Handbook to the Partners in Flight Population Estimates Database, Version 3.1

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Preface

This document describes the content of Version 3.1 of the Partners in Flight (PIF) Population Estimates Database (PIF 2020b), which provides population estimates for breeding USA/Canada landbirds at several geographic scales following the ***Partners in Flight approach*** described initially in Rich et al. (2004), by Rosenberg and Blancher (2005), and most recently refined by Stanton et al. (2019). The Handbook also provides details about how the estimates were derived, information on limitations and caveats, a guide to using the estimates, and future desired directions for improving the estimates.

This version of the database is intended as a companion to the *Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States* (Rosenberg et al. 2016), although estimates for most species included in the database have been updated from those used in the 2016 Plan. Most of the estimates in the database are based on North American Breeding Bird Survey (BBS) data for landbirds from the decade 2006–2015. The information in this 2020 Version of the Handbook, for Version 3.1 of the database, describes all changes that have been made to the database since 2007 (Version 1.0, cf. Blancher et al. 2007)—including the additions documented in the Handbook for Version 2.0 (Blancher et al. 2013)—and therefore serves as a single source document describing the current database.

Version 3.1 of the database addressed some of the recommendations suggested by Thogmartin et al. (2006) but does not yet fully address other limitations noted by Thogmartin et al. (2006), Blancher et al. (2007), Thogmartin (2010), Matsuoka et al. (2012), and Twedt (2015). By far, the most substantial change to the database comprises the incorporation of quantitative uncertainty bounds around population estimates for most species (see Stanton et al. 2019 for details). PIF Science anticipates that future versions of the database will occur in stages: first, improving elements of the basic PIF approach (e.g., incorporating more recent BBS data, updating Time of Day Adjustments, and refining Pair Adjustments); next, addressing additional concerns inherent in the PIF approach (e.g., replacing average maximum detection distance bins with research-derived species-specific effective detection radii); and later, perhaps replacing the sample-based PIF approach with a spatially-explicit, model-based (pixel-based) approach that more deliberately incorporates habitat and road biases and the proportion of birds available but not detected by current sampling methodology.

This current Version 3.1 of the Handbook incorporates minor improvements in text clarity over the previous 3.0 version, updates citations in the Literature Cited, and documents changes in sources for a few species. The content of the Population Estimates Database itself remains the same except for changes to the estimates for Black Vulture at all scales (see p. 14); the estimates for California Scrub-Jay and Woodhouse's Scrub-Jay at all scales (p. 14); revised Time of Day adjustments and population estimates at all scales for Mexican Whip-poor-will and Long-eared, Elf, Flammulated, Western Screech, Great Gray, and Northern Hawk owls; the global and USA/Canada estimates for Dusky Grouse, Snowy Owl, and Peregrine Falcon; the global estimates and percent of global estimate in USA/Canada for Black-billed Cuckoo, Belted Kingfisher, Willow Flycatcher, Red-eyed Vireo, Bluethroat, Golden-winged Warbler, American Redstart, and Indigo Bunting; and updated taxonomic sequence and name changes corresponding to the 60th supplement to the AOS Check-list of North American Birds (Chesser et al. 2019).

Contents

Background

Population size is a central measure in most species assessment schemes, particularly those aimed at identifying species with a high risk of extinction (e.g., IUCN 2001, various national endangered species programs). Small populations are generally considered more vulnerable than large ones, even among those species not immediately at risk. Partners in Flight (PIF) includes global Population Size (PS) as one of several factors assessed to determine species of high conservation importance (Panjabi et al. 2020), using an order of magnitude scale to assess relative risk (Stanton et al. 2019).

The *PIF North American Landbird Conservation Plan* (Rich et al. 2004) first published global population size estimates for 448 native landbirds of the United States and Canada. These estimates were used in assessing conservation importance of individual species and the immediacy of conservation action required. The estimates also provided a sense of the magnitude of the task of meeting Plan objectives—for example, achieving a doubling of a species' current population.

Meeting continental objectives requires actions at regional or state scales, and PIF received many requests to step the continental population estimates down to smaller geographic scales where they could be used as a starting point in setting regional objectives or judging the magnitude of actions needed to meet those objectives. AFWA state reports (Rosenberg 2004) provided that breakdown for priority species in each U.S. state. However, the data underlying the estimates were not widely available, making it difficult to interpret or revise estimates in light of other regional data and expertise or to use the data for other related needs. The purpose of the first version (2007) of the PIF Population Estimates Database was to make these data broadly available and to provide a base for future improvements to the estimates.

Raw counts of birds from the North American Breeding Bird Survey (BBS) (cf. Pardiek et al. 2018 for data archives; see also Sauer et al. 2013) formed the basis for most of PIF's population estimates in the 2007 version of the database and in subsequent revisions. Although BBS was not designed specifically to produce population estimates, and there are difficulties to overcome as a result, there are important advantages (Rosenberg et al. 2017). In the BBS, data from across much of USA/Canada have been collected according to a single standardized method; surveys employ random start points and directions, thus enhancing regional representation of the avifauna (roadside bias notwithstanding); and the data are readily available for the bulk of USA/Canada landbirds. For regions with a paucity of BBS routes, PIF used other available count data.

Partner response to the 2007 PIF Population Estimates Database generated both enthusiasm (finally, some reasonably reliable numbers for the size of bird populations at multiple scales!) and probably an equal amount of animated discussion and skepticism regarding some of the numbers. Thogmartin et al. (2006), Blancher et al. (2007), Confer et al. (2008), Thogmartin (2010), Matsuoka et al. (2012), and Twedt (2015) all offered thoughtful critiques of the methodology. Although population estimates were not an explicit product of *Saving Our Shared*

Birds (Berlanga et al. 2010), updated estimates were used in that publication for scoring the Population Size assessment factor, estimating the magnitude of loss of common birds in steep decline, and illustrating the high percentage of birds shared internationally. These updated estimates, produced mostly in 2008 for use in *Saving Our Shared Birds*, provided the foundation for the next iteration of the Population Estimates Database. Version 2.0 (2013) of the database addressed some of the recommendations of the Thogmartin et al. (2006) review and incorporated other changes documented in detail in Blancher et al. (2013), including in part:

- Updating BBS count data to the 1998-2007 decade (1990-1999 in Version 1);
- Using Ontario atlas point count data from 2001-2005 to fill a large gap in BBS coverage in northern Ontario and adjacent provinces;
- Updating population estimates from species-specific surveys where possible;
- Changing some maximum Detection Distance Adjustments based on detection data in a few other large datasets (from Ontario, California, Colorado, and boreal Canada);
- Using species-specific Pair Adjustments rather than a multiple of 2 for all species;
- Revising Time of Day Adjustments to include BBS data from 1997 to 2005 (previously 1997 to 2002);
- Using NatureServe digital range data to extrapolate populations south of the U.S.; and
- Reducing estimates for regions in the Canadian arctic by the proportion of permanent ice cover in those regions.

This current Version 3.1 (2020) of the PIF Population Estimates Database continues to incorporate and refine the changes noted above for Version 2.0 (2013) and adds the following refinements:

- Updating BBS count data to the more recent 2006–2015 decade;
- Revising Time of Day Adjustments to include BBS data from 1997 to 2015;
- Replacing non-linear polynomial models with generalized additive models to fit models of species counts to stop number for estimating Time of Day Adjustments;
- Shifting the range of the Detection Distance Adjustment downward;
- Replacing NatureServe digital range data with eBird relative frequency data to extrapolate continental and global populations *for species with ranges extending south of the U.S.* (see Extrapolation to Global Estimates section below; NatureServe range data were retained for extrapolations to unsampled range within the U.S. and Canada); and
- Replacing the original (Version 1, 2007) data quality analysis with quantitative upper and lower bounds of uncertainty around population size estimates (Stanton et al. 2019).

By far the most important advancement in Version 3.1 of the database is the incorporation of quantitative uncertainty bounds around the population estimates for all landbird species with sufficient data (as described below and in Stanton et al. 2019). Estimating this uncertainty required a revised methodology for determining average BBS species counts over the decade 2006–2015 (see the methodological descriptions that follow, and especially Stanton et al. 2019). We refer to this method of estimating population size—from initial descriptions in Rich et al. (2004) and Rosenberg and Blancher (2005) through several subsequent refinements, including Stanton et al. (2019)—as the ***Partners in Flight approach***. We hope that, as a result of these modifications, partners will better appreciate the underlying assumptions and caveats of the modeling process and carry that understanding forward as they make use of the estimates in advancing the conservation of birds.

The following text integrates into a single narrative the original (2007) description of the database with all subsequent (Version 2.0 and Version 3) changes in content and methodology. Users should be aware that the estimated abundance of some species has changed significantly since the 1990s—as an artifact of changes in methodology, but also as a result of changes on the landscape and the consequent biological responses of the birds those landscapes support.

Geographic Scale of Estimates

Estimates are presented in the database at the following geographic scales:

- Global population estimates for USA/Canada landbirds
- USA/Canada estimates (Canada and continental United States)
- BBS coverage area (USA/Canada minus arctic Canada)
- Bird Conservation Regions (BCRs) (CEC 1998; Bird Studies Canada and NABCI 2014)
- Individual States, Provinces, and Territories
- BCRs within States, Provinces, and Territories (hereafter referred to as *physio-political regions*).

For species whose estimates were based on BBS data, estimates within physio-political regions were the building blocks for estimates at larger scales. For example, population estimates for North Dakota are summed from the portions of BCR 11 and BCR 17 within North Dakota; estimates for BCR 12 encompass estimates from the portions of the six states and provinces that intersect that BCR. Estimates within physio-political regions are more likely to suffer from small sample sizes and/or high variance than those at larger scales. The physio-political estimates are provided in the database so that users can have access to all of the data that went into estimates at broader scales and for the benefit of those who would like to work with the data at the finer physio-political scale.

Deriving the Population Estimates

The PIF Population Estimates Database uses a sample-based approach to estimating population size in which the fundamental data for each species are derived from a survey or sample count conducted according to a particular protocol and/or survey design. The general model used to calculate an estimate within each physio-political region is:

Population Estimate = (Species Count / Area Sampled) x Region Area x Detection Adjustments

where the last term includes adjustments for Detection Distance, Time of Day, and likelihood of detecting both members of breeding pairs—each described in detail below along with other components of the basic model.

In order to arrive at a quantitative estimate of the overall uncertainty underlying each landbird species population estimate, Stanton et al. (2019) used a Monte Carlo simulation to propagate the uncertainty arising from each individual component of the estimation model, including the raw species count data, through to the final estimation of total population size. Using this methodology means that the final result is a ***distribution of population size estimates*** for each species in each geographic region—as opposed to the single point estimate presented in previous versions of the database. The distribution can then be described using standard descriptive statistics, including the mean, median, and percentiles surrounding the mean (Stanton et al. 2019). Because each variable component of the model is now treated as a distribution, the descriptions of these components differ somewhat from those in previous versions of the database Handbook.

Species Count

As noted above, a count of individual birds of each species—derived from a survey conducted according to a particular protocol and/or survey design—is the fundamental component of the PIF approach for estimating breeding population size. BBS provided these data for most species, but in regions with a paucity of BBS routes, we used other available count data or extrapolated BBS data to regions for which no samples were available.

Species Count: Breeding Bird Survey (BBS) Average

For most landbird species in the database, species-specific counts per 50-stop BBS route provided the basic data on relative abundance. These data provide comparable values derived from a standard technique applied across much of USA/Canada. BBS routes are restricted to roadsides, so there is some habitat bias, the amount and direction of which depends on species and region. However, BBS route start points and direction are randomly determined, minimizing selection bias and providing a reasonably representative sample of the avifauna in most regions. Nonetheless, an assumption of the PIF model is that BBS routes sample the habitats used by birds at a similar frequency at which those habitats occur on the landscape as a whole (cf. Veech et al. 2012, Veech et al. 2017).

