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REVIEW

Use of North American Breeding Bird Survey data in avian conservation assessments

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ABSTRACT

Conservation resources are limited, and prioritizing species based on their relative vulnerability and risk of extinction is a fundamental component of conservation planning. In North America, the conservation consortium Partners in Flight (PIF) has developed and implemented a data-driven species assessment process, at global and regional scales, based on quantitative vulnerability criteria. This species assessment process has formed the biological basis for PIF's continental and regional planning and has informed the ranking and legal listing of bird species for conservation protection by state, provincial, and national agencies in Canada, the U.S., and Mexico. Because of its long time series, extensive geographic and species coverage, standardized survey methods, and prompt availability of results, the North American Breeding Bird Survey (BBS) has been an invaluable source of data, allowing PIF to assign objective vulnerability scores calibrated across more than 460 landbird species. BBS data have been most valuable for assessing long-term population trends (PT score). PIF has also developed methods for estimating population size by extrapolating from BBS abundance indices, allowing the assignment of categorical population size (PS) scores for landbird species. At regional scales, BBS relative abundance indices have allowed PIF to assess the area importance (i.e. stewardship responsibility) of each Bird Conservation Region (BCR) for each species, using measures of both relative density and percent of total population in each BCR. Besides direct applicability to assessment scores, PIF has recently used BBS trend data to create new metrics of conservation urgency (e.g., 'half-life'), as well as for setting population objectives for tracking progress toward meeting conservation goals. Future directions include integrating BBS data with other sources (e.g., eBird) to assess additional species and nonbreeding season measures, working closely with BBS coordinators to expand surveys into Mexico, and providing assessment scores at implementation-relevant scales, such as for migratory bird joint ventures.

Keywords: Breeding Bird Survey, Partners in Flight, species conservation assessment, population trends

Utilisation des données du Relevé des oiseaux nicheurs de l'Amérique du Nord dans les évaluations de la conservation aviaire

RÉSUMÉ

Les ressources en conservation sont limitées et le classement des espèces par ordre de priorité selon leur vulnérabilité relative et le risque d'extinction est une composante fondamentale de la planification de la conservation. En Amérique du Nord, le consortium pour la conservation Partenaires d'envol (PIF) a développé et mis en œuvre un processus d'évaluation des espèces axé sur les données, à l'échelle mondiale et des régions, basé sur des critères de vulnérabilité quantitatifs. Ce processus d'évaluation des espèces a constitué la base biologique pour la planification continentale et régionale de PIF et a documenté le classement et la liste légale des espèces d'oiseaux devant être protégées par les agences d'État, provinciales et nationales au Canada, aux États-Unis et au Mexique. En raison de sa longue série temporelle, de sa vaste couverture géographique et des espèces, des méthodes d'inventaire standardisées et de la disponibilité rapide des résultats, le Relevé des oiseaux nicheurs (BBS) de l'Amérique du Nord a été une source inestimable de données, permettant à PIF d'attribuer un pointage objectif de vulnérabilité calibré sur plus de 460 espèces d'oiseaux terrestres. Les données du BBS ont été très utiles pour évaluer les tendances des populations à long terme (pointage PT). PIF a également développé des méthodes pour estimer la taille des populations en extrapolant les indices d'abondance du BBS, ce qui permet d'assigner des pointages par catégorie de taille des populations (PS) pour les oiseaux terrestres. Aux échelles régionales, les indices d'abondance relative du BBS ont permis à PIF d'évaluer l'importance (i.e. la responsabilité de l'intendance) de chaque région de conservation des oiseaux (RCO) pour chaque espèce d'oiseau, en utilisant des mesures de la densité relative et le pourcentage de la population totale dans chaque RCO. En plus de l'applicabilité directe pour les pointages d'évaluation, nous avons récemment utilisé les données de tendance du BBS pour créer de nouvelles mesures de l'urgence de la conservation (e.g. « demi-vie »), de même que pour établir des objectifs de population pour suivre les progrès vers l'atteinte des objectifs de conservation. Les directions futures comprennent l'intégration des données du BBS aux autres sources (e.g. eBird) afin d'évaluer les espèces additionnelles et les mesures hors de la saison de reproduction, en étroite collaboration avec le BBS pour étendre les relevés au Mexique, et en fournissant des pointages d'évaluation à des échelles pertinentes à la mise en œuvre, telles que pour les plans conjoints pour les oiseaux migrateurs.

Mots-clés: Relevé des oiseaux nicheurs, Partenaires d'envol, évaluation de la conservation des espèces, tendances des populations

Conservation resources are often severely limited, and thus prioritizing actions across a large number of taxa that differ in their vulnerability or risk of extinction is a necessary and fundamental step in conservation planning. Several global conservation assessment schemes have been developed and applied to various taxa, especially birds. Most well-known among these are the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2012) and NatureServe's global and state-based ranks (Faber-Langendoen et al. 2012). These assessment schemes were developed primarily to identify species threatened with extinction, across a broad range of taxa, using the best available scientific data. These global assessment schemes employ various thresholds for vulnerability, which are typically assessed across multiple factors, such as recent population trend, extent of current distribution, current population size, and current or future threats. A challenge for all assessment schemes is finding data sources that can be applied equally and broadly across all taxa of interest. Those tasked with applying the assessments often must weigh information from various sources and decide which are most credible. An additional challenge is downscaling global assessments to relevant regional scales at which conservation action is most effective; this challenge is especially acute for migratory birds, which are affected by factors across multiple regions and timeframes.

In response to growing concern about population declines of many North American birds, Partners in Flight (PIF) was formed in 1990 as a coalition of government agencies, nongovernmental organizations (NGOs), academic institutions, philanthropic foundations, and industry (Finch and Stangel 1993). The initial focus of PIF was on Neotropical migratory birds, but the emphasis has been expanded to include all landbirds, including resident species and those using certain aquatic habitats, such as saltmarsh (Rich et al. 2004). With more than 460 landbird species breeding in the U.S. and Canada, and limited resources for their conservation, identifying the relative need for conservation measures among species is essential to PIF's mission of helping species at risk and keeping common birds common. PIF has therefore developed a comprehensive species assessment process for all avian species as a fundamental step in conservation planning. The assessment also highlights stewardship responsibility and promotes conservation in core areas of species' ranges rather than on their periphery (Wells et al. 2010).

