and 40% if one was less than 2% of the other.

For precision, we reduced the weighting 10% if one survey had a precision estimate that was 2-4 percentage points higher than the other, 20% if the difference was 4-8%, 30% if the difference was 8-12%, and 40% if the difference was more than 12%.

Value of two trend estimates over one

There are two ways to determine the amount of improvement in a trend estimate by using two sources instead of one. First, we looked at the final weighting of the two trend estimates. The more even the weighting of the two trend sources, the more informative the combined estimate is. For survey weighting, the thresholds are:

- 0 = one survey contributed less than 10% to the combined estimate
- 1 = one survey contributed 10-20%
- 2 = one survey contributed 20-30%
- 3 = one survey contributed 30-40%
- 4 = one survey contributed 40-50%

Second, we looked at the amount of difference between the estimated trends. For trend difference, the thresholds are:

- 0 = more than 4% difference in the estimated average annual trend
- 1 = 2-4% difference in the trend estimates
- 2 = 1-2% difference in the trend estimates
- 3 = less than 1% difference in the trend estimates

RESULTS

Sample size and abundance for BBS and CBC

We currently have useful trends from one or both surveys for 550 species (Table 1). We have CBC trends for 470 species, and BBS trends for 405 species. If sample size is below 5 for any species or if abundance is below 0.01 for any species, then we report no trend for that species. Sample size score is 3 (50 or more routes or circles) for 280 species on both surveys, 398 species on CBC, and 359 species on BBS (Table 1). Relative abundance score is 3 (at least one bird per route or circle) for 142 species on both surveys, 273 species on CBC, and 251 species on BBS (Table 2).

Precision for BBS and CBC

Poor precision can be a problem on both the BBS and the CBC. Poor precision is caused when a species is irregularly encountered on a survey, usually because of rarity, difficulty of observation, or congregatory behavior. Of the species encountered on both surveys, 26 species on the CBC and 23 species on the BBS have precision scores of 1 or 0, indicating an inability to detect a decline that averages 6% per year or higher (0 indicates inability to detect a decline of 10% per year or higher; Table 3).

Range coverage for BBS and CBC

These surveys cover 100% of the range for very few species (20 on BBS and 16 on CBC; Appendix 1; also see Key to Appendix 1). Range coverage score is 3 (2/3s or more of range covered) for 92 species on both, 164 species on BBS and 128 species on CBC (Table 4).

Trend Reliability for BBS and CBC

We use trend reliability scores to determine how much faith to put in trend estimates for specific species in specific regions. For continental trends, we use four factors, including percentage of range covered by the survey, sample size, abundance, and precision. If a species has values of 3 for all factors, then we say that the trend is highly reliable and most useful. Forty-three (43) species have highly reliable trends for both surveys, 88 species for CBC only, and 131 species for BBS only (Table 5). When any species scores 2 or 3 for all factors, then the trend is very reliable and very useful. One hundred fifty-six (156) species have very reliable or highly reliable trends for both surveys; 59 species have very or highly reliable trends for CBC alone; 157 have very or highly reliable trends for BBS alone (Table 5). If all of the reliability scores for a species are 0 or 1 or higher, we still consider the trend information to be useful. Among species that lack highly reliable and very reliable trends on both surveys, 56 have useful trends on both surveys, 110 have useful trends on the CBC alone, and 12 have useful trends on the BBS alone (Table 5). In all, useful trends or better are available from either BBS or CBC for 550 North American bird species; useful trends or better are available from both surveys for 309 species.

Splits and Lumps

A challenge in creating 40-year trends from these two databases is that many species have been split (what was formerly considered one species is now considered to be two or three different species) or lumped (what was formerly considered two or three species is now considered to be one). In some cases, 40-year trends can be created for these species by extrapolating species

identity geographically based on the current distribution of the newly split species; however, we have not yet completed that process for the CBC (Appendix 2; also see Key to Appendix 2).

