Bird Wintering Ranges

Identification

1. Indicator Description

This indicator examines changes in the winter ranges of North American birds from the winters of 1966–1967 to 2013-2014. Changes in climate can affect ecosystems by influencing animal behavior and ranges. Birds are a particularly strong indicator of environmental change for several reasons described in the indicator text. This indicator focuses in particular on latitude—how far north or south birds travel—and distance from the coast. Inland areas tend to experience more extreme cold than coastal areas, but birds may shift inland over time as winter temperature extremes grow less severe.

Components of this indicator include:

- Shifts in the latitude of winter ranges of North American birds over the past half-century (Figure 1).
- Shifts in the distance to the coast of winter ranges of North American birds over the past half-century (Figure 2).

2. Revision History

April 2010:	Indicator published.
May 2014:	Updated indicator with data through 2013.
April 2017:	Updated documentation to reflect a newly published methods paper.

Data Sources

3. Data Sources

This indicator is based on data collected by the annual Christmas Bird Count (CBC), managed by the National Audubon Society. Data used in this indicator are collected by citizen scientists who systematically survey 15-mile diameter count circles annually to identify and count widespread bird species. The CBC has been in operation since 1900, but data used in this indicator begin in winter 1966–1967.

4. Data Availability

Complete raw CBC data are available in both print and electronic formats. Historical CBC data have been published in several periodicals—*Audubon Field Notes*, *American Birds*, and *Field Notes*—beginning in 1998. Additionally, historical, current year, and annual summary CBC data are available online at: www.audubon.org/conservation/science/christmas-bird-count. Descriptions of data are available with the data queried online. The appendix to National Audubon Society (2009) provides 40-year trends for each species, but not the full set of data by year. Annual relative abundance estimates estimated using hierarchical Bayesian models, used to estimate range shifts, are summarized in Soykan et al. (2016). EPA

obtained the complete data set for this indicator, with species-specific data through 2013, directly from the National Audubon Society.

A similar analysis is available from an interagency consortium at: https://archive.stateofthebirds.org/state-of-the-birds-2014-report/.

Methodology

5. Data Collection

This indicator is based on data collected by the annual CBC, managed by the National Audubon Society. Data used in this indicator are collected by citizen scientists who systematically survey certain areas and identify and count widespread bird species. Although the indicator relies on human observation rather than precise measuring instruments, the people who collect the data are skilled observers who follow strict protocols that are consistent across time and space. Moreover, the analytical methods used to produce relative abundance estimates and range shifts account for many sources of variation, including effort (person-hours of observation on each count circle) and regional effects. These data have supported many peer-reviewed studies, a list of which can be found on the National Audubon Society's website at: www.audubon.org/conservation/christmas-bird-count-bibliography.

Bird surveys take place each year in approximately 2,000 different locations throughout the contiguous 48 states and the southern portions of Alaska and Canada. All local counts take place between December 14 and January 5 of each winter. Each local count takes place over a 24-hour period in a defined "count circle" that is 15 miles in diameter. A variable number of volunteer observers separate into field parties, which survey different areas of the count circle and tally the total number of individuals of each species observed (National Audubon Society, 2009). This indicator covers 305 bird species, which are listed in Appendix 1 of National Audubon Society (2009). These species were included because they are widespread and they met specific criteria for data availability.

Much of the study description, including a list of species and a description of analyses performed to estimate range shifts from species-level relative abundance estimates, can be found in National Audubon Society (2009) and references therein. Descriptions of analyses performed to produce relative abundance estimates can be found in Soykan et al. (2016). Information on this study is also available on the National Audubon Society website at: http://web4.audubon.org/bird/bacc/techreport.html. For additional information on CBC survey design and methods, see Soykan et al. (2016) and the reports classified as "Methods" in the list at: http://www.audubon.org/conservation/christmas-bird-count-bibliography.