Like the IUCN and NatureServe assessments, the PIF species assessment is a data-driven process based entirely on biological criteria that evaluate distinct components of vulnerability (Mehlman et al. 2004), including extent of distribution, population size, population trend, and threats. The process was initially developed for all landbirds in Canada and the U.S. (Hunter et al. 1993), but has evolved over time as its application has been extended to all birds (Carter et al. 2000, Panjabi et al. 2005, 2012), and eventually south to Mexico (Berlanga et al. 2010) and Central America. The concepts and procedures of this assessment approach have been thoroughly tested, externally reviewed (Beissinger et al. 2000), and updated multiple times to address issues raised by reviewers and by Canadian and Latin American partners. In addition, the specifics of the assessment process are continually improved as new data are integrated from multiple sources. All of the information that is compiled, analyzed, and produced by the PIF species assessment process is stored in the PIF Species Assessment Database (http://pif.birdconservancy.org/).

The PIF Species Assessment Database has served as the biological foundation for PIF's range-wide landbird conservation plans for the U.S., Canada (Rich et al. 2004, Rosenberg et al. 2016), and Mexico (Berlanga et al. 2010). The database has also been used to identify national and regional Birds of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2008), as well as by numerous states, provinces, joint ventures, Canadian Bird Conservation Regions (ECCC 2017), and landscape conservation cooperatives, among others, for their priority lists. The assessment database for all avian taxa was recently used to inform the North American Bird Conservation Initiative's (NABCI) State of the Birds reports for the U.S. (NABCI U.S. 2014) and for Canada, the U.S., and Mexico (NABCI 2016). These efforts reflect an ongoing process to create the Avian Conservation Assessment Database, a single unified tool for conservation planning and decision-making for all bird species throughout the Western Hemisphere (http://pif.birdconservancy.org/ACAD/). The new Avian Conservation

TABLE 1. Conservation vulnerability measures used in Partners in Flight (PIF) species assessments of 460 landbirds in North America, and the value of North American Breeding Bird Survey (BBS) data in providing reliable information for each measure.

PIF assessment measure	BBS value
Recent population trend	Very high (main focus, many species)
Current population size	Moderate (relative abundance)
Distribution measures	Moderate (within U.S. and southern Canada)
Threats	Limited (but much use of data for research)
Area importance	High (relative abundance within U.S. and southern Canada)

Assessment Database will replace the PIF Species Assessment Database, and will apply the same PIF assessment methodology to all bird species.

Throughout the history of the species assessment process and database, PIF has made extensive use of North American Breeding Bird Survey (BBS) data to inform key aspects of its status assessments, especially information on population trends and relative abundance across regions. In this paper, we evaluate the degree to which the PIF species assessment process for landbirds breeding in the U.S. and Canada has relied on data from the BBS, relative to other surveys and sources of information. We present in detail the methods and rationale for how BBS data have been analyzed and used in PIF species assessments, describing refinements and improvements in the process since the review by Beissinger et al. (2000). We then present several novel uses of BBS results to enhance the PIF planning process, including new metrics of conservation urgency and setting measurable population objectives for species of high concern. Finally, we suggest future steps to improve and expand the use of BBS data in conservation assessments and to more fully integrate data from multiple sources to maximize the value of the Avian Conservation Assessment Database.

The Breeding Bird Survey as a Data Source for Species Assessment

To complete its species assessment, PIF looked to a variety of data sources, and naturally turned to the North American Breeding Bird Survey (BBS) as the most extensive and long-running survey for breeding birds in North America (Sauer et al. 2013, 2017). The BBS, designed in the 1960s in response to concerns over the effects of environmental degradation on biodiversity, now includes more than 5,000 routes throughout the U.S. and Canada and portions of Mexico (Sauer et al. 2013, 2017), and has proven valuable for estimating population trends for more than 400 bird species. In addition, the stratified random design of the BBS allows for trend estimation at ecoregional scales, in particular for Bird Conservation Regions across the U.S. and Canada (Sauer et al. 2003). The primary challenges that PIF faced in applying BBS data to species assessment were (1) how to use BBS trend data in an objective and consistent way across all North American landbird species, given the geographic and detectability limitations inherent in the BBS; and (2) how to use information other than trend (e.g. abundance, distribution) to inform additional aspects of the species assessment.

The overall strengths of the BBS for informing species assessment include the geographic breadth and intensity of route coverage, the length of the time series (50 yr and counting), and the prompt availability of raw data (i.e. Pardieck et al. 2016) and trend results (i.e. Sauer et al. 2014) on the BBS public website (www.pwrc.usgs.gov/bbs). Overall limitations of BBS data include poor coverage in remote geographic areas and for hard-to-detect species, and potential roadside bias (Veech et al. 2017). Another important limitation of the BBS is the restriction of data to a single time window for each route, corresponding to peak breeding activity; thus, assessments of migratory species during the nonbreeding season must rely on other data sources. The value of BBS data to providing information for PIF's assessment measures ranged from very high for population trends to limited for assessing threats to specific species (Table 1). PIF's decision of whether to use BBS data for a particular species in their assessment depended on the extent to which BBS routes sampled the breeding range of the species and the precision of trend estimates, which varied with species detectability and overall rarity.

Geographic coverage. The BBS samples nearly all latitude–longitude degree blocks in the lower 48 U.S. states and across southern Canada (Figure 1), with the greatest coverage in the eastern U.S., southeastern Canada, Pacific Coast states, southern Rocky Mountains, and Alberta. Coverage of degree blocks is much more scattered in the boreal forest of Canada and Alaska, and the Arctic is largely unsampled. The BBS therefore provides trend and relative abundance data for use in species assessments for most species breeding throughout the U.S. and southern Canada. Species with breeding ranges largely in the Arctic or boreal regions or largely south of the U.S. are only partially covered by the BBS; for northern species that winter largely within the U.S. and southern Canada, PIF uses data from the National Audubon Society's Christmas Bird Counts (Butcher and Niven 2007) to supplement their assessment scores, and for many Mexican species with peripheral populations in the U.S., PIF relies on expert opinion.