Combining BBS and CBC Trend Results by Species

We have divided population trends into five categories: large increase (I*), small increase (i), stable (S), small decrease (d), and large decrease (D*). Trends for 309 species receive reliability scores of 0 or higher in both surveys (Tables 1-5). Of those 309, 99 (32.0%) are in the same trend category according to the CBC and BBS (Table 6). Another 124 (40.0%) have a trend in one survey one category away from the trend in the other survey (I* vs. i, i vs. S, S vs. d, or d vs. D*); thus, 223 out of 309 (72.0%) show the same trend category or a similar trend category on the two surveys.

Trend similarity increases if only trends with higher reliability are used (Table 6). When all 309 trends are used, 72.2% have the same or similar trends. When the 279 trends of reliability 1 or higher are used, then 73.5% have the same or similar trends. The percentage rises to 75.0% for the 156 species with trends of reliability 2 or higher and to 79.1% for the 43 species with trends of reliability 3.

All four factors that contribute to the reliability scores are correlated with trend similarity (Table 7), with high variance on both surveys especially noticeable in the group with highly dissimilar trends. Low abundance on the CBC (and secondarily on the BBS) and low sample size on the BBS (and secondarily on the CBC) are also correlated with the highly dissimilar trends. Percent range coverage appears to be less important. Another factor strongly correlated with trend dissimilarity is increasing trend on the CBC and secondarily on the BBS (Table 7).

Bias or Changing Ranges?

Species are more likely to show higher trends on the CBC compared with the BBS. For all species with trends, CBC trends average +1.57% per year, and BBS trends average +0.24% per year. If only species and surveys with overall reliability scores of 2+ are used, then CBC trends average +0.48, and BBS trends average -0.18. These results suggest greatly reduced bias by using only trends with higher reliability.

For species encountered on both surveys, the overall difference averages less than 0.9% per year (Tables 7 and 9). Sixty-four percent of the species in different trend categories on the two surveys were in a higher trend category on the CBC than on the BBS (Table 8). CBC trends deviated more from BBS trends in those species with the greatest increases on the CBC (Table 9); such large increases are seldom shown on the BBS. Greater differences between CBC and BBS trends are correlated with low abundance of birds on the CBC and low sample sizes on both the BBS and CBC (Table 9). High degree of trend difference is correlated with low overall reliability scores (Table 7), and trend differences are greatly reduced when only trends with overall reliability or 2 or 3 are used (Table 6).

There are a number of reasons to expect CBC trends to be higher than BBS trends. Many of these reasons relate to birder behavior and lead us to believe more strongly in BBS trends than in CBC trends:

- 1) BBS routes are fixed; CBC routes are not. If habitat is lost, then CBC observers can spend more time in remaining good habitat. If good new habitat is discovered, CBC observers can add it to their survey.
- 2) Many believe that observers are getting better all the time, primarily due to better field guides and better optics. As a result, the BBS controls for observers (and indeed finds that newer observers see on average more birds than the ones they replaced). CBC does not (cannot?) control for observers.
- 3) Expectations keep increasing on CBCs. Many CBCs strive to see more species than they have in the past. CBC routes may change to increase the likelihood of seeing new species. As bird ranges change, CBC observers predict the arrival of new species and spend extra time pursuing them.

Here are a few species with a large positive bias on the CBC that are likely due to observer behavior: Allen's Hummingbird, Henslow's Sparrow, and King Rail. Henslow's Sparrow and King Rail are cryptic species; if birders are making a greater effort to find these species on CBCs, they would induce positive bias in CBC trends. Allen's Hummingbird is difficult to identify; we have disregarded CBC trends of several species of birds that are rare on CBCs and difficult to identify, such as the *Empidonax* flycatchers. Twenty to 40 years ago, very few birders would have tried to identify these species in the nonbreeding season, and data reviewers would have been unlikely to accept the identifications. Today, more people are confident that these species can be reliably identified in the nonbreeding season, so they are included in recent CBCs, but are not suitable for trend analysis.

The major alternative explanation for the CBC showing higher trends than the BBS is the expectation that bird ranges (both breeding and winter) are moving north due to global warming. The BBS captures the southern edge of the range for many widespread species, including many with either all or the northern part of their winter range in the CBC. If breeding birds are doing worse in the southern portions of their ranges than they are farther north (because of global warming), then BBS trends would be lower than CBC trends. Some species that may be showing this phenomenon include Rusty Blackbird, Common Merganser, and Red-breasted Merganser. For these species, the CBC trend is more likely to reflect the true trend of the continental population.