BBS data were selected from the most recent decade in which data were available (2006 through 2015 in this version of the database) in order to create an estimate that would be current yet reasonably robust to year-to-year natural variation in abundance and relatively insensitive to changes in which BBS routes were run in a given year or to which observers ran the routes. In their estimation of uncertainty in the count data, Stanton et al. (2019) accounted for both within-route and between-route variation. The mean and variance of total counts for each species along each route within a region defined a discrete distribution from which 10 random values were drawn regardless of how many times a route was actually run in the 10-year period. For each iteration of the full model population size calculation, the mean route-level count for a region was determined from the mean of the pooled simulated observations for all routes within the region (see Stanton et al. 2019 for details). To account for between-route variation, for each iteration of the full model, Stanton et al. (2019) randomly selected, with replacement, a set of routes to represent the region equal in size to the total number of routes within each region.

As a result, each BBS route sampled under acceptable conditions in at least one year during the 2006–2015 decade was equally weighted with every other BBS route in the same region, regardless of number of years sampled or the presence or absence of individual bird species.

BBS counts of very similar species are sometimes reported as "unidentified" birds of either species (e.g., "unid. Alder Flycatcher/Willow Flycatcher"). We summed these counts by BCR region to compare them to counts of each species in the region. In most cases, the unidentified counts were very small relative to identified counts. However counts for "unid. Cordilleran/ Pacific-slope Flycatcher" and "unid. Common Redpoll/Hoary Redpoll" were more substantive, such that ignoring these unidentified birds would underestimate population abundance. For these two pairs of species, unidentified birds in each region were assigned to species on the basis of the ratio of identified birds in the same BCR during 2006–2015 BBS counts.

Species Count: Ontario Breeding Bird Atlas Point Count Data

The BBS does not sample the Hudson Bay Lowlands in northern Ontario or neighbouring provinces due to a dearth of both roads and people. These lowlands encompass a large portion (346,000 km^2) of the Taiga Shield and Hudson Plains Bird Conservation Region (BCR 7; U.S. NABCI Committee 2000). In the original (2007) version of the PIF database, population estimates for this region were extrapolated from relatively few BBS routes scattered across the vast Taiga Shield portion of BCR 7. In the 2013 update, we replaced extrapolations with estimates based on atlas point count data collected in Ontario during 2001-2005 (Cadman et al. 2007).

Point count averages were calculated for each species in each of 82 10 x 10 km^2 atlas squares in Ontario BCR 7 that included at least 10 point counts – 1,855 point counts in all, each of 5 minutes duration. A point count average for the full region was calculated by averaging the atlas square averages, stratifying by the extent of species NatureServe breeding range (Ridgely et al. 2005) in each of 3 ecoregions (Hudson Bay Coast, Northern Taiga, James Bay) within BCR 7. These region-wide count averages were then converted to a BBS route average equivalent, based on a comparison of atlas point count averages and BBS route averages in BCR 12 Ontario, a region well sampled by both programs in 2001-2005.

BBS equivalent averages for Ontario BCR 7 were also used to fill gaps in Manitoba and Quebec portions of BCR 7, averaged with BBS data from Labrador BCR 7 in the case of Quebec, and adjusted by the relative extent of species breeding range (Ridgely et al. 2005) in Ontario versus the other regions.

Species Count: Extrapolations to Unsampled Range

In other regions within the USA and Canada with no relative abundance information, average counts were assumed to be the same as in neighbouring regions within the same BCR, with an adjustment based on the relative size of breeding range in the source and recipient regions. Range information was based on the Ridgely et al. (2005) NatureServe digital maps.

In the case of some species, BBS data were augmented with data from other sources to account for partial relative abundance information in a particular BCR, State/Province, or physio-political region. These additional data sources are documented in the *Data Source* column of the downloadable files. The Continental/Global file also provides an additional column, *Population Estimate BBS,* which denotes the estimate derived only from BBS data (usually identical to the USA/Canada estimate). For species with partial relative abundance information in some regions, the *Population Estimate BBS* was calculated by starting with the USA/Canada estimate, then subtracting the BCR 3 Canada estimate (based on a combination of NT/NU checklist data, Breeding Bird Census density data [cf. p.14], and range adjustments), subtracting Ontario BCR 7 estimates (which were based on atlas data), and subtracting half of Quebec BCR 7 estimates (since those were an average of atlas data from Ontario BCR 7 *and* BBS averages from Newfoundland/ Labrador BCR 7, adjusted for range).

Area Sampled

The area sampled by a BBS route was based on the 400-m limit within which birds observed are counted, yielding a potential coverage area of 25.1 km^2 per route ($50 \times \pi \times (0.4)^2$). The BBS average divided by the area sampled per route yields an estimated density of birds. Of course, not all bird species are detectable out to the 400 m limit, and others may be effectively detected at a greater distance (e.g., birds with very loud calls, birds that fly into the count area during the count). These species-specific differences in detection distance are dealt with in the section below describing the Detection Distance Adjustment factor.

Physio-political Region Area

The area of each physio-political region was used to extrapolate estimates from the scale of a BBS route to the full region. Area, reported here in square kilometers, is derived from an overlay of BCR and State and Province shape files and, as noted above, excludes the portion of a physio-political region that falls outside of a species range as determined by NatureServe digital range maps (Ridgely et al. 2005).

The Region Area also excludes the area of water in very large lakes the size of Utah's Great Salt Lake or larger (e.g., all of the Great Lakes were excluded, as were several large lakes between Lake Winnipeg, Manitoba and Great Bear Lake, Northwest Territories). In the case of the Canadian Arctic (BCR 3), Region Area also excludes areas covered by snow and ice in the breeding season. Advanced very high resolution radiometer (AVHRR) land cover data from 1995 (Natural Resources Canada 1995) provided the basis for estimating % cover of snow and ice in the three ecoregions that comprise BCR 3: Arctic Cordillera (75.3% snow and ice), Northern Arctic (29.0%), and Southern Arctic (1.7%).

Detection Adjustments

Clearly, not all birds present with the 400-m bounds of each BBS stop are detected within 3-minute counts. Ideally we would like to have a measure of the proportion of birds actually present that are detected at BBS stops. This proportion will vary by species, habitat, and location, and much additional research and review of existing information will be required to determine or even to estimate this proportion. In lieu of using species-specific adjustments for every species, we have used three measures to adjust the population estimate to approximate detectability of individual species. Each adjustment factor is intended to be used together with BBS data to obtain an approximate estimate of population size.

Detection Adjustments: Detection Distance

We placed each species into one of seven Detection Distance Adjustment categories—50, 80, 100, 125, 200, 300, or 400 m—based on literature (Rosenberg and Blancher 2005) and a consideration of habitat, song strength, and species-specific behaviour (amount of time spent in flight, secretiveness, etc.). The Detection Distance Adjustment modifies the BBS radius of observation to account for differences between species in observability, both visual and auditory, due to distance. Such detection distance classes have sometimes been referenced in the literature as average maximum detection distances (MDDs, cf. Matsuoka et al. 2012), but although PIF Science originally started with an MDD-like approach, we have made numerous modifications to these distance classes over the years for various reasons. For Version 2.0 (2013) of the database, we reviewed and in many cases modified the 2007 distance categories used for each species based on information received following a PIF request for input, new published data (e.g., Hamel et al. 2009), and comparisons with distance information in four regional point count datasets (California, Colorado, Ontario, and boreal Canada). Nonetheless, the distance classes used in the PIF database tend to be larger than estimates from empirically-derived effective detection distances (e.g., from program Distance)—in part because we have also adjusted density with Pair and Time of Day adjustments (see below), but also because movement of birds during counts means that a larger area has been sampled than is indicated by the distance to bird detections. Consequently, PIF's population estimates appear to be generally conservative relative to other sources of estimates (Rosenberg and Blancher 2005, Matsuoka et al. 2012, Twedt 2015). Population estimates in this database are strongly sensitive to the detection distance used; for example, if Detection Distance is halved, the population estimate is quadrupled. Refinement of detection distances is thus an important area for future work.

To better reflect uncertainty inherent in the Detection Distance Adjustment, Stanton et al. (2019) sampled randomly from uniform distributions with the lower bound set at 80% of the difference between a species' assigned distance adjustment category and the next lower category and the upper bound set at a 10% increase over the assigned category. Stanton et al. (2019) reasoned that this distribution would include the assigned distance, would likely encompass the uncertainty of the adjustment parameter, and would partly account for recent empirical estimates suggesting that the assigned PIF distance categories tended to overestimate detection distance (see Matsuoka et al. 2012, Twedt 2015).

Detection Adjustments: Pair Adjustment

Original (2007) estimates included a multiple of 2 for all species on the assumption that, on average across BBS routes at the peak time of detection, no more than one bird per pair is detected on BBS counts. For many songbirds, counts at the peak time of day are of singing males, with females relatively rarely detected; for other breeding birds, time spent out of view at nests or perched in silence will often result in only one member of a pair being detected. However, we know that detection of both members of a pair differs across species, largely depending on how they are detected on BBS routes (e.g., by song or by sight, singly vs. in groups). To improve the relativity of estimates across species, we assigned species to one of five Pair Adjustment categories (1.0, 1.25, 1.5, 1.75, 2.0) after considering the following information for each species:

- Time of day of peak detection—if at dawn (BBS stop 1), then Pair Adjustment = 2 on the assumption that birds detected at dawn are largely males detected by song;
- Proportion of birds detected singly at individual BBS stops (from BBS stop by stop dataset)—if > 90%, then Pair Adjustment = 2; otherwise the Pair Adjustment was assumed to be lower;
- Proportion of sexes detected in five available point count data sets with sex information—greater skew to one sex suggested a need for a greater Pair Adjustment (if > 90% of detected birds were of one sex, then Pair Adjustment was likely to be 2, otherwise adjustment was lower);
- Breeding phenology of the species at the time of BBS surveys—Pair Adjustment was assumed to be higher during incubation or early nestling stages, with lower adjustments used if many birds were likely to be feeding older nestlings or fledglings at the time of BBS surveys;
- Proportion of birds in BBS counts that included 5 or more individuals at a single stop. All else being equal (above), a higher proportion of large counts was assumed to indicate that birds of both sexes were being detected, and thus a lower Pair Adjustment was assigned.

Stanton et al. (2019) incorporated uncertainty in the PIF Pair Adjustment assignments by replacing them with normal distributions truncated at 1.0 and 2.0 with a mean at the assigned PIF Pair Adjustment value and with a variance term (sd = 0.13) that would allow overlap between the categorical distributions.

Detection Adjustments: Time of Day Adjustment

Due to daily cycles of activity, detectability of most bird species is strongly influenced by the time of day a count is taken, often showing a strong increase and/or decrease during the 4–5 hour duration of a 50-stop BBS survey. Under the assumption that birds are missed at all other times of the survey in proportion to the degree to which counts fall below the time of peak detection, we calculated a species-specific Time of Day Adjustment to move the BBS average upwards to the peak time of detection by dividing the count at peak BBS stops by the average count across all BBS stops. This adjustment will be an underestimate for species whose peak time of detection falls outside the prescribed BBS morning hours—principally some crepuscular and nocturnal species.

The peak time of detection was determined using stop-by-stop data from all BBS routes survey-wide from the period 1997 to 2015. The average number of individuals of a species counted per stop was calculated for each BBS route, and then species counts at each BBS stop number (1 through 50) were summed across all BBS routes. Stanton et al. (2019) used generalized additive models to relate the time of day (i.e., stop number) to the number of birds observed at each stop while also accounting for route-level variation and observation trends by year (see details in Appendix 1 of Stanton et al. 2019). By sampling from the distribution of the fitted curve at each stop, Stanton et al. (2019) calculated a distribution for the Time of Day Adjustment for each species.

Calculation of the peak time of detection assumes that suitable habitat is found in similar amounts early or late in the BBS morning survey when summed across many BBS routes. For many species, data from large numbers of routes results in a relatively robust Time of Day Adjustment. For species detected on only a few BBS routes, or for species that are highly colonial, time of day patterns are more difficult to separate from random variation among stops. For species recorded on fewer than 100 routes (e.g., nocturnal species), we calculated an average weighted by number of routes from all species in the same taxonomic group with more than 100 routes (see Stanton et al. 2019 for further details).