Species coverage. The BBS estimates range-wide trends for 423 bird species (Sauer et al. 2014, but see updated analysis in Sauer et al. 2017). Available reliability ratings

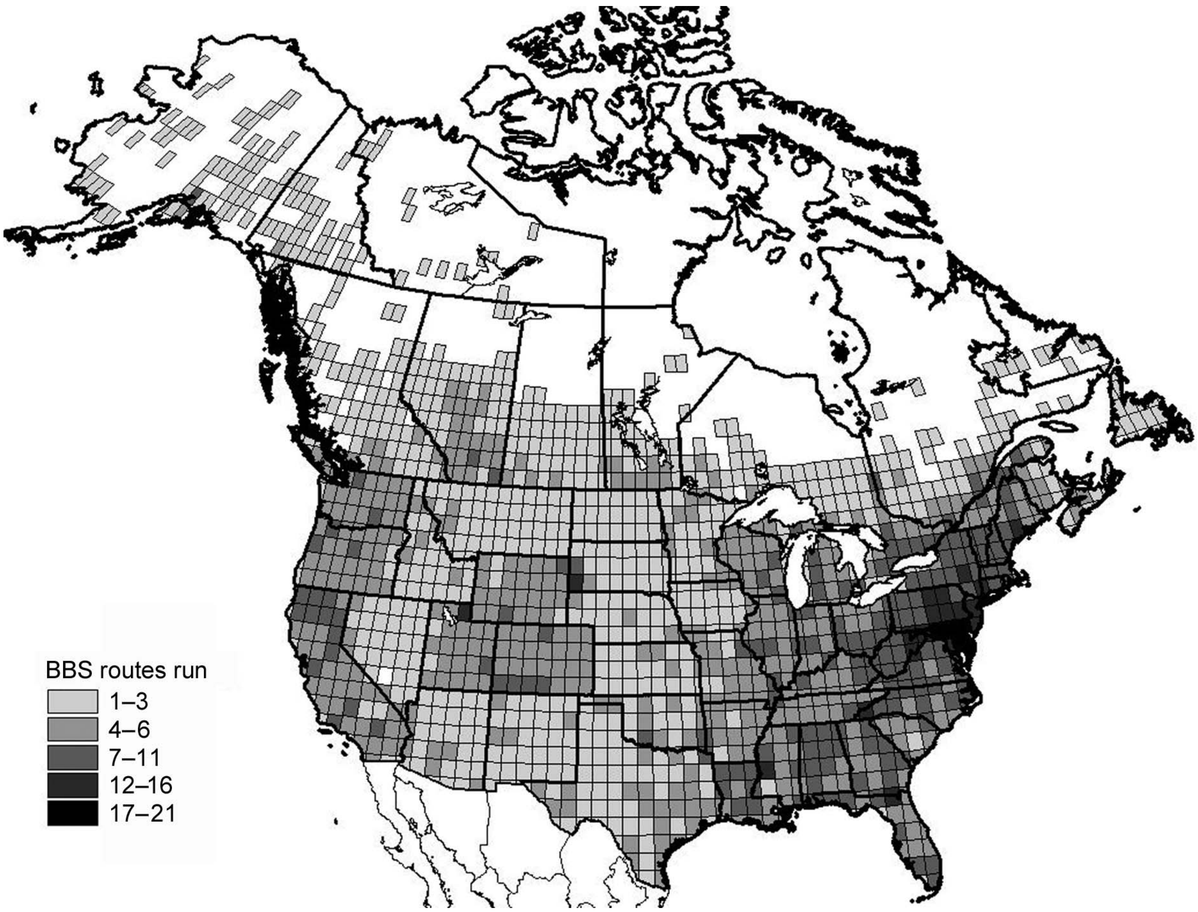

FIGURE 1. Number of North American Breeding Bird Survey (BBS) routes run as of 2014, summarized by latitude–longitude degree block. Data from Pardieck et al. (2015).

for these trend estimates indicate that trends are estimated with high reliability for 256 species, moderate reliability for 128 species, and low reliability for 39 species. The majority of species with reliable trend data are widespread and common landbirds; 125 species native to North America lack any BBS trend data. In particular, data are lacking for many nocturnal birds, rare and patchily distributed species, and primarily Mexican or Caribbean species with only peripheral populations in the U.S.

For PIF's assessment of continent-scale population trends, 287 of 460 landbird species (62%) relied on BBS data exclusively, and another 15 relied on BBS data together with other information (Figure 2). Christmas Bird Counts (CBC) alone provided trend information for 32 species. For the majority of the remaining species, PIF relied primarily on expert opinion, either from the PIF Science Committee or a committee of Mexican ornithologists (Mexican National Species Assessment Committee) applying species assessments to the Mexican avifauna. For 8 species, trend information came from species-specific surveys or expertise, such as that of endangered species recovery teams (Panjabi et al. 2012). Similarly, of 308 landbirds with the majority of their breeding ranges in the U.S. and Canada, 274 relied on BBS data for estimates of population size within the U.S. and Canadian portions of their ranges. For many species, PIF then adjusted this population size estimate based on the percentage of the range that was outside the U.S. and Canada (based on species range maps from NatureServe; Ridgely et al. 2003).