Over the past 30 years, winters have warmed more in North America than have summers (**need citation**). Thus, it is expected that more species will be wintering farther north now than they did in the past. The CBC covers only the northern portions of the wintering range for many species. If winter ranges are moving north more than summer ranges, then it is expected that CBC trends would be greater than BBS trends for the same species, and the differences may not be due to bias after all. Here are some of the species that show CBC trends higher than BBS trends and that may be wintering farther north than they used to: Cave Swallow, Allen's Hummingbird, White-winged Dove, Black-bellied Whistling-Duck, Glossy and White-faced Ibis, Black-necked Stilt, Rufous Hummingbird, Lesser Yellowlegs, Cassin's Kingbird, Wood Stork, Black-throated Green Warbler, Costa's and Broad-tailed Hummingbird, and Solitary Sandpiper. For many of these species, it is quite possible that there is an interaction between birds wintering farther north and birders making extra efforts to find them (and being more willing to accept them as occurring now than they would have earlier). If CBC trends are greatly affected by species

wintering farther north, then the BBS trend is more likely to reflect the true trend of the continental population.

Is the combined trend better than one of the single trends?

Our results clearly show that trends are most reliable when overall reliability scores are 2 or 3. Thus, we recommend combining trends when both surveys have an overall reliability score of 2 or 3. Trends with overall reliability scores of 0 or 1 provide useful information, but must be used with caution. We also combine trends when both surveys have reliability scores of 0 or 1. We do not combine trends when the reliability score on one survey is 2 or 3 and the reliability score on the other survey is 0 or 1.

How strongly should we rely on the trend?

We believe that trends with quality scores of 2 or 3 are quite valuable and likely to be superior to expert opinion in the absence of other quantitative data. Trends with quality scores of 0 or 1 remain suspect and should be leavened with expert opinion in species assessments.

Continentially Declining Species

Of the species with overall trend reliability scores of 2 or 3, 44 species show annual average declines of -2.28% per year or worse; 104 show average annual declines of -0.54% to -2.28% per year (Appendix 3). Of the species with overall trend reliability scores of 0 or 1, 26 show annual average declines of -2.28% per year or worse; 21 show average annual declines of -0.54% to -2.28% per year.

Common Birds in Decline

We are interested in identifying common birds in decline (Table 10). To qualify for the list, a species must number 500,000 individuals or more, and its range must be 1 million square kilometers or larger. These thresholds were chosen because they are the thresholds for a priority score of 3 for Partners in Flight (Panjabi et al. 2005). Population estimates are derived from the North American bird conservation initiatives: North American Waterfowl Management Plan, Partners in Flight, U.S. Shorebird Conservation Plan, and Waterbirds for the Americas. Range sizes are derived from NatureServe (online). Reliability scores for the BBS or CBC must be 2 or 3. Many species are not well covered by the BBS or CBC, but most common birds are. The species must be declining according to the BBS or CBC. We found 20 species with average declines of -1.90 or worse; added up over 40 years, these species have all lost more than 50%

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Combining CBC and BBS for Continental Bird Population Trends

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Table 1: Number of species with each sample size score

	Both	BBS	CBC	BBS or CBC
3	280	359	398	477
2+	324	405	449	530
1+	325	405	470	550

		CBC				
		3	2	1	x	TOTAL
BBS	3	280	5	0	74	359
	2	28	11	1	6	46
	1	0	0	0	0	0
	x	90	35	20	0	145
	TOTAL	398	51	21	80	550

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	50+ routes or circles that recorded the species at least twice in 40 years
2	14-49 routes or circles
1	5-13 routes or circles
x	fewer than 5 routes or circles

Table 2: Number of species with each relative abundance score

	Both	BBS	CBC	BBS or CBC
3	142	251	273	382
2+	265	387	382	437
1+	325	405	470	550

		CBC				
		3	2	1	x	TOTAL
BBS	3	142	22	29	58	251
	2	64	37	15	20	136
	1	4	7	5	2	18
	x	63	43	39	0	145
	TOTAL	273	109	88	80	550

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	Average of 1.0 birds or more per route or circle
2	Between 0.1 and 1.0 birds per route or circle
1	Between 0.01 and 0.1 birds per route or circle
x	Average of 0.01 birds or fewer per route or circle

Table 3: Number of species with each precision score

This table includes only the 309 species that **have** useful trends on both the CBC and the BBS.