We did not consider regional variation in Time of Day Adjustments because most species lack sufficient sample sizes to calculate separate adjustments in each region. However, examination of daily patterns for a selection of widespread landbirds suggested generally similar adjustments and time of day patterns across regions for most species.

In summary, the Time of Day Adjustment results in extrapolated population estimates based on counts of birds during their peak time of detection, thus reducing but not eliminating underestimates due to undetected individuals. We acknowledge that there will still be an unknown fraction of the population that remains undetected even during the time of peak detection within the BBS survey—resulting in an underestimate of population size, particularly for some cryptic and/or nocturnal species. Exploration of alternative approaches incorporating empirical estimates of detection probability will undoubtedly lead to changes in subsequent revisions of the database.

Other Possible Adjustments

We did not provide adjustments to correct for habitat bias in BBS coverage (cf. Veech et al. 2012, Veech et al. 2017), seasonal peaks in detection outside of the BBS survey dates, or low detection rates among secretive birds. Where data exist to address these issues, users may wish to apply their own adjustments to the information underlying the database estimates (cf. *Desired Next Steps* and *A Guide to Using the Database*, below).

Combining Model Elements: Estimating Population Size and Uncertainty for Species with BBS Data

Stanton et al. (2019) incorporated uncertainty into the PIF process by using a Monte Carlo approach to estimate population size distributions for the 336 landbird species for which BBS was the sole or major data source for Species Count in the PIF model. In each of 1,000 iterations, prior to calculating the population size estimate, independent values were sampled randomly from each variable component of the model—mean route-level BBS Count, Detection Distance adjustment, Pair Adjustment, and Time of Day Adjustment—for each species in each physio-political region. The 1,000 iterations of the full model calculation thus described a population size distribution for each species from which Stanton et al. (2019) presented a median estimate with either 80% or 95% bounds. The standardized interquantile distance—the difference between upper and lower 80% (or 95%) estimation bounds divided by the mean population size estimate—quantifies the degree of uncertainty around the population size estimate. Additional details and source code can be found in the text and appendices in Stanton et al. (2019). Note that in contrast to the median estimates presented in Stanton et al. (2019), we provide mean population estimates in the online database so that estimates at smaller scales will sum to the estimates at the broadest scales and to avoid misleading estimates of zero when birds are present on only a few BBS routes. Both mean and median estimates are available in the downloadable files.

While partners should find the population estimates helpful in developing purposeful planning at multiple scales, it is our hope that understanding the level of uncertainty in the population estimates will help temper unwarranted inferences. In addition, understanding the greatest sources of uncertainty in the estimates should help direct future studies.

Other Sources of Population Estimates

More refined sources of population estimates were available for some species at physio-political region scales as a result of targeted surveys (e.g., Kirtland's Warbler in northern Lower Peninsular Michigan). For other species, more accurate assessments using non-BBS datasets may have been conducted at a continental scale. In the Population Estimates Database, we tried to use the best available information for estimates—with the caveat that we considered range-wide consistency within species groups to be a guiding principle. For example, a targeted breeding gamebird survey in a portion of a species range, however accurate for that physio-political area, might not be as useful as an estimate from BBS-derived data if the local survey could not be easily extrapolated to the entire range of the species.

In the case of Black Vulture, we adopted the Black Vulture-specific methodology of Zimmerman et al. (2019) to estimate Black Vulture population size at all scales from the 2018 BBS annual index adjusted for vulture time in flight and percent BBS detections of flying vultures (both adjustments derived from targeted research studies).

Chesser et al. (2016) recently split California (CASJ) and Woodhouse’s (WOSJ) Scrub-Jay as full species from Western Scrub-Jay (WESJ). In the BBS dataset used for most landbirds in the

Population Estimates Database (PED), detections throughout the range of these species were recorded as WESJ. In PED 3.0, we split WESJ estimates between CASJ and WOSJ along BCR lines, assigning all estimates in a given BCR to the species with greater abundance in that BCR. This BCR approach created anomalies, however—e.g., assignment of WOSJ estimates to Oregon and Washington, where the species is not known to occur regularly. In PED 3.1, we used eBird maps and BirdLife range files to split WOSJ and CASJ estimates within each BCR—along state lines, if appropriate (BCRs 9 and 10, OR and WA), or by manually estimating % range where species shared both states and BCRs (BCR 9, NV and CA)—to extrapolate population estimates for each species. After making these corrections at the physio-political scale, we summed estimates for each BCR, state, and the USA. We did not duplicate the Stanton et al. (2019) analysis to estimate birds/route or uncertainty intervals for the geographies originally affected by the PED 3.0 misallocation, and so we left these cells blank. We used PED 3.0 estimates for Mexico to recalculate *% Global* estimates of CASJ and WOSJ in USA/Canada. We then extrapolated new global population estimates for the two species from the new USA estimates and recalculated *% Global* and *% USA/Canada* estimates from the new unrounded global and USA population estimates.

In all cases, sources for these and other alternative estimates are designated in the *Source* field in the database. For several wide-ranging species, we were able to obtain continental estimates from other sources but lacked the regional or local data to make credible estimates at finer scales. In these instances, we generally provided estimates only at the global or continental scale and left the BCR or physio-political region cells blank.

Population Estimates Based on NT/NU Checklists

There are almost no BBS data in arctic Canada (Canadian part of BCR 3). Since this region is so large (approximately 2.6 million km^2), it was not useful to extrapolate estimates from the Alaskan part of BCR 3. Instead we used a combination of density estimates from the Breeding Bird Census (BBC, Kennedy et al. 1999) and relative abundance from the Northwest Territories and Nunavut Bird Checklist Survey (hereafter NT/NU Checklist) to estimate population size of landbirds in the arctic. Details of the methods are presented in Appendix B of Rich et al. (2004, p. 79). Checklist data came from 649 sites visited between 1995 and 2001.

Extrapolation to Global Estimates

Fewer than half of the landbird species in the database have breeding ranges confined to USA/Canada. For the remainder, estimates of global population size were based on two types of extrapolation from USA/Canada estimates.

First, the proportion of eBird checklists on which a species was recorded during June and the first week of July (cf. Sullivan et al. 2014) was compared across regions within the Western Hemisphere to obtain relative frequencies for each species in each region. (BCRs were the regions used within USA/Canada, whereas regions were mostly full countries elsewhere in the hemisphere—with the exception of Mexico, Brazil, and Argentina, where sample sizes allowed us to subdivide into several geographic regions per country). These relative frequencies were then weighted by region size, with the resulting area-weighted frequencies serving as the basis for estimated percent of population. Using Cerulean Warbler as a test case, we compared this eBird checklist frequency approach with breeding region percentages based on range maps (which assume a similar density across the range) and with abundance-based percentages using BBS count data and eBird modeled abundance (Fink et al. 2010, Johnston et al. 2015; also see Understanding eBird Abundance Models on the eBird website). We found a high degree of similarity in regional proportions of population between the BBS count data and eBird modeled abundances; range-based proportions of population were less similar; as expected, eBird frequency-based proportions were intermediate between abundance-based estimates and range map-based proportions. In the future, we expect that abundance models for the Western Hemisphere will be available for many more species, but for the present, we rely on eBird frequency-based extrapolations rather than our previous use of range map-based extrapolations.

In only a few cases where we suspected that eBird data represented mostly migrant or extralimital records and expert opinion and/or published sources verified that >99% of a species breeding population resided within USA/Canada, we used the rounded USA/Canada population estimate as the global estimate and estimated the USA/Canada percent population to be between 99.8% and 100%.

Second, since eBird checklist density is represented more sporadically outside of the Western Hemisphere, we have continued to rely on a variety of published range maps to extrapolate population estimates to the Eastern Hemisphere. When a species had a very high proportion of its breeding range outside of North America, the PIF Science Committee found other sources for estimates of global population or simply estimated the global population to within an order of magnitude based on range extent and relative density compared to other species.

Global population estimates are used by PIF to assign an order of magnitude Population Size assessment score (PS) and to estimate the proportion of global population that breeds in USA/Canada or in any region within North America. This helps users to understand a region's responsibility for the species.

Comparisons with Other Recent Published Sources of PIF Population Estimates

For reasons outlined below, some values in Version 3.1 of the Population Estimates Database (PED)—both the actual estimates as well as %Population figures—may differ slightly from those presented in other recent PIF or PIF-related publications.

The USA/Canada population estimates tabled in Appendix A of the *Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States* (Rosenberg et al. 2016), for example, used methods identical to those described in this Handbook, but were calculated based on a different time series of BBS data—the decade 2005–2014 vs. 2006–2015 for Version 3.1 of the PED. The *% of Breeding Population* figures presented in the Area Importance column of the Joint Venture profile tables were likewise derived from the earlier

10-year period and were also calculated for Joint Venture boundaries, obviously a different regional scale than the BCR or physio-political scales presented in Version 3.1 and previous versions of the PED.

In the Supplementary Appendix in Stanton et al. (2019), the authors presented the *median* estimates resulting from the sampling methodology described above, while we utilized *mean* population estimates from the same analysis in the online PED. We used means so that estimates at smaller scales would sum to the estimates at the broadest scales and to avoid misleading estimates of zero when birds are present on one or two BBS routes in a region. Both mean and median estimates are available in the downloadable files of the PED, and the median estimates are identical to those presented in Stanton et al. (2019).

The supplementary data files (Data S1 and S2) associated with Rosenberg et al. (2019) provide the population estimates for 530 species of North American birds at the USA/Canada scale that were used in an analysis of population change across the continental avifauna. For most landbirds, Rosenberg et al. (2019) compiled estimates directly from Stanton et al. (2019), and the mean estimates in Rosenberg et al. (2019) and Version 3.1 of the PED are identical for 350 landbird species. In the approximately 20 instances where Rosenberg et al. (2019) used non-PIF-calculated sources for USA/Canada populations, there may be a few differences between the PED and Rosenberg et al. (2019). In addition, the PED includes USA/Canada estimates for 82 species that were not included in Rosenberg et al. (2019), largely because they lacked a USA/Canada trend, needed for inclusion in Rosenberg et al. (2019) but not required for inclusion in the PED.

Finally, the recently updated 2019 *Avian Conservation Assessment Database (ACAD)* relies on the population estimates presented in Version 3.1 of the Population Estimates Database (PED) for landbirds at the global and USA/Canada scales. However, the %Population (percent of global population within a region, or %Pop) figures a*t the regional (BCR) scale* may differ between the ACAD and PED. The main reason is that in the ACAD Regionals, we relied more on eBird frequencies *within* USA/Canada for species not well detected by BBS surveys, thereby providing data in many more regions than was possible using just BBS in the PED. We also used the decade 2005–2014 to calculate %Pop in the Regional ACAD vs. 2006–2015 for Version 3.1 of the PED. In the ACAD, %Population and Relative Density (RD) are used at the Regional scale to indicate conservation responsibility. When the source in the ACAD for RD and %Pop in a BCR was BBS, differences in %Pop between ACAD and PED are minor; when the source in ACAD was eBird, then the differences in % values may be more substantial.

Comparisons with PIF Population Estimates in Version 2.0

Here we examine the extent to which PIF population estimates have changed between Version 2.0 of the database (2013) and this Version 3.1 update (2019). For a comparison of Version 1.0 (2007) and Version 2.0 estimates, see the previous Handbook (Blancher et al. 2013).

At the global scale, some estimates changed due to a change in estimate source, while other changes reflect differences in the time period and methodology. On average (geometric mean), there was a 15.1% increase in population estimates across 450 species with estimates in both time periods (median 8.3% increase). These changes resulted in 51 changes in Population Size (PS) assessment scores (cf. Panjabi et al. 2020), 34 increases in score due to lower global estimates, and 17 decreases in score due to higher global estimates. Most (43) of these score changes resulted at least in part from a change in estimate source, including some that resulted when we replaced range maps with eBird data in calculating extrapolations south of the U.S. Of the eight score changes among species whose PIF calculated estimate sources did not change, seven were decreases in score (increased population estimates) and one was an increase in score.