Use of BBS Data for PIF Assessment Scores

A major aspect of the overall PIF conservation assessment is the assignment of species assessment scores. Each species is assigned global scores for 6 factors that assess largely independent aspects of vulnerability to extinction or regional extirpation at the range-wide scale: population size (PS), breeding distribution (BD), nonbreeding distribution (ND), threats to breeding (TB), threats to nonbreeding (TN), and population trend (PT). Each score reflects the degree of a species' vulnerability (i.e. risk of significant population decline or range-wide extinction) as a result of that factor, ranging from 1 for low vulnerability

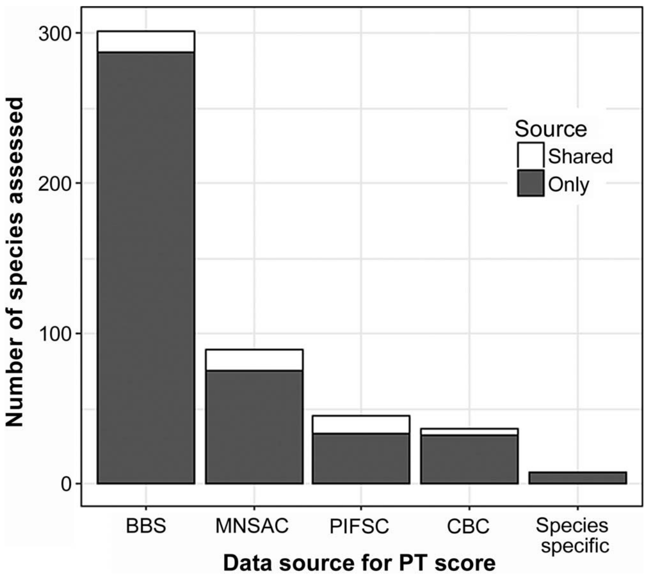

FIGURE 2. Data sources used for assessing North American population trend (PT) scores for 460 landbird species. 'BBS' indicates PT scores derived from North American Breeding Bird Survey trends from 1970 to 2014, provided by J. Sauer. 'MNSAC' indicates PT decisions made by the Mexican National Species Assessment Committee. 'PIFSC' refers to PT scores based on expert opinion of the Partners in Flight Science Committee. 'CBC' indicates scores from National Audubon Society's Christmas Bird Count (Butcher and Niven 2007). 'Species specific' refers to PT scores derived from single-species surveys, studies, or endangered species recovery reports. 'Shared' indicates that data from sources in addition to the primary survey were considered in determining PT, vs. data only from that single source ('Only').

to 5 for high vulnerability (Carter et al. 2000, Panjabi et al. 2012).

In addition to global scores, PIF assigns region-specific scores for the vulnerability factors that may vary geographically: population trend (PT), threats to breeding (TB), and—for species that reside in the region outside the breeding season—threats to nonbreeding (TN). The PIF assessment process considers 2 measures of area importance: the percentage of the global population that occurs in the region of interest during the breeding or nonbreeding season, and the relative density of the species among regions. This information is used to assess stewardship responsibility for regional and jurisdictional (e.g., agency) planning.

Because the primary strength of the BBS lies in providing long-term trend data for terrestrial species, PIF relies most heavily on BBS data for developing global and regional population trend (PT) scores. Relative abundance indices from the BBS are also the primary data source for developing global population size (PS) scores, and for calculating the 2 measures that determine regional area importance in the breeding season. Below, we provide more detail on how PIF uses the BBS to develop these 3 important assessment metrics.

Population trend (PT) score. The population trend (PT) score indicates vulnerability to extinction or regional extirpation due to the direction and magnitude of recent changes in population size within North America. Species that have declined by 50% or more since 1970 are considered most vulnerable, whereas species with increasing trends are least vulnerable (Table 2). The primary source of trend data is the BBS, but the CBC or specialized data sources are used where these are the best available breeding or nonbreeding data on North American population trends (Figure 2). Where empirical data do not exist, PT is assigned by expert opinion, using the qualitative definitions in Table 2 as guidelines.

For the most recent update of PT scores (Rosenberg et al. 2016), PIF used BBS trends from 1970 to 2014 (provided specifically for PIF by J. Sauer in 2016), then converted annual rates of population change to total population size change for the period of consideration. PT scores were then determined based on the total population size change and the precision and reliability of the annual rate of population change estimate, as presented in Table 2. Across 287 species for which PT scores were based solely on BBS long-term trends, 57 species were determined to have declined by more than 50% since 1970 (PT = 5) and 86 species to have declined by 15–50% (PT = 4), while 64 species were considered to be stable or slightly increasing (PT = 2) and 51 species to have increased by more than 50% (PT = 1; Figure 3A). Relatively few species (29) were assigned a PT score of 3 (uncertain trend or small decline) based on BBS data, whereas a PT score of 3 was predominant among species assessed using non-BBS data sources or expert opinion (73 of 158 species).

Note that although the BBS began in 1966, expanded coverage in the western U.S. and Canada was not completed until 1968, with significant sample sizes in the west not reached until about 1970. In addition, PT scores have previously been based on trend analyses using route-regression methods (Sauer and Link 2011), whereas the most recent analyses have used endpoint analysis. Therefore, we carefully evaluated the effect of newer endpoint analyses on magnitude and year-to-year stability of PT scores (see Appendix). From this comparison, we concluded that trends based on a log-scale linear regression analysis fit to BBS annual abundance indices provided the most stability in PT scores (Appendix Table 7), and this method was adopted for PIF species assessment. Because PIF now uses a linear regression approach, and only considers BBS data from 1970 onward, the trends and resulting PT scores used in the current species assessment and most recent PIF Landbird Conservation Plan (Rosenberg et al. 2016) differ slightly from those presented on the public BBS website.

TABLE 2. Definitions and rule sets for scoring the population trend (PT) portion of Partners in Flight (PIF) species assessment scores of landbirds in North America. Percent change refers to the estimated total percent change in population size measured (or estimated based on expert opinion for species lacking empirical data) between 1970 and 2014. Percent change value, significance level (credible interval), and reliability determine the PT score.