6. Indicator Derivation

At the end of the 24-hour observation period, each count circle tallies the total number of individuals of each species seen in the count circle. Audubon scientists then run the data through several levels of analysis and quality control to determine final count numbers from each circle and each region. Data processing steps include corrections for different levels of sampling effort—for example, if some count circles had more observers and more person-hours of effort than others. Population trends over the 48-year period of this indicator and annual indices of abundance were estimated for the entire survey area with hierarchical models in a Bayesian analysis using Markov chain Monte Carlo techniques (Soykan et al., 2016).

This indicator is based on the center of abundance for each species, which is the center of the population distribution at any point in time. In terms of latitude, half of the individuals in the population live north of the center of abundance and the other half live to the south. Similarly, in terms of longitude, half of the individuals live west of the center of abundance, and the other half live to the east. The center of abundance is a common way to characterize the general location of a population. For example, if a population were to shift generally northward, the center of abundance would be expected to shift northward as well. This indicator uses CBC data starting in 1966, consistent with the start of the Breeding Bird Survey, as data prior to 1966 lack sufficient data quality and quantity for a North American-scaled analysis.

This indicator examines the center of abundance from two perspectives:

- Latitude—testing the hypothesis that bird populations are moving northward along with the observed rise in overall temperatures throughout North America.

- Distance from coast—testing the hypothesis that bird populations are able to move further from the coast as a generally warming climate moderates the inland temperature extremes that would normally occur in the winter.

- This indicator reports the position of the center of abundance for each year, relative to the position of the center of abundance in 1966 (winter 1966–1967). The change in position is averaged across all 305 species for changes in latitude (Figure 1) and across 272 species for changes in distance from the coast (Figure 2). The indicator excludes 33 species from the analysis of distance from the coast because these species depend on a saltwater or brackish water habitat. Lake shorelines (including the Great Lakes) were not considered coastlines for the purposes of the "distance from coast" metric.

- Figures 1 and 2 show average distances moved north and moved inland, based on an unweighted average of all species. Thus, no adjustments are made for population differences across species.

No attempt was made to generate estimates outside the surveyed area. The indicator does not include Mexico or northern parts of Alaska and Canada because data for these areas were too sparse to support meaningful trend analysis. Due to its distance from the North American continent, Hawaii is also omitted from the analysis. No attempt was made to estimate trends prior to 1966 (i.e., prior to the availability of complete spatial coverage and standardized methods), and no attempt was made to project trends into the future.

Information on study methods is available on the National Audubon Society website at: http://web4.audubon.org/bird/bacc/techreport.html and in Soykan et al. (2016). Methods are largely based on those used for an earlier analysis, which is documented in National Audubon Society (2009) and references therein.

7. Quality Assurance and Quality Control

As part of the overall data compilation effort, Audubon scientists have performed several statistical analyses to ensure that potential error and variability are adequately addressed. Quality assurance/quality control procedures are described in National Audubon Society (2009), Soykan et al.

(2016), and in a variety of methodology reports listed at: www.audubon.org/conservation/christmas-bird-count-bibliography.

Analysis

8. Comparability Over Time and Space

The CBC has been in operation since 1900, but data used in this indicator begin in winter 1966–1967. The National Audubon Society chose this start date to ensure sufficient sample size throughout the survey area as well as consistent methods, as the CBC design and methodology have remained generally consistent since the 1960s. All local counts take place between December 14 and January 5 of each winter, and they follow consistent methods regardless of the location.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. Many factors can influence bird ranges, including food availability, habitat alteration, and interactions with other species. Some of the birds covered in this indicator might have moved northward or inland for reasons other than changing temperatures.

2. This indicator does not show how responses to climate change vary among different types of birds. For example, National Audubon Society (2009) found large differences between coastal birds, grassland birds, and birds adapted to feeders, which all have varying abilities to adapt to temperature changes. This Audubon report also shows the large differences between individual species—some of which moved hundreds of miles while others did not move significantly at all.

3. Some data variations are caused by differences between count circles, such as inconsistent level of effort by volunteer observers, but these differences are carefully corrected in Audubon's statistical analysis (Soykan et al., 2016).