	Both	BBS	CBC	BBS or CBC
3	131	175	206	250
2+	263	286	283	306
1+	277	302	296	308

		CBC				
		3	2	1	0	TOTAL
BBS	3	131	32	7	5	175
	2	67	33	4	7	111
	1	6	8	2	0	16
	0	2	4	0	1	7
	TOTAL	206	77	13	13	309

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	Able to detect a decline of 2% or less
2	Able to detect a decline between 2% and 6%
1	Able to detect a decline between 6% and 10%
x	Unable to detect a decline of 10% or less

Table 4: Number of species with each range coverage score

This table includes only the 309 species that have useful trends on both the CBC and the BBS.

	Both	BBS	CBC	BBS or CBC
3	92	164	128	200
2+	197	254	206	263
1+	304	307	298	308

		CBC				
		3	2	1	0	TOTAL
BBS	3	92	38	30	4	164
	2	29	38	20	3	90
	1	7	2	41	3	53
	0	0	0	1	1	2
	TOTAL	128	78	92	11	309

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	More than 66.6% of the breeding (BBS) or wintering (CBC) range included in the survey
2	Between 33.3% and 66.6% of the breeding or wintering range
1	Between 1% and 33.3% of the breeding or wintering range
0	Less than 1% of the breeding or wintering range

Table 5: Number of species with each overall reliability score

	Both	BBS	CBC	BBS or CBC
3	43	131	88	176
2+	156	313	215	372
1+	279	395	379	495
0+	325	405	470	550

		CBC					
		3	2	1	0	x	TOTAL
BBS	3	43	24	20	12	32	131
	2	29	60	38	19	36	182
	1	6	16	43	5	12	82
	0	0	2	4	4	0	10
	x	10	25	59	51	0	145
	TOTAL	88	127	164	91	80	550

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	All scores for sample size, abundance, precision, and range coverage are 3
2	All scores are 2 or 3
1	All scores are 1, 2, or 3
0	All scores are 0, 1, 2, or 3
x	At least one score was x

Table 6. Comparison of BBS and CBC trend categories within species

Species with trends on both CBC and BBS

		CBC					
		I*	i	S	d	D*	Total
BBS	I*	41	11	5	2	0	59
	i	25	16	13	7	4	65
	S	14	14	15	10	4	57
	d	10	27	24	15	18	94
	D*	0	9	4	9	12	34
	Total	90	77	61	43	38	309

Proportion (and number) of trend categories different

0	1	2	3	4
0.32 (99)	0.40 (124)	0.20 (61)	0.08 (25)	0.00 (0)

Species with trends on both and reliability scores on both of 1 or higher

		CBC					
		I*	i	S	d	D*	Total
BBS	I*	38	8	4	2	0	52
	i	23	15	9	5	3	55
	S	13	13	15	9	4	54
	d	8	23	22	14	18	85
	D*	0	9	3	9	12	33
	Total	82	68	53	39	37	279

Proportion (and number) of trend categories different

0	1	2	3	4
0.34(94)	0.40(111)	0.19(52)	0.08(22)	0.00 (0)

**Species with trends on both and reliability scores on both of 1 or higher
CBC**

	I*	i	S	d	D*	Total	
BBS	I*	38	8	4	2	0	52
	i	23	15	9	5	3	55
	S	13	13	15	9	4	54
	d	8	23	22	14	18	85
	D*	0	9	3	9	12	33
	Total	82	68	53	39	37	279

Proportion (and number) of trend categories different

0	1	2	3	4
0.34(94)	0.40(111)	0.19(52)	0.08(22)	0.00 (0)

**Species with trends on both and reliability scores on both of 1 or higher
CBC**

	I*	i	S	d	D*	Total	
BBS	I*	38	8	4	2	0	52
	i	23	15	9	5	3	55
	S	13	13	15	9	4	54
	d	8	23	22	14	18	85
	D*	0	9	3	9	12	33
	Total	82	68	53	39	37	279