PT score	Description	Percent change	Credible interval (CI)
1	Significant large increase	$\geq$50	90% CI excludes 0
2	Significant small increase	0 to 50	90% CI excludes 0
	Possible increase	>0	67% CI excludes 0; 90% CI includes 0
	Stable	>−15	67% CI includes 0; reliable trend [a]
3	Uncertain population change		67% CI includes 0; unreliable trend [a]
	Stable or possible decrease	$\leq$15	67% CI includes 0; reliable trend [a]
	Possible small decrease	−15 to 0	67% CI excludes 0; 90% CI includes 0
	Significant small decrease	−15 to 0	90% CI excludes 0
4	Possible moderate decrease	−15 to −50	67% CI excludes 0; 90% CI includes 0
	Significant moderate decrease	−15 to −50	90% CI excludes 0
	Possible large decrease	$\leq$−50	67% CI excludes 0; 90% CI includes 0
5	Significant large decrease	$\leq$−50	90% CI excludes 0

[a] All of the following criteria must be met for a trend to be considered reliable: (1) Trend precision: North American Breeding Bird Survey (BBS) 90% credible interval <3% per year above or below trend; (2) Sample size: BBS degrees of freedom $\geq$14; and (3) Count abundance: average count $\geq$0.1 per route.

Population size (PS) score. Population size is a central measure in most species assessment schemes, particularly those aimed at identifying species at a high risk of extinction (e.g., IUCN 2012, various national endangered species programs). Small populations are generally considered more vulnerable to extirpation or extinction than large ones, even among those species not immediately at risk. Population size (PS) indicates vulnerability to extinction due to the total number of adult individuals in the global population. Each species is assigned a PS score representing an order-of-magnitude category of population size from $\geq$50,000,000 (PS = 1) to <50,000 (PS = 5; Table 3). For species occurring in Canada and the U.S., scores are assigned using population estimates derived primarily from abundance data collected by the BBS, extrapolated after various adjustments to range size outside BBS coverage, but other data on abundance are used when appropriate (Rich et al. 2004, Rosenberg and Blancher 2005; details in the PIF Landbird Population Estimates Database [http://pif.birdconservancy.org/PopEstimates/] and associated guides; Blancher et al. 2007, 2013).

Although the BBS was not designed specifically to produce population estimates, and there are difficulties to overcome as a result, there are important advantages to using BBS data to estimate population size. The main ones are that data from across much of North America are 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 North American landbirds. Note that PIF previously relied on BBS relative abundance (RA) indices directly as a measure of range-wide abundance (Carter et al. 2000), and the current method of calculating PS scores was developed in part because of recommendations made by Beissinger et al. (2000) to consider species differences in range extents and detection differences that were not accounted for in the RA score.

PIF's population size estimates rely on a Fermi type approximation (Morrison 1963), whereby a series of adjustment factors, assumptions, and rough estimates are applied to extrapolate from mean route counts to regional population estimates. This type of back-of-the-envelope approximation is used across many disciplines when data are scarce. Further, population size estimates using this approach have been shown to be in accordance with independent estimates of population size when comparable data have been available (Rosenberg and Blancher 2005). Because PIF's goal was to place each species' population size within broad, order-of-magnitude categories, even the crude estimates generated from BBS counts were considered adequate to produce a relative scale of vulnerability due to population size.

Since the first population size estimates were published (Rich et al. 2004), the approach has gone through several rounds of revisions (Blancher et al. 2007, 2013) in an attempt to refine the method and respond to critiques (Thogmartin et al. 2006, Thogmartin 2010). Further refinements and improvements to the approach remain an active area of ongoing work for PIF. For example, the latest update to the PS scores was completed in 2016 (Rosenberg et al. 2016) and used BBS data for the years 2005–2014 (Pardieck et al. 2015). PS scores were derived for 332 species using BBS data and NatureServe range maps (Ridgely et al. 2003) to extrapolate global scores beyond BBS coverage. The largest proportion of landbird species fell into the 5–50 million individuals population

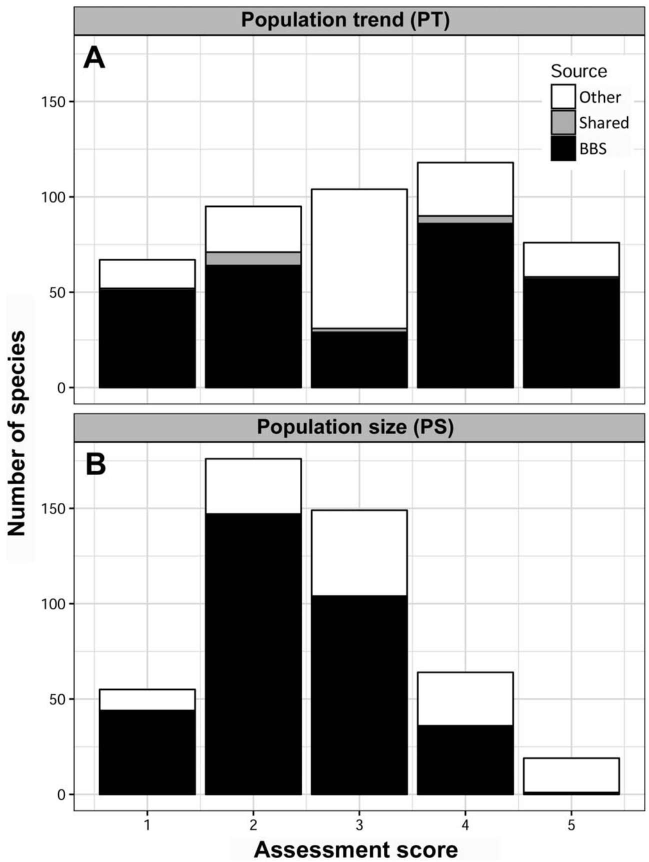

FIGURE 3. Distribution of scores for (**A**) population trend (PT) and (**B**) population size (PS) among 460 North American landbird species assessed, based on data from the North American Breeding Bird Survey (BBS) and other sources. The PT score indicates vulnerability to extirpation or extinction based on the direction and magnitude of recent changes in population size within North America. PT scores were assigned based on 1970–2014 trends for each species (see Table 2 for additional details). The PS score indicates vulnerability to extirpation or extinction based on the total number of adult individuals in the population. PS scores were assigned based on extrapolation from mean counts along BBS routes (see Table 3 for additional details). For both scores, 1 = lowest vulnerability and 5 = highest vulnerability. 'Other' indicates that data came from sources other than the BBS; 'Shared' indicates that other data sources were considered in addition to BBS data.

range (PS = 2), and only 1 species was assessed as PS = 5 based on BBS data (Figure 3B). Other data sources (e.g., Birds of North America, https://birdsna.org; Birdlife International, www.birdlife.org; or species experts) were generally more useful for rarer species.