4. While observers attempt to identify and count every bird observed during the 24-hour observation period, rare and nocturnal species may be undersampled. Gregarious species (i.e., species that tend to gather in large groups) can also be difficult to count, and they could be either overcounted or undercounted, depending on group size and the visibility of their roosts. These species tend to congregate in known and expected locations along CBC routes, however, so observers virtually always know to check these spots. Locations with large roosts are often assigned to observers with specific experience in estimating large numbers of birds. However, species that are poorly surveyed by the CBC were excluded from analyses (National Audubon Society, 2009; Soykan et al., 2016) and do not contribute to these range shift estimates.

5. The tendency for saltwater-dependent species to stay near coastlines could impact the change in latitude calculation for species living near the Gulf of Mexico. By integrating these species into the latitudinal calculation, Figure 1 may understate the total extent of northward movement of species.

10. Sources of Uncertainty

The sources of uncertainty in this indicator have been analyzed, quantified, and accounted for to the extent possible, as described in Soykan et al. (2016). The statistical significance of the trends (see Section 12) suggests that the conclusions one might draw from this indicator are robust.

One potential source of uncertainty in these data is uneven effort among count circles. Various studies that discuss the best ways to account for this source of error have been published in peer-reviewed journals. Link and Sauer (1999) and Soykan et al. (2016) describe the methods that Audubon used to account for variability in effort.

11. Sources of Variability

Rare or difficult-to-observe bird species could lead to increased variability. For this analysis, the National Audubon Society included only 305 widespread bird species that met criteria for abundance and the availability of data to enable the detection of meaningful trends.

12. Statistical/Trend Analysis

Appendix 1 of National Audubon Society (2009) documents the statistical significance of trends in the wintering range for each species included in an earlier version of this indicator. Using annual data points for each species, EPA applied an ordinary least-squares regression to determine the statistical significance of each species' movement, as well as the statistical significance of each overall trend. Tables TD-1 and TD-2 present these two analyses. Both of these tables are based on an analysis of all 305 species that the National Audubon Society studied.

Table TD-1. Statistical Analyses of Aggregate (All Species) Trends

Indicator component	Regression slope	P-value	Total miles moved
Northward (latitude)	0.993 miles/year	<0.0001	46.7
Inward from the coast	0.231 miles/year	<0.0001	10.9

Table TD-2. Statistical Analyses of Species-Specific Trends

Statistical calculation	Figure 1	Figure 2
Species with significant* northward/inward movement	186	174
Species with significant* southward/coastward movement	82	97
Species with northward/inward movement >200 miles	48	3

**In Tables TD-1 and TD2, "significant" refers to 95 percent confidence ($p < 0.05$).*

The shaded bands in Figures 1 and 2 show 95 percent upper and lower confidence intervals around the mean. These confidence intervals are based on the distribution of all the individual species-level centers

of abundance, relative to where they were in 1966. The confidence interval grows wider over time in both Figure 1 and Figure 2, which is to be expected as the distribution of species naturally continues to spread from a common origin (1966). A few species have moved hundreds of miles northward, and they continue to move northward at a relatively high rate. Some species have moved southward and continue to move in that direction. Others fall in between. Over time, as species-level data points continue to spread out, the standard deviation of the distribution will increase, and therefore the confidence band around the mean—which is ultimately based on the sample size (constant number of species) and standard deviation (increasing)—will grow wider.

Other published studies have also found evidence of shifts in bird wintering ranges over time using these data. For example, La Sorte and Thompson (2007) analyzed long-term data from the CBC and concluded that ranges have shifted northward, even after accounting for various regional influences.

References

La Sorte, F.A., and F.R. Thompson III. 2007. Poleward shifts in winter ranges of North American birds. Ecology 88(7):1803–1812.

Link, W.A., and J.R. Sauer. 1999. Controlling for varying effort in count surveys: An analysis of Christmas Bird Count data. J. Agric. Biol. Envir. S. 4:116–125.

National Audubon Society. 2009. Northward shifts in the abundance of North American birds in early winter: a response to warmer winter temperatures? http://web4.audubon.org/bird/bacc/techreport.html.

Soykan, C.U., J. Sauer, J.G. Schuetz, G.S. LeBaron, K. Dale, and G.M. Langham. 2016. Population trends for North American winter birds based on hierarchical models. Ecosphere 7(5):e01351.