Proportion (and number) of trend categories different

0	1	2	3	4
0.34(94)	0.40(111)	0.19(52)	0.08(22)	0.00 (0)

**Species with trends on both and reliability scores on both of 2 or higher
CBC**

		I*	i	S	d	D*	Total
BBS	I*	15	7	2	2	0	26
	i	14	7	6	2	1	30
	S	7	6	9	5	2	29
	d	5	12	14	9	12	52
	D*	0	6	0	6	7	19
	Total	41	38	31	24	22	156

Proportion (and number) of trend categories different

0	1	2	3	4
0.30(47)	0.45(70)	0.16(25)	0.09(14)	0.00(0)

**Species with trends on both and reliability scores of 3 on both
CBC**

		I*	i	S	d	D*	Total
BBS	I*	4	1	0	0	0	5
	i	8	0	0	0	0	8
	S	4	2	3	0	0	9
	d	1	4	4	3	5	17
	D*	0	0	0	0	4	4
	Total	17	7	7	3	9	43

Proportion (and number) of trend categories different

0	1	2	3	4
0.33(14)	0.47(20)	0.19(8)	0.02(1)	0.00(0)

Table 7. Quartile averages for trend difference scores
See Key to Appendix 2 for category definitions

---- See Excel document attachment for this chart ---

Table 8. Bias in trend differences between CBC and BBS

BBS and CBC trend categories by species are shown in Table 7.

All 309 species with trends on both CBC and BBS						
Number of trend categories different						
	1	2	3	4	Total	
Proportion	CBC higher	0.22	0.15	0.06	0.00	0.44
	BBS higher	0.16	0.06	0.02	0.00	0.24
	Difference	0.06	0.09	0.04	0.00	0.19
Number of species		1	2	3	4	Total
	CBC higher	72	45	19	0	136
	BBS higher	52	16	6	0	74
	Difference	20	29	13	0	62

279 species with trends on both and reliability scores on both of 1 or higher						
Number of trend categories different						
	1	2	3	4	Total	
Proportion	CBC higher	0.24	0.14	0.06	0.00	0.44
	BBS higher	0.16	0.05	0.02	0.00	0.22
	Difference	0.08	0.09	0.04	0.00	0.22
Number of species		1	2	3	4	Total
	CBC higher	67	39	17	0	123
	BBS higher	44	13	5	0	62
	Difference	23	26	12	0	61

156 species with trends on both and reliability scores on both of 2 or higher						
Number of trend categories different						
	1	2	3	4	Total	
Proportion	CBC higher	0.26	0.12	0.07	0.00	0.38
	BBS higher	0.19	0.04	0.02	0.00	0.25
	Difference	0.06	0.08	0.05	0.00	0.20
Number of species		1	2	3	4	Total
	CBC higher	40	19	11	0	60
	BBS higher	30	6	3	0	39
	Difference	10	13	8	0	31

Table 8. Bias in trend differences between CBC and BBS, *continued*

43 species with trends on both and reliability scores of 3 on both

		Number of trend categories different				Total
		1	2	3	4	
Proportion	CBC higher	0.33	0.19	0.02	0.00	0.53
	BBS higher	0.14	0.00	0.00	0.00	0.14
	Difference	0.19	0.19	0.02	0.00	0.40

		Number of trend categories different				Total
		1	2	3	4	
Number of species	CBC higher	14	8	1	0	23
	BBS higher	6	0	0	0	6
	Difference	8	8	1	0	17

Table 9. Quartile averages for the absolute value trend differences
See Key to Appendix 2 for category definitions