Regional area importance. At a regional scale, the PIF assessment provides 2 measures of how important a given area is for each species, relative to other areas within the species' range: relative density (RD), and percent of population (%Pop). These measures help practitioners prioritize where scarce conservation resources should be

TABLE 3. Categories of population size (PS) score used in the Partners in Flight (PIF) species assessments of landbirds in North America. Species with the smallest global populations (number of breeding adults) are considered the most vulnerable to extinction and are assigned the highest PS score.

PS score	Global breeding population size
1	≥50,000,000
2	<50,000,000 and ≥5,000,000
3	<5,000,000 and ≥500,000
4	<500,000 and ≥50,000
5	<50,000

allocated by distinguishing, for example, species that are at the periphery vs. the core of their breeding range (Wells et al. 2010). In addition, PIF's %Pop is an important measure of the stewardship responsibility that each jurisdiction shares for the overall conservation of a given species, as applied at the scale of migratory bird joint ventures in PIF's recently revised Landbird Conservation Plan (Rosenberg et al. 2016). Both RD and %Pop measures rely heavily on BBS relative abundance indices for a majority of North American landbirds. When applying BBS indices to both of these measures, PIF first stratifies BBS data by the state and/or province portions (polygons) of each Bird Conservation Region (BCR), and then adjusts for coverage of species range if the BBS does not cover all latitude–longitude degree blocks within a polygon, to reduce the influence of geographic intensity of BBS coverage; the assumptions are made that (1) detection probabilities are fairly constant for a given species across polygons, and (2) the spatial coverage of BBS routes is roughly equivalent across polygons (i.e. the proportion of routes on which a given species occurs is representative of each polygon).

Relative density (RD) scores reflect the mean density of a species within a given BCR relative to density in the single BCR in which the species occurs at its highest density (Table 4). The underlying assumption of this score is that conservation action taken in regions where the species occurs at the highest densities will affect the largest number of birds per unit area. Because the score is one of *relative* density, it is unaffected by the size of the BCR or the absolute density of the species. RD scores for most species are calculated from BBS data for the breeding season (based on mean birds per route per year within the BCR). Other sources of data and expert opinion are used for species with few range-wide abundance data. Scoring by expert opinion is based on estimation of mean density across entire BCRs (including both suitable and unsuitable areas), to make scores comparable with those based on BBS data. RD scores for the Wood Thrush (*Hylocichla mustelina*) are presented as an example of how RD scores are derived (Table 5).

TABLE 4. Relative density (RD) scores used in Partners in Flight (PIF) regional species assessments of landbirds in Bird Conservation Regions (BCRs) in North America; relative density values are derived from North American Breed Bird Survey (BBS) abundance indices across all Bird Conservation Regions (BCRs) within a species' range.

RD score	Quantitative definition	Equivalent qualitative definition
P		Peripheral: has bred only irregularly, or strong evidence of regular breeding is lacking
1	BCR density <1% of the maximum density	Breeds regularly, but in very small numbers or in only a very small part of the region in question
2	BCR density 1–10% of maximum density	Breeds in low mean abundance relative to the region(s) in which the species occurs at maximum density
3	BCR density 11–25% of maximum density	Breeds in moderate mean abundance relative to the region(s) in which the species occurs at maximum density
4	BCR density 26–50% of maximum density	Breeds in moderately high mean abundance relative to the region(s) in which the species occurs at maximum density
5	BCR density >50% of maximum density	Breeds in high mean abundance, similar to the region(s) in which the species occurs at maximum density

Percent of population (%Pop) values reflect the proportion of the global population of a species that is contained within a BCR during the breeding season. The underlying assumption of this value (a continuous variable, unlike the scores discussed thus far) is that regions with high proportions of a species' total population have a high responsibility for the species as a whole, and that actions taken in these regions will affect the largest number of individuals of that species. Unlike RD, %Pop is influenced by the size of a BCR. Thus, large BCRs may have high population percentages but relatively low densities, or vice versa. The %Pop score therefore complements the RD score.

To calculate %Pop, relative abundance (mean birds per route per year) is calculated for each species sampled by the BBS in each BCR. This value is multiplied by the size of the BCR (km^2), and the area-weighted value is then divided by the sum of area-weighted values from all the BCRs in which the species occurs. For species with populations outside the BBS coverage area, %Pop values are then adjusted by the range outside this area, assuming similar densities to those within the BBS survey area. Because relative abundance information is typically not available for other areas, %Pop values for species that are at the periphery of their range in the U.S. and Canada may be slightly inflated if the species is much more common outside the BBS survey area. This affects few species, however, and will be addressed in the near future using eBird data to adjust %Pop and RD values for such species. Even if the BBS greatly underestimates the absolute abundance of a species, relative abundance values and %Pop estimates should be valid as long as the detectability of a species on BBS routes is relatively constant across the species' range.

An example of %Pop estimates across BCRs is given for the Golden-winged Warbler (*Vermivora chrysoptera*; Table 6). These regional responsibility values were used to

TABLE 5. Calculations of relative density (RD) scores (Table 4) for the Wood Thrush (*Hylocichla mustelina*), derived from North American Breeding Bird Survey (BBS) counts. 'Avg per route' indicates the average number of birds per BBS route, stratified by state or province within each Bird Conservation Region (BCR).