The bulk of PIF's estimates are based on extrapolations of BBS counts, as described in detail above (pp. 7–8, 12). The following comparisons between Version 2.0 and Version 3.1 are restricted to 342 landbird species in 182 regions (BCR portions of State/Province/Territory jurisdictions) whose estimates were based solely on BBS data. These estimates accounted for 90.4% of PIF's current landbird estimates across US/Canada. Taxonomic splits of 3 species that occurred between Version 2.0 and 3.1 were ignored for this comparison; thus the comparison includes Western Scrub-Jay (sum of California and Woodhouse's Scrub-Jay estimates in Version 3), Sage Sparrow (Sagebrush and Bell's Sparrows), and Red Crossbill (Red and Cassia Crossbill).

There was a very high correlation of the estimates across species (Figure 1), with updated estimates tending to be slightly higher than previous estimates on average. The average (geometric mean) change across these 342 species was +19.6% (median +17.0%), with the bulk of species having higher estimates in Version 3.1 (see summary in Table 1). Below we explore how those changes break down across the parameters used to calculate the estimates and in particular what portion of the change was due to methodological change (changes in how adjustment factors were calculated) versus changes in BBS counts between time periods (which should reflect biological change as well as sampling error).

We made no changes to species assignments for Distance or Pair Adjustment categories between time periods. However, these adjustments were sampled from a distribution range around category values in the Version 3.1 update, and this sampling did impact species estimates. In particular, because Distance adjustment samples were pulled from a distribution skewed more below than above each category value, all species showed an increase in estimates due to this sampling, averaging a 19.6% increase (median change 24.1%, Table 1).

Pair adjustment distributions were not skewed, but still resulted in a small decrease in estimates on average (-1.3%, Table 1). Changes to Time of Day Adjustments involved updating the underlying BBS data and some change in methodology (see details above); overall these changes resulted in a 3.9% increase in population estimates on average (Table 1).

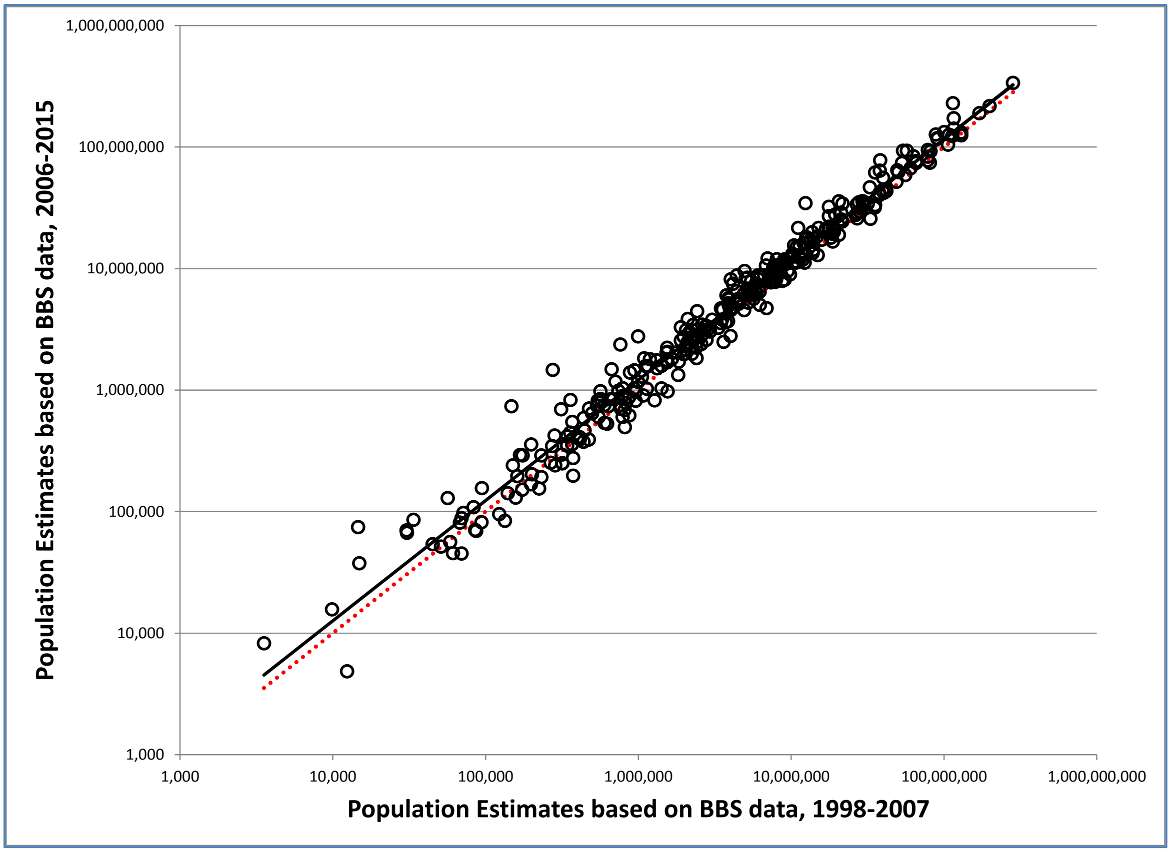

Figure 1. Comparison of updated (2006–2015) versus previous (1998-2007) estimates that were based solely on BBS data (342 species summed across 182 regions). Each circle represents one species; solid black line is a log-linear fit to the points; and the red dashed line is a 1:1 line (indicating where update and previous estimates are identical).

BBS counts were lower on average in the update (-2.4%, median -4.0%, Table 1), and more species had negative changes in BBS counts (203) than positive changes (139). Note that published BBS trends are a more robust measure of change between time periods than these raw count changes, as BBS trends control for changes in routes run and observer effects. Nevertheless, the lower BBS counts for groups such as grassland birds (-2.9%, 28 species) and aerial insectivores (-13.5%, 25 species) do tend to reflect the declines seen in trends for those birds, as do increases across the family Vireonidae (+1.7%, 12 species).

Changes to Distance adjustment sampling caused the largest change in population estimates for more than half of these species (176, Table 1). BBS counts caused the largest change in about a third of species, while changes in Time of Day and Pair adjustments tended to be relatively small for most species (Table 1).

Table 1. Relative impact of each underlying parameter on direction and magnitude of change in BBS-based estimates from Version 2.0 (1998-2007) to Version 3.1 (2006-2015) for 342 species. "# Species by Largest Impact" is based on the source (BBS count or adjustment parameter) that had the largest change between time periods for each species.

Measure	Sources of Change by Parameter				
	BBS Counts	Distance Adjust Sampling	Pair Adjust Sampling	Time of Day Adjust	Overall Net Change
Geometric Mean Change	-2.4%	19.6%	-1.3%	3.9%	19.6%
Median Change	-4.0%	24.1%	-2.6%	3.0%	17.0%
# Species with Positive Change	139	342	50	226	264
# Species with Negative Change	203	0	255	116	78
# of Species by Largest Impact	113	176	0	53	
- Positive	50	176	0	34	
- Negative	63	0	0	19	

Desired Next Steps

Although in many cases PIF's population estimates correspond well with estimates from other sources, the Partners in Flight Science Committee envisions updates to both the continental and regional Population Estimates Database with the goal of improving precision as well as decreasing potential biases. Again following recommendations from Thogmartin et al. (2006) and additional input from Blancher et al. (2007), Thogmartin (2010), Matsuoka et al. (2012), and Twedt (2015), the PIF Science Committee (with the help of its academic and organizational partners) anticipates a series of database improvements in distinct stages (separate update versions):

Phase 1 — Maintaining and improving PIF's current sample-based approach:

- Periodic updates of the database to incorporate the most recent decade of BBS data.
- Continued revision of Time of Day and Pair adjustment factors.
- Incorporation of possible species range refinements and new BCR boundary adjustments (Bird Studies Canada and NABCI 2014).
- Improving estimates for species in arctic regions north of BBS coverage using whatever current data are or may become available.

- Additional species-related adjustments—e.g., a seasonal adjustment to account for early spring breeding (outside the BBS window) of some species, potentially based on year-round eBird data.
- Reducing potential bias associated with BBS road-side surveys, which may not correctly sample the distribution of habitat across a physio-political area or in which species may be attracted to or avoid roads (cf. Matsuoka et al. 2011). Pending a model-based approach in Phase 3, regional adjustments for habitat coverage bias might be relatively coarse initially—e.g., adjusting for the percent of habitats sampled by BBS routes compared to a regional GIS analysis of the proportion of habitats represented on the landscape.
- Addition of regional population estimates for non-landbirds with reasonably adequate BBS data (e.g., terrestrial shorebirds, herons, some waterfowl).
- Providing population estimates at the Joint Venture scale.

Phase 2 — Substantially modifying the current PIF sample-based approach:

- Improving estimate precision by refining the Detection Distance factor. Because the PIF population estimation procedure is most sensitive to changes in Detection Distance, improving estimates of species detectability is probably the most promising avenue for improving the overall precision of population estimates. Detectability is a function of availability and perceptibility. Availability is a function of whether the species is vocalizing and/or visible during the count period and within the count radius of a Breeding Bird Survey stop location; perceptibility is a function of whether the bird is available for detection given the skill level of the observer, proximate bird cues, and environmental conditions.
- Encouraging continued scientific studies by academic and agency partners into factors that contribute to the detectability of bird species and would potentially improve the accuracy of our population estimates, for example: the frequency of calls within the 3-min time period of a BBS stop survey, the effect of movement of birds during stationary counts, and—in preparation for a transition to the use of effective detection radii (EDRs)—determination of EDRs from road-based counts or calculation of adjustment factors for EDRs derived from off-road counts (assuming we will continue to make use of BBS as our primary data source).
- Replacement of the Detection Distance bins, possibly with empirically derived, regionally appropriate, species-specific EDRs (cf. Matsuoka et al. 2012). Where data are unavailable for a species, PIF Science would explore using an EDR derived from a surrogate species with similar phylogenetic, morphological, behavioural, community, and ecological characteristics.

Phase 3 — Exploring alternative approaches to population estimation:

PIF Science anticipates possible transition from a sample-based to an integrated model-based (pixel-based) approach to population estimation. The Boreal Avian Modeling Project at the University of Alberta has made impressive progress in developing model-based population estimate predictions for boreal landbirds that incorporate and integrate multiple data sets and include habitat attributes that allow mapping of estimates on GIS spatial layers. This model-based approach would directly address the habitat and roadside biases inherent in the assumptions of the current PIF methodology and would incorporate empirically derived detectability adjustments. A big advantage is that the pixel-based approach would be fully scalable, generating species population estimates for any polygon traced on a map. Since partners often request population estimates stepped down to their particular geographies of concern, whether that may be a Joint Venture or a National Park, such an approach would address an expressed conservation need. Following the leads of Marques et al. (2007), Matsuoka et al. (2012), Sólymos et al. (2013), Veech et al. (2017), and the eBird abundance modeling process (Johnston et al. 2015), PIF Science is interested in further exploring the benefits and costs of this change in population estimation methodology in the hopes of providing more utility to landscape conservation partners. For additional perspectives on improvements to the PIF population estimation approach, see the final section, *Future of Population Size Estimation*, in Stanton et al. (2019).

Guide to Using the Population Estimates Database

As noted in the previous section, the population estimates in the Population Estimates Database (PED) are rough approximations for landbirds breeding in the U.S. and Canada. The estimates are based primarily on data from the North American Breeding Bird Survey, which was designed to derive indices of population trend, not measures of population density (Thogmartin et al. 2006). Although the adjustments described in this Handbook were designed to adapt BBS data for broad-scale approximations of density, the number and proportion of undetected birds present during BBS counts remain unknown and are only roughly estimated here. To make wise and informed use of the numbers in the database, we urge partners to become acquainted with the methodology described above. The envisioned improvements outlined in the previous section, in addition to providing guidance for future research, also provide insights into some of the limitations in the current version of the database. Nevertheless, the underlying data and results of this PIF effort comprise the single best source for estimating population numbers across all USA/Canada landbirds on the same comparative scale. As such, the estimates can be used for several different purposes, including a few outlined briefly below.