---- See Excel document attachment for this chart ---

Table 10. Continental Trends for the Top 20 Common Birds in Decline

Species	Survey	Trend category	Change over 40 years	Average annual trend	2.5% CI (%change/yr)	97.5% CI (%change/yr)	Variance
Northern Bobwhite	combined	D*	-82%	-4.3	-4.9	-3.6	0.0968
Evening Grosbeak	combined	D*	-78%	-3.7	-4.8	-2.6	0.3305
Northern Pintail	combined	D*	-77%	-3.6	-5.5	-1.8	0.9289
Greater Scaup	CBC	d	-75%	-3.4	-9.2	0.7	14.5085
Boreal Chickadee	CBC	D*	-73%	-3.3	-4.6	-1.9	0.5036
Eastern Meadowlark	combined	D*	-72%	-3.1	-3.4	-2.8	0.0260
Common Tern*	BBS	D*	-70%	-3.0	-4.2	-1.9	0.1734
Loggerhead Shrike	combined	D*	-70%	-3.0	-3.5	-2.7	0.0420
Field Sparrow	combined	D*	-68%	-2.8	-3.2	-2.4	0.0407
Grasshopper Sparrow	combined	D*	-65%	-2.6	-3.3	-1.8	0.1411
Snow Bunting	CBC	D*	-64%	-2.5	-4.8	-0.5	1.2321
Black-throated Sparrow	combined	D*	-63%	-2.5	-3.9	-1.0	0.5614
Lark Sparrow	combined	D*	-63%	-2.4	-3.1	-1.7	0.1319
Common Grackle	combined	D*	-61%	-2.4	-3.1	-1.6	0.1379
American Bittern	combined	d	-59%	-2.2	-3.4	-1.0	0.3625
Rufous Hummingbird	BBS	d	-58%	-2.1	-3.6	-0.7	0.5631
Whip-poor-will	combined	d	-57%	-2.1	-2.9	-1.3	0.1799
Horned Lark	combined	d	-56%	-2.0	-2.8	-1.3	0.1514
Little Blue Heron	combined	d	-54%	-1.9	-3.7	-0.2	0.8123
Ruffed Grouse	combined	d	-54%	-1.9	-3.0	-0.8	0.2987

*Stable or increasing at managed colonies; decreasing at unmanaged colonies

Key to Appendix 1:

40-year trends for all species covered by the Breeding Bird Survey (BBS) or Christmas Bird Count (CBC)

The following columns are meant to show in Excel. Other columns have been hidden to allow calculations to be made. If the hidden columns appear, we recommend that you hide all but the columns below:

A – Species. Species are listed in taxonomic order according to the latest supplement to the American Ornithologists' Union Checklist. All species with useful trends from the Breeding Bird Survey or the Christmas Bird Count are included. See Table 6 for species that have been split or lumped over the past 40 years.

B – Trends – BBS, CBC, or Combined. Start of a new section

BBS = Breeding Bird Survey. (See text for more information on this survey.)

CBC = Christmas Bird Count. (See text for more information about the CBC.)

E – Trend Difference Score. For all species with a useful trend on both the BBS and the CBC, we calculate a trend difference score:

0 = more than 4% difference in the estimated average annual trend

1 = 2-4% difference in the trend estimates

2 = 1-2% difference in the trend estimates

3 = less than 1% difference in the trend estimates

F – Absolute value CBC trend – BBS trend. For each species with a useful trend on both the BBS and the CBC, we calculate the absolute value of the difference between the two trends.

G – CBC trend – BBS trend. For each species with a useful trend on both the BBS and the CBC, we calculate the difference between the two trends. A positive value means that the CBC trend is more positive than the BBS trend.

H-I – Trend scores – some combined after weighting. Numeric thresholds in Methods.

D* = large and statistically significant decrease

d = small decrease or one that is not statistically significant

S = stable population (tiny increases or decreases are considered stable)

i = small increase or one that is not statistically significant

I* = large and statistically significant increase

If the species is only covered by one survey, then the trend is from that survey. If one survey has reliability 2 or 3 (see later columns) and the other survey has reliability 0 or 1, then only the higher reliability survey is used. If both surveys have reliability 2 or 3 or reliability 0 or 1, then a combined trend is calculated with weighting (see Methods).

J – Trend – Some combined and weighted. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

N – Variance of trend. A statistic that reflects how consistent the trend is over time and space.

P – 2.5% C.I. This is the lower confidence interval for the BBS trend or combined trend, or the lower credible interval for the CBC trend. (Different terminology is used in Bayesian statistics.)

Q – 97.5% C.I. This is the upper confidence or credible interval. If the upper and lower C.I.s are both positive or both negative, then the increase or decrease is statistically significant. Otherwise, the trend is not statistically significant.