BCR number	BCR name	Avg per route	Relative density	RD score
28	Appalachian Mountains	12.83	100%	5
29	Piedmont	8.51	66%	5
30	New England/Mid-Atlantic Coast	7.71	60%	5
27	Southeastern Coastal Plain	5.80	45%	4
24	Central Hardwoods	4.75	37%	4
13	Lower Great Lakes/St. Lawrence Plain	4.50	35%	4
25	West Gulf Coastal Plain/Ouachitas	3.08	24%	3
14	Atlantic Northern Forest	2.18	17%	3
23	Prairie Hardwood Transition	1.60	13%	3
26	Mississippi Alluvial Valley	1.46	11%	3
12	Boreal Hardwood Transition	1.29	10%	3
23	Prairie Hardwood Transition	0.73	6%	2
8	Boreal Softwood Shield	0.02	0%	1
19	Central Mixed-grass Prairie	0.02	0%	1

TABLE 6. Percent of population (%Pop) estimates for the Golden-winged Warbler (*Vermivora chrysoptera*) in Bird Conservation Regions (BCR) across its breeding range. To calculate %Pop, the relative abundance (mean birds per Breeding Bird Survey route per year) in each BCR is multiplied by the size of the BCR (km^2), and the area-weighted value is then divided by the sum of area-weighted values from all of the BCRs in which the species occurs, then down-weighted by the percentage of the range that is outside BCRs in the U.S. and Canada, if the species breeds elsewhere.

BCR number	BCR name	%Pop
12	Boreal Hardwood Transition	80%
23	Prairie Hardwood Transition	10%
28	Appalachian Mountains	5%
13	Lower Great Lakes/St. Lawrence Plain	4%
6	Boreal Taiga Plains	1%

determine focal areas for the breeding grounds conservation plan for this species (Roth et al. 2012).

PIF Metrics of Conservation Urgency

In addition to the PIF assessment scores, PIF has introduced new metrics for continental and regional conservation planning and priority setting (Rosenberg et al. 2016). One new metric is based on the concept of 'population half-life,' which incorporates year-to-year variability in addition to recent population trends to forecast future rates of population change.

The half-life urgency metric predicts the number of years until a population that is half the current size is expected to be observed. This urgency metric, as presented in the PIF 2016 Landbird Conservation Plan (Rosenberg et al. 2016), is equivalent to the median time to a 50% population decline described by Stanton et al. (2016). A half-life urgency metric is presented for species on the PIF Watch List and Common Species in Steep Decline list whenever there is sufficient data to calculate a metric and the upper bound on 95% confidence limits is within a maximum time horizon of 150 yr. Half-life estimates predicted to occur within the next 50 yr but with wide confidence intervals (>40 yr) are noted with an asterisk in the 2016 Landbird Conservation Plan (Rosenberg et al. 2016).

PIF's half-life prediction is based on the assumption that the population trends observed over the past decade and the year-to-year variability estimated over the past 4 decades will continue unabated (Stanton et al. 2016). The half-life urgency metric is calculated using BBS abundance indices (Sauer et al. 2014) for 303 landbird species and provides a ranked urgency criterion for these species across 33 BCRs and also at the binational level (U.S. and Canada; Stanton et al. 2016). The half-life urgency metric, while subject to some of the same considerations and limitations as the BBS (undersampling of rare or hard-to-observe species, spatial bias, etc.), has the potential to be a powerful way both to monitor the effectiveness of future conservation actions and to communicate the state of the birds to managers, decision makers, and the public. The half-life metric differs from the PT score principally in the fact that the population projection is based on recent trends (past decade), whereas the PT score is based on longer-term population trends (since 1970). PIF feels that it is important to consider both longer-term and shorter-term trends as both can at times express different risks. Long-term trends, such as PT scores, express the overall population gains or losses over several decades, but may not adequately account for changing conditions that might signal a new threat. The new half-life metric also differs from other PIF metrics by more effectively communicating the urgency of needed conservation action by expressing the metric in terms of a future timeframe.

Using the BBS to Set Population Objectives

While information on its population trend is essential for assessing the conservation status of a species, monitoring population change is also essential for tracking and evaluating the response to conservation or management actions. Ideally, if conservation efforts are successful, a positive population response will be detected by a long-term survey such as the BBS. For this reason, PIF has developed range-wide population objectives which set measurable targets that regional managers, such as those in migratory bird joint ventures, can use to track progress toward reversing the declines of high-priority species. At a continental scale, most of PIF's population objectives are based on trends derived from the BBS. As first presented by Rich et al. (2004), these trend-based objectives were a simple reflection of the BBS population change over the previous 30 yr; for example, if a species had declined by ≥50% (i.e. PT = 5), the objective was to double the population within the next 30 yr.

In the 2016 Landbird Conservation Plan revision (Rosenberg et al. 2016), PIF proposes new continental population objectives that are still based on BBS population trends. These new objectives set measurable targets for 3 time intervals—10 yr, 20 yr, and 30 yr—representing short-, medium-, and long-term objectives. The specific targets for each species depend on the magnitude of declines, acknowledging that reversing declines is a multiphased effort that first focuses on lessening the rate of decline, then stabilizing the population, and then creating population growth where possible. At every phase, new BBS trend data will be used to periodically assess progress.

Looking to the Future

PIF remains committed to bringing the highest-quality data and the most innovative approaches to avian species assessment to our partners in conservation. A few examples of future goals for PIF include: (1) expanding assessments to the full life cycle, incorporating more information about distributions and movements during migration and over-wintering; (2) delineating natural subpopulation boundaries (Rushing et al. 2016); and (3) expanding the PIF assessment process to other regions and taxa. The BBS has been and will continue to be an invaluable resource toward meeting those goals. While there are other valuable repositories of bird data now available, such as the Christmas Bird Count (Butcher and Niven 2007) and eBird (Sullivan et al. 2014), none of these can replace the BBS with its combination of long time series, species coverage, geography, and adherence to set sampling protocols. PIF has supplemented information from the BBS with data from other sources in the assessment process in the past, and will continue to do so when data from different sources can be complementary.