Setting Regional Objectives and Advancing Conservation Design

PIF's landbird population size estimates were originally designed to more rigorously assign an order of magnitude Population Size (PS) score for every species in the PIF Species Assessment Database (cf. Panjabi et al. 2012). These PS estimates therefore should be used in concert with the other factors comprising conservation vulnerability assessment scores for all species in the current PIF Avian Conservation Assessment Database (ACAD) (Partners in Flight 2020a). We urge all regional conservation practitioners to consult the ACAD as well as the PED in their planning, as the ACAD provides information on regional population trends, size of the breeding and non-breeding range, threats during the breeding and non-breeding seasons, and stewardship responsibility relative to other regions—in addition to population size. Individually and in consort, these factors provide both insight into potential conservation actions as well as a full life cycle context for species of concern (cf. Panjabi et al. 2020).

The population estimates in the PED also have utility on their own: they provide the necessary link between range-wide population status and regional and local habitat conservation implemented to sustain bird populations. Success in meeting objectives outlined in the PIF Landbird Conservation Plan (Rosenberg et al. 2016) will depend heavily on setting biologically sound, measurable, population-based habitat targets at regional and local scales and implementing actions designed to reach these targets (Will et al. 2005). The data and estimates provided in the PED can advance conservation design by framing the magnitude and connectivity of the resource and by providing a starting point for defining more refined habitat management strategies. To augment the PED figures, if local data are available, regional planners might think critically about potential regional habitat bias in BBS counts or regional habitat-specific detection distance adjustments. Likewise, planners might supplement or replace BBS averages with more extensive data from other sources if available. In the absence of more specific local information, however, we hope that the PED estimates will provide an incentive for initiating or continuing habitat delivery and attendant monitoring of the effect of conservation action.

Providing Context for Independent Estimates of Population Size and Mortality

Species status reports often rely on population estimates from a variety of sources, and the PED will therefore be useful in that context. PIF's population estimation methodology was designed to provide a consistent approach across all landbird species and across the vast and varied geography of the U.S. and Canada. Thus the PED breeding season estimates can provide continental and regional context for environmental impact assessments, assessments of population vulnerability and resiliency, and the cumulative effects of various sources of mortality on bird populations.

Providing Data to Support Regional Importance for Species Conservation

The PED provides information on the proportion of population of each species in each region based on the Version 3.1 PIF approach to estimating population size. While these data also provide insight regarding regional importance, the % of global population (%Pop) values tabled in the ACAD (PIF 2020a) comprise the PIF-recommended source, along with the Relative Density (RD) score, for assessing the importance of a region for the conservation of a species and for inferring regional stewardship responsibility. As explained in the section *Comparisons with Other Recent PIF Sources of Information* (p. 15), the %Pop values in the ACAD and PED may differ somewhat. When regional expert teams reviewed the ACAD breeding season scores, they used the ACAD %Pop values for inference, and PIF Science used the ACAD %Pop values to calculate Regional Stewardship.

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The data on which most of the population estimates are based were collected by many thousands of volunteers and coordinators with the North American Breeding Bird Survey (BBS), Northwest Territories/Nunavut Bird Checklist Survey, Breeding Bird Census, and hawk watches and other surveys—as well as scientists involved with individual species, many of whom provided input on individual species estimates. Our heartfelt thanks to all of these people, to staff of the U.S. Geological Survey BBS offices in the U.S. and the Canadian Wildlife Service for screening and making the data readily available online, and to other agencies that have worked hard to vet and make these data available to all.

For quantifying range sizes we relied on digital distribution maps of birds provided by NatureServe in collaboration with Robert Ridgely, James Zook, The Nature Conservancy's Migratory Bird Program, Conservation International's Center for Applied Biodiversity Science, World Wildlife Fund U.S., and Environment Canada's WildSpace (see Ridgely et al. 2005).

A peer review of this project organized and hosted by the USGS in 2004 led to publication of the Thogmartin et al. (2006) review that provided many constructive avenues for improving population estimates and future versions of the database. Thanks to members of the peer review committee and to the USGS for undertaking that task. The USGS Upper Midwest Environmental Sciences Center also provided support to Jessica Stanton who worked tirelessly on the quantitative details leading to the assessment of uncertainty surrounding the estimates in the current database.

Regional point count datasets that were used to modify Detection Distance assignments were provided by C.J. Ralph (California), Arvind Panjabi / Bird Conservancy of the Rockies (Colorado grasslands), Denis Lepage / Bird Studies Canada (Ontario), and Erin Bayne / Boreal Avian Modelling Project (boreal Canada). Bob Altman and Christopher Rustay helped develop the species-specific Pair Adjustments developed for the previous update and retained here. Ian Marshall provided the AVHRR land cover data for arctic ecozones. Several members of the PIF Science Committee provided comments on drafts of this document and content of the database itself.

Finally we wish to thank those scientists and conservation practitioners who have critically evaluated the PIF approach to population estimates, made suggestions for improvements, and/or developed alternative approaches for more reliable estimates (see examples in

Literature Cited below). In time those approaches may replace the need for the tens of thousands of BBS-based population estimates provided here.

Literature Cited

Berlanga, H., J.A. Kennedy, T.D. Rich, M.C. Arizmendi, C.J. Beardmore, P.J. Blancher, G.S. Butcher, A.R. Couturier, A.A. Dayer, D.W. Demarest, W.E. Easton, M. Gustafson, E. Iñigo-Elias, E.A. Krebs, A.O. Panjabi, V. Rodriguez Contreras, K.V. Rosenberg, J.M. Ruth, E. Santana Castellón, R.Ma. Vidal, and T. Will. 2010. Saving Our Shared Birds: Partners in Flight Tri-National Vision for Landbird Conservation. Cornell Lab of Ornithology: Ithaca, NY. www.savingoursharedbirds.org.

Bird Studies Canada and NABCI. 2014. Bird Conservation Regions. Published by Bird Studies Canada on behalf of the North American Bird Conservation Initiative. http://www.birdscanada.org/research/gislab/index.jsp?targetpg=bcr.

Blockstein, D. E. 2002. Passenger Pigeon (Ectopistes migratorius). In The Birds of North America, No. 611 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Blancher, P.J., K.V. Rosenberg, A.O. Panjabi, B. Altman, J. Bart, C.J. Beardmore, G.S. Butcher, D. Demarest, R. Dettmers, E.H. Dunn, W. Easton, W.C. Hunter, E.E. Iñigo-Elias, D.N. Pashley, C.J. Ralph, T.D. Rich, C.M. Rustay, J.M. Ruth, and T.C. Will. 2007. Guide to the Partners in Flight Population Estimates Database. Version: North American Landbird Conservation Plan 2004. Partners in Flight Technical Series No 5. https://www.partnersinflight.org/wp-content/uploads/2017/03/PIF-Technical-Series-05-ARCHIVE-Guide-to-PIF-Pop-Est-DB-2007.pdf.

Blancher, P.J., K.V. Rosenberg, A.O. Panjabi, B. Altman, A.R. Couturier, W.E. Thogmartin, and the Partners in Flight Science Committee. 2013. Handbook to the Partners in Flight Population Estimates Database, Version 2.0. PIF Technical Series No 6. https://www.partnersinflight.org/wp-content/uploads/2018/11/PIF-Technical-Series-06-–-Handbook-to-PIF-Pop-Est-DB-2013.pdf

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier. 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources and Ontario Nature, Toronto, ON.

CEC (Commission for Environmental Cooperation). 1998. A Proposed Framework for Delineating Ecologically-based Planning, Implementation, and Evaluation Units for Cooperative Bird Conservation in the U.S. U.S. Fish and Wildlife Service, Washington, DC, USA. Available at: https://www.partnersinflight.org/wp-content/uploads/2019/01/CEC-Proposed-BCR-Framework-1998.pdf.

Chesser, R.T., K.J. Burns, C. Cicero, J.L. Dunn, A.W. Kratter, I.J. Lovette, P.C. Rasmussen, J.V. Remsen Jr., J.D. Rising, D.F. Stotz, and K. Winker. 2019. Fifty-seventh Supplement to the American Ornithologists' Union Check-list of North American Birds. Auk 133(3): 544–560. https://doi.org/10.1642/AUK-16-77.1.

Chesser, R.T., K.J. Burns, C. Cicero, J.L. Dunn, A.W. Kratter, I.J. Lovette, P.C. Rasmussen, J.V. Remsen Jr., D.F. Stotz, and K. Winker. 2019. Sixtieth Supplement to the American Ornithological Society's Check-list of North American Birds. Auk 136(3). https://doi.org/10.1093/auk/ukz042.

Confer, J.L., R.E. Serrell, M. Hager, and E. Lahr. 2008. Field Tests of the Rosenberg-Blancher Method for Converting Point Counts to Abundance Estimates. Auk 125: 932–938.

Fink, D., W.M. Hochachka, B. Zuckerberg, D.W.Winkler, B. Shaby, M.A. Munson, G. Hooker, M. Riedewald , D. Sheldon , and S. Kelling. 2010. Spatiotemporal Exploratory Models for Broad-scale Survey Data. Ecological Applications 20(8): 2131–2147.

Hamel, P.B., M.J. Welton, C.G. Smith, and R.P. Ford. 2009. Test of Partners in Flight Effective Detection Distance for Cerulean Warbler. Proceedings of the Fourth International Partners in Flight Conference: Tundra to Tropics 328–333.

IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp. http://intranet.iucn.org/webfiles/doc/SSC/RedList/redlistcatsenglish.pdf

Johnston, A., D. Fink, M.D. Reynolds, W.M. Hochachka, B.L. Sullivan, N.E. Bruns, E. Hallstein, M.S. Merrifield, S. Matsumoto, and S. Kelling. 2015. Abundance Models Improve Spatial and Temporal Prioritization of Conservation Resources. Ecological Applications 25: 1749–1756.

Kennedy, J.A., P. Dilworth-Christie, and A.J. Erskine. 1999. The Canadian Breeding Bird (Mapping) Census Database. Technical Report Series No. 342, Canadian Wildlife Service, Ottawa, Ontario. http://dsp-psd.pwgsc.gc.ca/Collection/CW69-5-342E.pdf

Marques, T.A., L. Thomas, S.G. Fancy, and S.T. Buckland. 2007. Improving Estimates of Bird Density using Multiple-covariate Distance Sampling. Auk 124(4): 1229-1243.

Matsuoka, S.M., P. Sólymos, T. Fontaine, and E. Bayne. 2011. Roadside Surveys of Boreal Forest Birds: How Representative Are They and How Can We Improve Current Sampling? Boreal Avian Modelling Project, Report to Environment Canada.

Matsuoka, S.M., E.M. Bayne, P. Sólymos, P.C. Fontaine, S.G. Cumming, F.K.A. Schmiegelow, and S.J. Song. 2012. Using Binomial Distance-sampling Models to Estimate the Effective Detection Radius of Point-count Surveys across Boreal Canada. Auk 129: 268-282.

Natural Resources Canada. 1995. AVHRR Land Cover of Canada. Ottawa: Canada Centre for Remote Sensing.

Northwest Territories / Nunavut Bird Checklist Survey. http://www.mb.ec.gc.ca/nature/migratorybirds/nwtbcs/index.en.html

Panjabi, A.O., P.J. Blancher, R. Dettmers, and K.V. Rosenberg. 2012. The Partners in Flight Handbook on Species Assessment, Version 2012. Partners in Flight Technical Series No. 3.

Panjabi, A.O., W.E. Easton, P.J. Blancher, A.E. Shaw, B.A. Andres, C.J. Beardmore, A.F. Camfield, D.W. Demarest, R. Dettmers, R.H. Keller, K.V. Rosenberg, T. Will, and M.A. Gahbauer. 2020. Avian Conservation Assessment Database Handbook, Version 2020. Partners in Flight Technical Series No. 8.1. pif.birdconservancy.org/acad.handbook.pdf

Pardieck, K.L., D.J. Ziolkowski Jr., M. Lutmerding and M.-A.R. Hudson. 2018. North American Breeding Bird Survey Dataset 1966 - 2017, version 2017.0. U.S. Geological Survey, Patuxent Wildlife Research Center. https://doi.org/10.5066/F76972V8.