T – Equal weighting score. The more even the weighting of the two trend sources, the more informative the combined estimate is. For survey weighting, the thresholds are:

0 = one survey contributed less than 10% to the combined estimate

Combining CBC and BBS for Continental Bird Population Trends

- 1 = one survey contributed 10-20%
- 2 = one survey contributed 20-30%
- 3 = one survey contributed 30-40%
- 4 = one survey contributed 40-50%

U – Percent CBC weighting. This varies from 0 to 100.

V – CBC Trends. Start of a new section.

W – CBC trend score. Numeric thresholds in Methods.

- D* = large and statistically significant decrease
- d = small decrease or one that is not statistically significant
- S = stable population (tiny increases or decreases are considered stable)
- i = small increase or one that is not statistically significant
- I* = large and statistically significant increase

X – CBC trend – continental. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

Y – 2.5% C.I. This is the lower credible interval for the CBC trend.

Z – 97.5% C.I. This is the upper credible interval. If the upper and lower C.I.s are both positive or both negative, then the increase or decrease is statistically significant. Otherwise, the trend is not statistically significant.

AA – Variance – CBC. A statistic that reflects how consistent the trend is over time and space.

AB – Precision estimate for CBC. The size of a trend required for statistical significance given the inherent variability of the data for each species. The number is average percent change per year.

AC – Precision score for CBC.

- 0 = 10% per year change required for significance
- 1 = 6-10% per year change required for significance
- 2 = 2-6% per year change required for significance
- 3 = 2% or less per year change required for significance

AD – Number of CBC circles where species present (at least twice in 40 years).

AE – Sample size score.

- x = Fewer than 5 routes or circles
- 1 = 5 – 13 routes or circles
- 2 = 14 – 49 routes or circles
- 3 = 50+ routes or circles

AF – Relative abundance – CBC. Expressed as number of birds per CBC circle with average effort.

AG – Abundance score – CBC.

- x = 0.01 birds or less per circle
- 1 = between 0.01 and 0.1
- 2 = between 0.1 and 1.0

Combining CBC and BBS for Continental Bird Population Trends

3 = equal to or greater than 1.0 birds per circle

AH – % North American range covered by CBC.

AI – CBC Range coverage score.

0 = less than 1% of the breeding or wintering range

1 = between 1% and 33.3% of the breeding or wintering range

2 = between 33.3% and 66.6% of the breeding or wintering range

3 = more than 66.6% of the breeding or wintering range

AJ – Reliability score for CBC. This is the lowest of the preceding scores and is used in deciding how much reliance should be put in the CBC trend. In general, 2 and 3 are reliable; 0 and 1, less so.

AK – BBS trends. Start of a new section.

AL – BBS trend score. Numeric thresholds in Methods.

D* = large and statistically significant decrease

d = small decrease or one that is not statistically significant

S = stable population (tiny increases or decreases are considered stable)

i = small increase or one that is not statistically significant

I* = large and statistically significant increase

AM – BBS trend – continental. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

AN – p. – If $p < 0.05$, then the trend is statistically significant. If $p < 0.35$, then the trend is interesting; if $p > 0.35$, then the trend probably isn't useful.

AO – 2.5% C.I. This is the lower confidence interval for the BBS trend.

AP – 97.5% C.I. This is the upper confidence interval. If the upper and lower C.I.s are both positive or both negative, then the increase or decrease is statistically significant. Otherwise, the trend is not statistically significant.

AQ – Variance – BBS. A statistic that reflects how consistent the trend is over time and space.

AR – Precision estimate - BBS. The size of a trend required for statistical significance given the inherent variability of the data for each species. The number is average percent change per year.

AS – Precision score - BBS.

0 = 10% per year change required for significance

1 = 6-10% per year change required for significance

2 = 2-6% per year change required for significance

3 = 2% or less per year change required for significance

AT – Number of BBS routes where species present (at least twice in 40 years).

AU – Sample size score.

x = Fewer than 5 routes or circles

1 = 5 – 13 routes or circles

2 = 14 – 49 routes or circles

Combining CBC and BBS for Continental Bird Population Trends

3 = 50+ routes or circles

AV – Relative abundance – BBS. Expressed as average number of birds per BBS route.