PIF scientists will continue to work closely with BBS scientists to improve and expand the utility of BBS data for conservation assessments. Some specific areas of mutual interest that PIF and BBS scientists hope to work on together in the near future include:

(1) Developing integrated models that draw inference from both eBird and the BBS to address some of the limitations of the BBS relative to habitat and geographic coverage;
(2) Assisting with the expansion of the BBS into Mexico (and northern Canada and Alaska) to improve geographic coverage for species for which the BBS can provide reliable trend and abundance data;
(3) Comparing and calibrating estimates of relative abundances derived from BBS data with data on frequency and abundance from eBird across regions, to be able to use eBird for assessing area importance measures in the nonbreeding season; initial efforts in this regard have been very promising;
(4) Working with BBS analysts to provide data at scales relevant to the implementation of conservation actions, such as within migratory bird joint ventures;
(5) Defining metrics for evaluating progress toward meeting PIF population objectives using BBS trend data at relevant scales, e.g., BBS-wide, BCR-wide, across migratory bird joint ventures; and
(6) Refining PIF's use of BBS data for waterbirds and other taxa as the Avian Conservation Assessment Database is expanded to include all birds.

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Data deposits: Our data is deposited with the Bird Conservancy of the Rockies in the PIF Species Assessment Database at http://pif.birdconservancy.org/

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APPENDIX

Evaluating Stability of Population Trend Analyses Using Endpoint Analyses vs. Route-regression Methods

Until recently, PIF's population trend (PT) scores were based largely on trend analyses using route-regression methods (e.g., PT scores described by Panjabi et al. 2012). Most trend analyses have since moved to using hierarchical models, with population change over a given survey period defined as the ratio of endpoints (i.e. ratio of estimated abundance for last and first years of the survey period) and with annual trend derived from the geometric mean of that ratio, given the number of years in the interval (Sauer and Link 2011). Before adopting the newer endpoint (EP) analysis using single years at each endpoint, we evaluated its effect on year-to-year stability of PT scores in comparison with using ratios of rolling 3- or 5-yr averages at each endpoint (AV3 and AV5 methods, respectively; e.g., the AV3 trend for 1970–2012 was based on the ratio of the 2010–2012 average to the 1970–1972 average). We also compared these 3 endpoint methods with a log-scale linear regression (LR) fit to annual indices from the hierarchical analysis. Variance in species' trends, estimated precision of trends, and variance in PT scores were calculated for each method across 4 trend periods, 1970–2009, 1970–2010, 1970–2011, and 1970–2012, for 426 species at a BBS-wide scale, simulating updates to PT scores in 4 consecutive years. All trend estimates were computed as derived statistics of parameters from the hierarchical model of population change. This model was fit using Bayesian analyses (i.e. posterior distributions of the model parameters were used as the basis of estimation) with Markov chain Monte Carlo (MCMC) methods. The annual indices derived from the analyses were used to estimate trend for all 4 methods. For the LR analyses, trend was computed as the slope of a log-scale linear regression through the annual indices. For the endpoint average approaches (EP, AV3, and AV5), trends were computed as described above from the ratios of the averages of annual indices for the appropriate years (1, 3, or 5 yr at each endpoint, respectively), using the number of years elapsed between midpoints of the averaged end periods to calculate the geometric mean trend. The MCMC procedure produced replicated estimates of the derived trend parameters that were used to estimate posterior distributions. Median trends and credible intervals (CIs) were taken as percentiles from these distributions. J. Sauer (personal communication) provided all of the species' trends and trend variances for this analysis.

For all methods, variance in trends across the 4 time periods was small, with <8% of species showing trend

APPENDIX TABLE 7. Variance in population trends across 4 endpoint years (2009, 2010, 2011, and 2012) for 426 bird species, compared among 4 trend summary methods. All trend analyses used hierarchical models, with trends defined as the ratio of endpoints (EP method; Sauer and Link 2011). The AV3 and AV5 methods used rolling 3-yr and 5-yr averages, respectively, at each endpoint (e.g., the AV3 trend for 1970–2012 was the ratio of the 2010–2012 average to the 1970–1972 average), and the LR method used a log-scale linear regression (LR) fit to annual indices from the hierarchical analysis.

	Trend method			
	EP	LR	AV3	AV5
Median trend range (max–min, % per year)	0.22%	0.07%	0.12%	0.20%
Median variance in trends, relative to EP [a]	1.00	0.35	0.57	0.81
% species with trend variance < EP		92%	86%	58%
90% credible interval (CI), relative to EP CI		0.86	0.91	0.82
% species with 90% CI < EP CI		97%	92%	94%

[a] Based on standard deviation (SD) of species trend across years using LR, AV3, or AV5 method divided by SD of trend using EP method.

differences of $>1.0\%$ yr^{-1} across years in any method (EP: 7.5%, LR: 0.5%, AV3: 1.9%, AV5: 3.8%). However, median trend differences among years and standard deviations of trends across years showed the greatest variance using the EP method and the least variance with the LR method (Appendix Table 7); the LR method reduced annual fluctuations in trend values by nearly two-thirds relative to the EP method. Precision of trends increased slightly using the LR method as well (14% median reduction in the width of the credible interval; Appendix Table 7). The rolling average endpoint methods generally produced intermediate results (Appendix Table 7).

More importantly to PIF species assessments, the number of changes in PT scores between 2009 and 2012 was reduced by more than half with the LR method (40 of 426 species changed PT score using the LR method, vs. 88 using the current EP method, 57 with the AV3 method, and 73 with the AV5 method). Similarly, reversals of PT scores between 2009 and 2012 (PT score moved up, then down, or vice versa) were reduced from 36 species with PT score reversals based on the EP method to 0 species with PT score reversals using the LR method (8 with the AV3 method, 4 with the AV5 method). Frequently changing PT scores because of sensitivity to selected years in successive EP analyses is an undesirable result that can cause species to flip-flop in their priority status, thus weakening the utility of the PIF species assessment process for long-term planning.

From this comparison, we concluded that trends based on linear regression across the indices produced by the hierarchical model (LR method) provided more stability in PT scores than the EP method, and we adopted the LR method for PT scores in PIF species assessments.