Partners in Flight. 2020a. Avian Conservation Assessment Database, version 2020. Available at http://pif.birdconservancy.org/ACAD.

Partners in Flight. 2020b. Population Estimates Database, version 3.1. Available at http://pif.birdconservancy.org/PopEstimates.

Rich, T.D., C.J. Beardmore, H. Berlanga, P.J. Blancher, M.S. W. Bradstreet, G.S. Butcher, D.W. Demarest, E.H. Dunn, W.C. Hunter, E.E. Iñigo-Elias, J.A. Kennedy, A.M. Martell, A.O. Panjabi, D.N. Pashley, K.V. Rosenberg, C.M. Rustay, J.S. Wendt, and T.C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, New York. http://www.partnersinflight.org/cont_plan/default.htm

Ridgely, R.S., T.F. Allnutt, T. Brooks, D.K. McNicol, D.W. Mehlman, B.E. Young, and J.R. Zook. 2005. Digital Distribution Maps of the Birds of the Western Hemisphere, version 2.1. NatureServe, Arlington, Virginia, USA.

Rosenberg, K.V. 2004. Association of Fish and Wildlife Agencies Partners in Flight Landbird Reports. [Reports no longer publicly available.]

Rosenberg, K.V., and P.J. Blancher. 2005. Setting Numerical Population Objectives for Priority Landbird Species. Pages 57-67 in C.J. Ralph and T.D. Rich (eds.), Bird Conservation and Implementation in the Americas: Proceedings of the Third International Partners in Flight Conference. Vol. 1. United States Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-191. Albany, CA http://www.fs.fed.us/psw/publications/documents/psw_gtr191/Asilomar/pdfs/57-67.pdf

Rosenberg, K.V., P.J. Blancher, J.C. Stanton, and A.O. Panjabi. 2017. Use of Breeding Bird Survey Data in Avian Conservation Assessments. Condor 19: DOI**:** 10.1650/CONDOR-17-57.1

Rosenberg, K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A. Panjabi, L. Helft, M. Parr, and P.P. Mara. 2019. Decline of the North American Avifauna. Science 10.1126/science.aaw1313.

Runge, M.C., J.R. Sauer, M.L. Avery, B.F. Blackwell, and M.D. Koneff. 2009. Assessing Allowable Take of Migratory Birds. Journal of Wildlife Management 73: 556–565.

Sauer, J.R., W.A. Link, J.E. Fallon, K.L. Pardieck, and D.J.Ziolkowski Jr. 2013. The North American Breeding Bird Survey 1966-2011: Summary Analysis and Species Accounts. North American Fauna 79: 1–32. doi:10.3996/nafa.79.0001.

Shorger, A.W. 1955. The Passenger Pigeon: Its Natural History and Extinction. University of Wisconsin Press, Madison.

Sólymos, P., S.M. Matsuoka, E.M. Bayne, S.R. Lele, P. Fontaine, S.G. Cumming, D. Stralberg, F.K.A. Schmiegelow, and S.J. Song. 2013. Calibrating Indices of Avian Density from Non-standardized Survey Data: Making the Most of a Messy Situation. Methods Ecol. and Evol. 4: 1047–1058.

Sólymos, P., J.D. Toms, S.M. Matsuoka, S.G. Cumming, N.K.S. Barker, W.E. Thogmartin, D. Stralberg, A.D. Crosby, F.V. Dénes, S. Haché, L. Mahon, F.K.A. Schmiegelow, and E.M. Bayne. 2020. Lessons Learned from Comparing Spatially Explicit Models and the Partners in Flight Approach to Estimate Population Sizes of Boreal Birds in Alberta, Canada. Condor 122: 1–22, DOI: 10.1093/condor/duaa007.

Stanton, J.C., P. Blancher, K.V. Rosenberg, A.O. Panjabi, and W.E. Thogmartin. 2019. Estimating Uncertainty of North American Landbird Population Sizes. *Avian Conservation and Ecology* 14(1):4. https://doi.org/10.5751/ACE-01331-140104.

Sullivan, B.L., J.L. Aycrigg, J.H. Barry, R.E. Bonney, N. Bruns, C.B. Cooper, T. Damoulas, A.A. Dhondt, T. Dietterich, A. Farnsworth, D. Fink, J.W. Fitzpatrick, T. Fredericks, J. Gerbracht, C. Gomes, W.M. Hochachka, M.J. Iliff, C. Lagoze, F.A. La Sorte, M. Merrifield, W. Morris, T.B. Phillips, M. Reynolds, A.D. Rodewald, K.V. Rosenberg, N.M. Trautmann, A. Wiggins, D.W. Winkler, W-K. Wong, C.L. Wood,

J. Yu, and S. Kelling. 2014. The eBird Enterprise: An Integrated Approach to Development and Application of Citizen Science. Biological Conservation 169: 31–40.

Thogmartin, W.E. 2010. Sensitivity Analysis of North American Bird Population Estimates. Ecological Modelling 221: 173–177.

Thogmartin, W.E., F.P. Howe, F.C. James, D.H. Johnson, E.T. Reed, J.R. Sauer, and F.R. Thompson III. 2006. A Review of the Population Estimation Approach of the North American Landbird Conservation Plan. Auk 123: 892–904.

Twedt, D.J. 2015. Estimating Regional Landbird Populations from Enhanced North American Breeding Bird Surveys: Estimating Regional Landbird Populations. Journal of Field Ornithology 86: 352–368.

U.S. NABCI Committee. 2000. North American Bird Conservation Initiative. Bird Conservation Region Descriptions. A Supplement to the North American Bird Conservation Initiative Bird Conservation Regions Map. September 2000. http://www.nabci-us.org/aboutnabci/bcrdescrip.pdf.

Veech, J.A., M.F. Small, and J.T. Baccus. 2012. Representativeness of Land Cover Composition along Routes of the North American Breeding Bird Survey. Auk 129(2): 259–267.

Veech, J.A., K.L. Pardieck, and D.J. Ziolkowski Jr. 2017. How Well Do Route Survey Areas Represent Landscapes at Larger Spatial Extents? An Analysis of Land Cover Composition along Breeding Bird Survey Routes. Condor Ecological Applications 119: 607–615.

Will, T.C., J.M. Ruth, K.V. Rosenberg, D. Krueper, D. Hahn, J. Fitzgerald, R. Dettmers, and C.J. Beardmore. 2005. The Five Elements Process: Designing Optimal Landscapes to Meet Bird Conservation Objectives. Partners in Flight Technical Series No. 1. Partners in Flight website: http://www.partnersinflight.org/pubs/ts/01-FiveElements.pdf.

Zimmerman, G.S., B.A. Millsap, M.L. Avery, J.R. Sauer, M.C. Runge, and K.D. Richkus. 2019. Allowable Take of Black Vultures in the Eastern United States. Journal of Wildlife Management 83(2): 272–282.

Appendix 1: Data Dictionary

The Version 3.1 Population Estimates Database structure remains largely the same as in previous versions, allowing online queries at USA/Canada, Bird Conservation Region (BCR), and State/Province/Territory scales—and with separate downloadable spreadsheets available for those three scales as well as for the physio-political building block scale comprised of intersection polygons of BCRs and state, province, and/or territory boundaries.
In contrast to species population estimates presented in the tables for regional scales, the USA/Canada/Global database also includes broader scale estimates extrapolated from BBS counts or other data for a total of 406 USA/Canada breeding landbirds. The BCR, State/Province/Territory, and physio-political scales in most cases only include population estimates for species for which BBS data were available, including the 336 landbird species for which BBS was the sole or major data source for Species Count in the PIF model and for which we estimated uncertainty bounds.

The following tables describe the data fields contained in the database in brief; additional detail can be found in the Handbook text. Unless otherwise indicated in the Field identifier, all population estimates are tabled as rounded numbers; unrounded estimates are available in the downloadable spreadsheets and are so indicated in the Field label. These tables are also duplicated in a "Definitions" worksheet included with the downloadable spreadsheets, where Field names serve as column headers.

Table A1: Description of Data Fields Associated with USA/Canada/Global Population Estimates

Fields viewable in Global/USA/Canada on-screen website queries:

Field	Explanation
English Name	AOS English common name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Scientific Name	AOS scientific name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Population Estimate Global	Estimated global breeding population, based on extrapolating USA/Canada population to other parts of global range (individuals, not pairs). Estimates have been rounded.
Source for Global Estimate	Sources of data used for Global Population Estimate, with sources listed in descending order by proportion of population estimate: "BBS" = North American Breeding Bird Survey (2006–2015); "NWT" = Northwest Territories & Nunavut Checklist survey data (1995-2001) combined with Breeding Bird Census data; "ONA" = Ontario 2nd Breeding Bird Atlas point counts (2001-2005); "eBird" = eBird relative frequency data for June and 1st week of July (1970-2017) used to extrapolate to the Western Hemisphere south of USA; "RNG" = range map-based extrapolation to the Eastern Hemisphere; "PIFSC" = estimated by Partners in Flight Science Committee. See other sources in Appendix 2.

Population Estimate USA/Canada	Estimated breeding population in USA/Canada, a sum of BBS-based estimates, Ontario atlas-based estimates, and NWT checklist-based estimates (individuals, not pairs). Estimates have been rounded.
Lower 95% bound USA/Canada	Lower 95% bound from 1,000 re-sampled population estimates for USA/Canada, rounded.
Upper 95% bound USA/Canada	Upper 95% bound from 1,000 re-sampled population estimates for USA/Canada, rounded.
Source for USA/Canada Estimate	Sources of data used for USA/Canada Population Estimate, with sources listed in descending order by proportion of population estimates; see sources above and in Appendix 2.
Population Estimate Canada	Estimated breeding population in Canada, a sum of BBS-based estimates, Ontario atlas-based estimates, and NWT checklist-based estimates (individuals, not pairs). Estimates have been rounded.
Population Estimate USA	Estimated breeding population in USA, from BBS-based estimates (individuals, not pairs). Estimates have been rounded.

***Additional* fields available in Global/USA/Canada downloadable spreadsheet:**

Field	Explanation
Sequence AOS 60	Sequence of species in AOS Checklist 7th Edition, 60th Supplement (Chesser et al. 2019).
Introduced	Introduced (non-native) species in USA/Canada.
Median Estimate USA/Canada	Median estimated population in USA and Canada derived from 1,000 re-sampled population estimates for USA/Canada, rounded.
Lower 95% bound Canada	Lower 95% bound from 1,000 re-sampled population estimates for Canada, rounded.
Upper 95% bound Canada	Upper 95% bound from 1,000 re-sampled population estimates for Canada, rounded.
Lower 95% bound USA	Lower 95% bound from 1,000 re-sampled population estimates for the USA, rounded.
Upper 95% bound USA	Upper 95% bound from 1,000 re-sampled population estimates for the USA, rounded.
Population Estimate BBS	Estimated breeding population in the BBS survey area (Canada and USA)—individuals, not pairs. Estimates have been rounded. See *Handbook* p.8.
Lower 95% bound BBS	Lower 95% bound from 1,000 re-sampled population estimates for the BBS survey area, rounded. If extrapolated for under-sampled region (see *Handbook* p.8), CI from source region scaled to size estimate in extrapolated region).
Upper 95% bound BBS	Upper 95% bound from 1,000 re-sampled population estimates for the BBS survey area, rounded. If extrapolated for under-sampled region (see *Handbook* p.8), CI from source region scaled to size estimate in extrapolated region).