AW – Abundance score – BBS.

x = 0.01 birds or less per circle

1 = between 0.01 and 0.1

2 = between 0.1 and 1.0

3 = equal to or greater than 1.0 birds per circle

AX – % North American range covered by BBS.

AY – BBS range coverage score.

0 = less than 1% of the breeding or wintering range

1 = between 1% and 33.3% of the breeding or wintering range

2 = between 33.3% and 66.6% of the breeding or wintering range

3 = more than 66.6% of the breeding or wintering range

AZ – Reliability score for BBS. This is the lowest of the preceding BBS scores and is used in deciding how much reliance should be put in the BBS trend. In general, 2 and 3 are reliable; 0 and 1, less so.

BA – List order. New section.

BB – List order – all species, no classification. If you sort the Excel file into a different order, these numbers allow you to return it to current taxonomic order according to the American Ornithologists' Union (2006).

Appendix 1. 40-year trends for all species covered by the Breeding Bird Survey or Christmas Bird Count.

Look for a separate key for this appendix

---- See Excel document attachment for this chart ---

Combining CBC and BBS for Continental Bird Population Trends

Key to Appendix 2 and 3:

2: 40-year trends for species that have been split or lumped within the past 40 years

3: Trends for all declining species

The following columns are meant to show in Excel. Other columns have been hidden to allow calculations to be made. If the hidden columns appear, we recommend that you hide all but the columns below:

A – Species. Old name, or name for combined species, is listed in quotes. A few species are listed not because of taxonomic changes but because of identification problems, especially in the nonbreeding season.

E – Trends – BBS, CBC, or Combined. Start of a new section.

BBS = Breeding Bird Survey. (See text for more information on this survey.)

CBC = Christmas Bird Count. (See text for more information about the CBC.)

F – Trend scores – some combined after weighting. Numeric thresholds in Methods.

D* = large and statistically significant decrease

d = small decrease or one that is not statistically significant

S = stable population (tiny increases or decreases are considered stable)

i = small increase or one that is not statistically significant

I* = large and statistically significant increase

If the species is only covered by one survey, then the trend is from that survey. If one survey has reliability 2 or 3 (see later columns) and the other survey has reliability 0 or 1, then only the higher reliability survey is used. If both surveys have reliability 2 or 3 or reliability 0 or 1, then a combined trend is calculated with weighting (see Methods).

G – Trend – some combined and weighted. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

R – Percent CBC weighting. This varies from 0 to 100.

S – CBC Trends. Start of a new section.

T – CBC trend score – continental. Numeric thresholds in Methods.

D* = large and statistically significant decrease

d = small decrease or one that is not statistically significant

S = stable population (tiny increases or decreases are considered stable)

i = small increase or one that is not statistically significant

I* = large and statistically significant increase

U – CBC trend – continental. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

AG – Reliability score for CBC. This is the lowest of the preceding scores and is used in deciding how much reliance should be put in the CBC trend. In general, 2 and 3 are reliable; 0 and 1, less so.

AH – BBS trends. Start of a new section.

Combining CBC and BBS for Continental Bird Population Trends

AI – BBS trend score – continental. Numeric thresholds in Methods.

D* = large and statistically significant decrease

d = small decrease or one that is not statistically significant

S = stable population (tiny increases or decreases are considered stable)

i = small increase or one that is not statistically significant

I* = large and statistically significant increase

AJ – BBS trend – continental. This is the average annual trend for the species on this survey, expressed as a percentage. See Methods on how these numbers are calculated.

AW – Reliability score for BBS. This is the lowest of the preceding BBS scores and is used in deciding how much reliance should be put in the BBS trend. In general, 2 and 3 are reliable; 0 and 1, less so.

Appendix 2. 40-year trends for species that have been split or lumped within the past 40 years
Look for a key for this appendix and Appendix 3

---- See Excel document attachment for this chart ---

Appendix 3. Trends for all declining species

Combined scores when BBS and CBC have reliability scores that are both 2 or 3 and when BBS and CBC are both 0 or 1. If the reliability score for BBS or CBC is 2 or 3, and the other score is 0 or 1, then only the survey with the score or 2 or 3 is used for the trend.

---- See Excel document attachment for this chart ---