Lower 80% bound USA/Canada	Lower 80% bound from 1,000 re-sampled population estimates for USA/Canada, rounded.
Upper 80% bound USA/Canada	Upper 80% bound from 1,000 re-sampled population estimates for USA/Canada, rounded.
Lower 80% bound BBS	Lower 80% bound from 1,000 re-sampled population estimates for the BBS survey area, rounded. If extrapolated for under-sampled region (see *Handbook* p.8), CI from source region scaled to size estimate in extrapolated region).
Upper 80% bound BBS	Upper 80% bound from 1,000 re-sampled population estimates for the BBS survey area, rounded. If extrapolated for under-sampled region (see *Handbook* p.8), CI from source region scaled to size estimate in extrapolated region).
Lower 80% bound Canada	Lower 80% bound from 1,000 re-sampled population estimates for Canada, rounded.
Upper 80% bound Canada	Upper 80% bound from 1,000 re-sampled population estimates for Canada, rounded.
Lower 80% bound USA	Lower 80% bound from 1,000 re-sampled population estimates for the USA, rounded.
Upper 80% bound USA	Upper 80% bound from 1,000 re-sampled population estimates for the USA, rounded.
% Global Estimate in USA/Canada	Estimated percent of global population that breeds in Canada and the U.S. based on eBird relative frequencies (Western Hemisphere) and range maps (Eastern Hemisphere).
% Global Estimate in Western Hemisphere	Estimated percent of global population that breeds in the Western Hemisphere, based on range maps.
BBS Routes	Number of BBS routes meeting data acceptance criteria in 2006–2015 in USA/Canada.
Species Routes	Number of BBS routes with acceptable data on which the species was detected in 2006–2015.
Detection Distance Category (m)	Approximated detection distance category (meters) at peak time of day during a 3-minute BBS count, accounting for movement of birds during the count.
Pair Adjust Category	Pair Adjustment: multiplies estimate by up to 2, depending on whether one or both members of a pair are likely to be detected.
Time Adjust Mean	Average Time of Day Adjustment: adjusts average count across all 50 BBS stops to a smoothed peak count.
Time Adjust SD	Standard deviation of Time of Day Adjustment, calculated by sampling the distribution of repeated time adjustment calculations.
Population Estimate USA/Canada (unrounded)	Estimated breeding population in USA/Canada (individuals, not pairs). Estimates as calculated, without rounding (see above for rounded values).

Lower 80% bound USA/Canada (unrounded)	Lower 80% bound from 1,000 re-sampled population estimates for USA/Canada, unrounded.
Upper 80% bound USA/Canada (unrounded)	Upper 80% bound from 1,000 re-sampled population estimates for USA/Canada, unrounded.
Lower 95% bound USA/Canada (unrounded)	Lower 95% bound from 1,000 re-sampled population estimates for USA/Canada, unrounded.
Upper 95% bound USA/Canada (unrounded)	Upper 95% bound from 1,000 re-sampled population estimates for USA/Canada, unrounded.
Population Estimate BBS (unrounded)	Estimated breeding population in the BBS survey area (within Canada and USA)—individuals, not pairs. Estimates as calculated, without rounding (see above for rounded values).
Population Estimate Canada (unrounded)	Estimated breeding population in Canada (individuals, not pairs). Estimates as calculated, without rounding (see above for rounded values).
Population Estimate USA (unrounded)	Estimated breeding population in the USA (individuals, not pairs). Estimates as calculated, without rounding (see above for rounded values).

Table A2: Description of Data Fields Associated with Regional (BCR) Population Estimates

Fields viewable in Regional (BCR) on-screen website queries:

Field	Explanation
English Name	AOS English common name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Scientific Name	AOS scientific name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
BCR	Bird Conservation Region identification number: see current map of BCR boundaries at https://nabci-us.org/resources/bird-conservation-regions-map/.
Population Estimate	Estimated breeding population in the Region (individuals, not pairs). Estimates have been rounded.
Lower 95% bound	Lower 95% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 95% bound	Upper 95% bound from 1,000 re-sampled population estimates for the region, rounded.

Data Source	Sources of data used to calculate Population Estimate: "BBS" = North American Breeding Bird Survey (2006–2015); "NWT" = Northwest Territories & Nunavut Checklist survey data (1995-2001) combined with Breeding Bird Census data; "ONA" = Ontario 2nd Breeding Bird Atlas point counts (2001-2005); "RNG" = range-based adjustments made when an estimate from one part of a region was extrapolated into another part that had no abundance data.
Estimated % of Global Population	Estimated percent of global population that breeds in the region, based on relative abundance among regions (see data source below).
Estimated % of USA/Canada Population	Estimated percent of USA/Canada population that breeds in the region, based on relative abundance among regions (see data source below).

***Additional* fields available in Regional (BCR) downloadable spreadsheet:**

Field	Explanation
Sequence AOS 60	Sequence of species in AOS Checklist 7th Edition, 60th Supplement (Chesser et al. 2019).
Introduced	Introduced (non-native) species in USA/Canada.
Median Estimate	Median estimated population from 1,000 re-sampled population estimates for the region, rounded.
Lower 80% bound	Lower 80% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 80% bound	Upper 80% bound from 1,000 re-sampled population estimates for the region, rounded.
BBS Average (birds/rte)	Average BBS Count per route per year (2006–2015) across all routes within a Region, stratified by jurisdictions (provinces, states, territories). For BCR 3 in Canada, values were converted from checklist and breeding bird census data; for BCR 7 in Ontario, values were converted from atlas point count data.
BBS Routes	BBS routes meeting data acceptance criteria in the Region in 2006–2015.
Species Routes	BBS routes in the Region where the species was detected in 2006–2015.
Area of Region (km^2)	Area of Region (BCR) in square-kilometres (km^2).
Detection Distance Category (m)	Approximated Detection Distance category (meters) at peak time of day during a 3-minute BBS count, accounting for movement of birds during the count.
Pair Adjust Category	Pair Adjustment: multiplies estimate by up to 2, depending on whether one or both members of a pair are likely to be detected.
Time Adjust Mean	Average Time of Day Adjustment: adjusts average count across all 50 BBS stops to a smoothed peak count.

Time Adjust SD	Standard deviation of Time of Day Adjustment, calculated by sampling the distribution of repeated time adjustment calculations.
Population Estimate (unrounded)	Estimated breeding population in the Region (individuals, not pairs). Estimates as calculated, without rounding (see above for rounded values).
Lower 80% bound (unrounded)	Lower 80% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 80% bound (unrounded)	Upper 80% bound from 1,000 re-sampled population estimates for the region, unrounded.
Lower 95% bound (unrounded)	Lower 95% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 95% bound (unrounded)	Upper 95% bound from 1,000 re-sampled population estimates for the region, unrounded.

Table A3: Description of Data Fields Associated with State, Province, and Territory Population Estimates

Fields viewable in political region on-screen website queries:

Field	Explanation
English Name	AOS English common name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Scientific Name	AOS scientific name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Province / State / Territory	Jurisdictions in Canada and continental USA.
Country	Canada (CAN) or the USA.
Population Estimate	Estimated breeding population in the Region (individuals, not pairs). Estimates have been rounded.
Lower 95% bound	Lower 95% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 95% bound	Upper 95% bound from 1,000 re-sampled population estimates for the region, rounded.
Data Source	Sources of data used to calculate Population Estimate: "BBS" = North American Breeding Bird Survey (2006–2015); "NWT" = Northwest Territories & Nunavut Checklist survey data (1995-2001) combined with Breeding Bird Census data; "ONA" = Ontario 2nd Breeding Bird Atlas point counts (2001-2005); "RNG" = range-based adjustments made when an estimate from one part of a region was extrapolated into another part that had no abundance data.
Estimated % of Global Population	Estimated percent of global population that breeds in the region, based on relative abundance among regions (see data source below).

Estimated % of USA/Canada Population	Estimated percent of USA/Canada population that breeds in the region, based on relative abundance among regions (see data source below).

***Additional* fields available in Political Region downloadable spreadsheet:**

Field	Explanation
Sequence AOS 60	Sequence of species in AOS Checklist 7th Edition, 60th Supplement (Chesser et al. 2019).
Introduced	Introduced (non-native) species in USA/Canada.
Median Estimate	Median estimated population from 1,000 re-sampled population estimates for the region, rounded.
Lower 80% bound	Lower 80% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 80% bound	Upper 80% bound from 1,000 re-sampled population estimates for the region, rounded.
BBS Average (birds/rte)	Average BBS Count per route per year (2006–2015) across all routes within this region, stratified by Bird Conservation Regions (BCRs). For the bulk of NT and NU territories, values were converted from checklist and breeding bird census data; in northern ON, values were converted from atlas point count data.
BBS Routes	BBS routes meeting data acceptance criteria in the Region in 2006–2015.
Species Routes	BBS routes in the Region where the species was detected in 2006–2015.
Area of Region (km^2)	Area of Region (jurisdiction) in square kilometres (km^2)
Detection Distance Category (m)	Approximated detection distance category (meters) at peak time of day during a 3-minute BBS count, accounting for movement of birds during the count.
Pair Adjust Category	Pair Adjustment: multiplies estimate by up to 2, depending on whether one or both members of a pair are likely to be detected.
Time Adjust Mean	Average Time of Day Adjustment: adjusts average count across all 50 BBS stops to a smoothed peak count.
Time Adjust SD	Standard deviation of Time of Day Adjustment, calculated by sampling the distribution of repeated time adjustment calculations.
Population Estimate (unrounded)	Estimated breeding population in the Region (individuals, not pairs). Estimates as calculated, without rounding (see above for rounded values).
Lower 80% bound (unrounded)	Lower 80% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 80% bound (unrounded)	Upper 80% bound from 1,000 re-sampled population estimates for the region, unrounded.

Lower 95% bound (unrounded)	Lower 95% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 95% bound (unrounded)	Upper 95% bound from 1,000 re-sampled population estimates for the region, unrounded.

Table A4: Description of Data Fields Associated with Physio-Political Population Estimates (intersections of State, Province, or Territory Boundaries and BCRs).

Fields available in Physio-Political Region downloadable spreadsheet:

Field	Explanation
Sequence AOS 60	Sequence of species in AOS Checklist 7th Edition, 60th Supplement (Chesser et al. 2019).
English Name	AOS English common name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Scientific Name	AOS scientific name—from 7th Edition, 60th Supplement (Chesser et al. 2019).
Introduced	Introduced (non-native) species in USA/Canada
BCR	BCR identification number: see current map of BCR boundaries at https://nabci-us.org/resources/bird-conservation-regions-map/.
Province / State / Territory	Jurisdictions in Canada and continental USA.
Country	Canada (CAN) or the USA.
Population Estimate	Estimated breeding population in the region (individuals, not pairs). Estimates have been rounded.
Lower 95% bound	Lower 95% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 95% bound	Upper 95% bound from 1,000 re-sampled population estimates for the region, rounded.
BCR Source	This and the following column give the BCR (ID number) and Province/State (2-letter code) source of the population estimate; when there were no abundance data in the region, values were extrapolated from neighbouring regions, usually part of the same BCR.
Jurisdiction Source	This and the preceding column give the BCR (ID number) and Province/State (2-letter code) source of the population estimate; when there were no abundance data in the region, values were extrapolated from neighbouring regions, usually part of the same BCR.
Data Source	Sources of data used to calculate Population Estimate: "BBS" = North American Breeding Bird Survey (2006–2015); "NWT" = Northwest Territories & Nunavut Checklist survey data (1995-2001) combined with Breeding Bird Census data; "ONA" = Ontario 2nd Breeding Bird Atlas point counts (2001-2005); "RNG" = range-based adjustments made when an estimate from one part of a region was extrapolated into another part that had no abundance data.

Estimated % of Global Population	Estimated percent of global population that breeds in the region based on relative abundance among regions (see data source below).
Estimated % of USA/Canada Population	Estimated percent of USA/Canada population that breeds in the region, based on relative abundance among regions (see data source below)
Median Estimate	Median estimated population, from 1,000 re-sampled population estimates for the region, rounded
Lower 80% bound	Lower 80% bound from 1,000 re-sampled population estimates for the region, rounded.
Upper 80% bound	Upper 80% bound from 1,000 re-sampled population estimates for the region, rounded.
BBS Average (birds/rte)	Average BBS Count per route per year (2006–2015) across all routes within this region, stratified by Bird Conservation Regions (BCRs). For the bulk of NT and NU territories, values were converted from checklist and breeding bird census data; in northern ON, values were converted from atlas point count data.
BBS Routes	BBS routes meeting data acceptance criteria in the region in 2006–2015.
Species Routes	BBS routes in the region where the species was detected in 2006–2015.
Area of Region (km^2)	Area of region in square-kilometres (km^2).
Detection Distance Category (m)	Approximated Detection Distance category (meters) at peak time of day during a 3-minute BBS count, accounting for movement of birds during the count.
Pair Adjust Category	Pair Adjustment: multiplies estimate by up to 2, depending on whether one or both members of a pair are likely to be detected.
Time Adjust Mean	Average Time of Day Adjustment: adjusts average count across all 50 BBS stops to a smoothed peak count.
Time Adjust SD	Standard deviation of Time of Day Adjustment calculated by sampling the distribution of repeated time adjustment calculations.
Population Estimate (unrounded)	Estimated breeding population in the Region - individuals, not pairs. Estimates as calculated, without rounding (see above for rounded values).
Lower 80% bound (unrounded)	Lower 80% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 80% bound (unrounded)	Upper 80% bound from 1,000 re-sampled population estimates for the region, unrounded.
Lower 95% bound (unrounded)	Lower 95% bound from 1,000 re-sampled population estimates for the region, unrounded.
Upper 95% bound (unrounded)	Upper 95% bound from 1,000 re-sampled population estimates for the region, unrounded.

Appendix 2: Dictionary of Sources

Table A5: Data source codes used in the Population Estimates Database and their associated explanations or references.

Source	Source Reference or Description
AZ Game & Fish	Arizona Game and Fish Department.
BBS (bbs)	North American Breeding Bird Survey, 2006–2015. Access at https://www.pwrc.usgs.gov/bbs/RawData/
Benkman 2018	Craig Bankman, University of Wyoming.
Bird Conservancy of the Rockies 2018	Bird Conservancy of the Rockies, unpublished data, 2018. For Black Rosy-Finch, mean abundance estimate (note high variance: 83% mean CV) from within IMBCR (https://birdconservancy.org/what-we-do/science/monitoring/imbcr-program/) 2017-2018 survey area of WY, MT, UT, and USFS land + some BLM land in S. ID, but no surveys in OR, NV, or rest of ID, so a min. estimate. For Brown-capped Rosy-Finch, estimate is mean from RMBO's Monitoring Colorado's Birds surveys of alpine habitat from 1999-2005.
Bird Conservancy of the Rockies 2020	Adjustments to California Scrub-Jay and Woodhouse's Scrub-Jay estimates described on p. 13, this document.
BirdLife International 2000	BirdLife International. 2000. Threatened birds of the world. Barcelona and Cambridge, UK: Lynx Edicions and BirdLife International.
BirdLife International 2018	BirdLife International. 2018. Data Zone. From http://datazone.birdlife.org/home
Blancher 2008	Peter Blancher's extrapolation of Bird Studies Canada's provincial owl surveys through 2002.
BNA Atwood & Bontrager 2001	Atwood, J.L., and D.R. Bontrager. 2001. California Gnatcatcher (*Polioptila californica*). In The Birds of North America, No. 574 (A. Poole and F. Gill, Eds.). The Birds of North America, Inc., Philadelphia, PA.
BNA Briskie 1993	Briskie, J.V. 1993. Smith's Longspur. In The Birds of North America, No. 34 (A. Poole, P. Stettenheim, and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.
BNA White et al. 2002	White, C.M., N.J. Clum, T.J. Cade, and W.G. Hunt (2002). Peregrine Falcon (*Falco peregrinus*), version 2.0. In The Birds of North America (A. Poole and F. Gill, Eds.). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.660.
California Condor Recovery Team 2017	U.S. Fish and Wildlife Service. 2017. California Condor Recovery Program 2017 Annual Condor Population Status Update. Available at https://www.fws.gov/cno/es/calcondor/PDF_files/2017-CA-condor-population-status.pdf.
D. Demarest	Dean Demarest, U.S. Fish and Wildlife Service.

eBird	eBird relative frequency data, 1970-2017, used to extrapolate population estimates from USA/Canada to breeding populations in the rest of the Western Hemisphere. See https://ebird.org/explore.
Fletcher 2016	Fletcher et al. 2016. Annual Progress Report on Snail Kite Demography. U.S. Geological Survey, FL CFWRU, Gainesville, FL.
FL FWCC 2011	Florida Fish and Wildlife Conservation Commission. 2011. White-crowned Pigeon Biological Status Review.
Franke 2016	Franke, A. 2016. Population Estimates for northern juvenile Peregrine Falcons with implications for harvest levels in North America. Journal of Fish and Wildlife Management. 7. 10.3996/062015-JFWM-050.
Green 2012	Michael Green, U.S. Fish and Wildlife Service, unpublished data from 2012 surveys
Gomez–Panjabi	Hector Gomez de Silva (Eagle-eye Tours, formerly with National Autonomous University of Mexico, UNAM) and Arvind Panjabi, Bird Conservancy of the Rockies. The suffix "–PS-g midpoint" appended to the source code indicates a population estimate based on the midpoint of the ACAD PS-g category range.
GUSG Final Rule 2014	Interior, U.S. Department of. 2014. Endangered and threatened wildlife and plants; Threatened status for Gunnison Sage-Grouse: Final Rule. Federal Register no. 79 (224):69192-69310.
Hunter-Wylie-Meyer	William C. Hunter, U.S. Fish and Wildlife Service; Jim Wylie, U.S. Geological Service; and Ken Meyer, Avian Research and Conservation Institute.
International Bicknell's Thrush Conservation Group 2017	Lloyd, J.D. and K.P. McFarland, Eds. 2017. A Conservation Action Plan for Bicknell's Thrush (*Catharus bicknelli*). International Bicknell's Thrush Conservation Group (IBTCG). Available at https://bicknellsthrush.org/conservation-action-plan/conservation-action-plan-for-bicknells-thrush/ or 10.6084/m9.figshare.4962608.
Kirtland's Warbler Conservation Team 2015	Kirtland's Warbler Conservation Team. Michigan Department of Natural Resources (MDNR), US Fish and Wildlife Service, and US Forest Service. 2015. Kirtland's Warbler Breeding Range Conservation Plan. Available online at https://www.michigan.gov/documents/dnr/Kirtlands_Warbler_CP_457727_7.pdf.
Matsuoka and Johnson 2008	Matsuoka, S., and J.A. Johnson. 2008. Using a multimodel approach to estimate the population size of McKay's Buntings. Condor 110(2): 371–376.
McDearman 2018	Will McDearman, USFWS Red-cockaded Woodpecker Recovery Team, Dec 2018.
T. Mecklenborg	Todd Mecklenborg, U.S. Fish and Wildlife Service.
Meese 2017	Meese, R.J. 2017. Results of the 2017 Tricolored Blackbird Statewide Survey. Calif. Dept. of Fish and Wildlife, Wildlife Branch, Nongame Wildlife Program Report 2017-XX, Sacramento, CA. 27 pp. + appendices.

NWT (nwt)	Northwest Territories / Nunavut Bird Checklist Survey (https://www.canada.ca/en/environment-climate-change/services/bird-surveys/landbird/ebird-northwest-territories-nunavut-checklist.html) combined with Breeding Bird Census density information from the same region (Kennedy et al. 1999. The Canadian Breeding Bird (Mapping) Census Database. Technical Report Series No. 342, Canadian Wildlife Service, Ottawa, Ontario).
ONA (ona)	Point count data from the 2nd Ontario Breeding Bird Atlas (2001-2005): Cadman et al. 2007. Atlas of the Breeding Birds of Ontario, 2001–2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, Ontario.
PIF CAW 2016	Partners in Flight Central America Workshop (2016). The suffix "–PS-g midpoint" appended to the source code indicates a population estimate based on the midpoint of the ACAD PS-g category range.
PIFcalc19–	Partners in Flight (PIF) population estimate from Stanton et al. (2019) calculated using BBS and/or other data sets indicated after the dash.
PIFSC–##	Partners in Flight Science Committee, where –## indicates the year when the estimate was made: e.g., PIFSC–12 = 2012. The suffix "–PS-g midpoint" appended to the source code indicates a population estimate based on the midpoint of the ACAD PS-g category range. Most but not all of these estimates were reviewed in 2016.
PIFTC–##	Partners in Flight Technical Committee where –## indicates the year when the estimate was made: e.g., PIFTC–02 = 2002. The suffix "–PS-g midpoint" appended to the source code indicates a population estimate based on the midpoint of the ACAD PS-g category range. Most but not all of these estimates were reviewed in 2016.
PIFTC–NBCI	6.7M in 1999 from Dimmick, R., M. Gudlin and D. McKenzie. The Northern Bobwhite Conservation Initiative: A Plan for Quail Population Recovery. PIF Technical Committee adjusted to 5.8M in 2007 based on declining BBS trend.
Potapov & Sale 2012	Potapov, E., and R. Sale. 2012. The Snowy Owl. London: T & AD Poyser.
Range (rng)	A variety of species-specific range maps were used to extrapolate population estimates to breeding areas in the Eastern Hemisphere, based on relative proportion of breeding range in Western and Eastern hemispheres.
Ruffed Grouse Conservation Plan 2006	Dessecker, D.R., G.W. Norman, and S.J. Williamson, eds. 2006. Ruffed Grouse Conservation Plan. Association of Fish and Wildlife Agencies, Resident Game Bird Working Group. Available at https://ruffedgrousesociety.org/wp-content/uploads/2019/07/RG_ConservationPlan-ExecRep.pdf From RGCP: 8.1M males in 2005 (sum of BCR totals, excluding BCR 4). PIF rounded to 9M to include BCR 4, then doubled to include females.
Smith 1996	Smith, P.W. 1996. Antillean Nighthawk. In Rodgers, Kale, and Smith, eds., Rare and Endangered Biota of Florida. Vol. 5. University of Florida Press, Gainesville.

Spruce Grouse Continental Conservation Plan 2008	Williamson, S.J., D. Keppie, R. Davison, D. Budeau, S. Carriere, D. Rabe, and M. Schroeder. 2008. Spruce Grouse Continental Conservation Plan. Association of Fish and Wildlife Agencies. Washington, DC. 74 pp.
Swallow-tailed Kite Conservation Alliance 2016	Swallow-tailed Kite Conservation Alliance population estimate, 2016
USFWS Eagle Rule Revision 2016	U.S. Fish and Wildlife Service. 2016. Bald and Golden Eagles: Population demographics and estimation of sustainable take in the United States, 2016 update. Division of Migratory Bird Management, Washington D.C., USA. Available at https://www.fws.gov/birds/management/managed-species/eagle-management.php. Estimate = 143,000, with extrapolation to Canada.
WAFWA 2015	Western Association of Fish and Wildlife Agencies. 2015. Greater Sage-Grouse Population Trends: An Analysis of Lek Count Databases 1965–2015. http://www.wafwa.org/Documents%20and%20Settings/37/Site%20Documents/News/Lek%20Trend%20Analysis%20final%208-14-15.pdf
WAFWA/WEST 2017	McDonald, L., K. Nasman, T. Rintz, F. Hornsby, and G. Gardner. 2017. Range-wide population size of the Lesser Prairie-Chicken: 2012-2017. Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming, USA.
Wiest et al. 2019	Wiest, W.A., M.D. Correll, B.G. Marcot, B.J. Olsen, C.S. Elphick, T.P. Hodgman, G.R. Guntenspergen, and W.G. Shriver. 2019. Estimates of tidal-marsh bird densities using Bayesian networks. J. Wildlife Management 83 (1): 109-120.
Zimmerman et al. 2019 updated to BBS 2018	Zimmerman, G.S., B.A. Millsap, M.L. Avery, J.R. Sauer, M.C. Runge, and K.D. Richkus. 2019. Allowable take of Black Vultures in the eastern United States. Journal of Wildlife Management 83(2): 272–282. Methods followed Zimmerman et al. (2019) based on the most recent BBS annual index (2018).