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Long-term and large-scale multispecies dataset tracking population changes of common European breeding birds

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Around fifteen thousand fieldworkers annually count breeding birds using standardized protocols in 28 European countries. The observations are collected by using country-specific and standardized protocols, validated, summarized and finally used for the production of continent-wide annual and long-term indices of population size changes of 170 species. Here, we present the database and provide a detailed summary of the methodology used for fieldwork and calculation of the relative population size change estimates. We also provide a brief overview of how the data are used in research, conservation and policy. We believe this unique database, based on decades of bird monitoring alongside the comprehensive summary of its methodology, will facilitate and encourage further use of the Pan-European Common Bird Monitoring Scheme results.

Background & Summary

Biodiversity declines have multiple negative implications for entire ecosystems. Trophic interactions between organisms may be altered, functional diversity reduced and potential vulnerability to biodiversity loss increased due to these negative changes[1]. Despite the importance of biodiversity for human well-being[2] and awareness of this fact by international authorities (https://www.cbd.int/sp/targets/), a recent study shows an ongoing loss of biodiversity in the last few decades[3]. Therefore, evaluation of previous conservation efforts as well as the production of robust datasets for future assessments is essential to better understand and reverse these negative trends, and to understand positive trends at the same time.

Datasets that cover long term population changes across species distribution ranges are crucial to capture variability in processes behind recent biodiversity losses and to enable precise targeting of any necessary remedial

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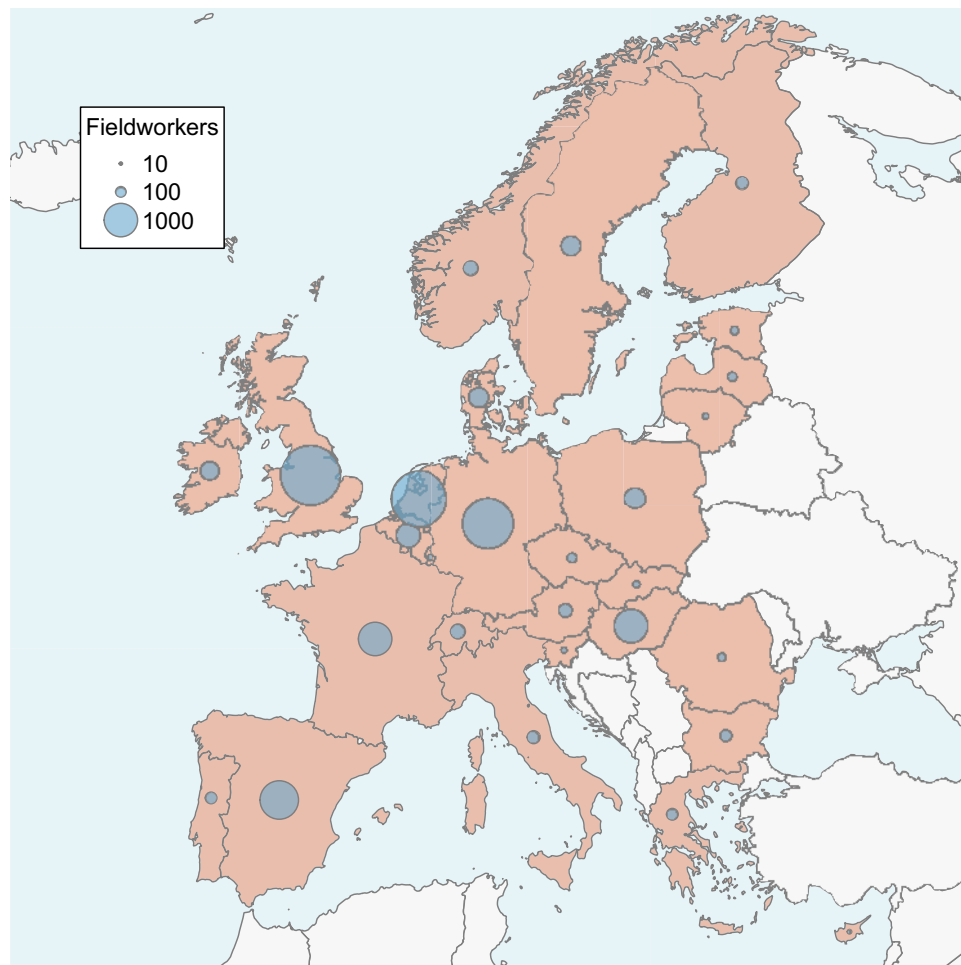
Fig. 1 Countries providing the national bird monitoring scheme(s) outputs to the Pan-European Common Bird Monitoring Scheme (orange) and the number of fieldworkers in the national monitoring schemes (dot size; dots in the legend represent the respective number of collaborators).

conservation actions. However, collecting long-term and broad-scale information on population changes for multiple species is challenging for various reasons. In particular, there are limited financial resources to support such efforts and limited human resources with adequate skills and training in the identification of species and systematic data collection[4].

Broad interest in birds worldwide has the potential to overcome some of these challenges[5]. Amateur birdwatchers are often well-trained in bird identification and many of them are willing to participate in citizen science projects aiming to better understand diverse natural processes[4,6,7]. In recent decades, numerous projects acquiring long-term and broad-scale population data on the relative abundance of birds have been established, especially in many European countries[8] and North America[9]. These networks of fieldworkers annually collect data on species' presence and abundance, in various habitats across numerous study plots, used for a wide range of applications[10] (Fig. 1).

The Pan-European Common Bird Monitoring Scheme (PECBMS)[11] uses data from the national bird monitoring schemes in Europe annually to produce a continental dataset on relative changes in breeding bird population sizes. So far, PECBMS has produced 15 annual updates of the between-year and long-term changes of widespread and common bird species breeding in Europe[10,12–14]. These data have been used for the evaluation of conservation efforts[15], investigation of various research questions[12,16–27] and for reporting on international biodiversity targets[28,29]. In addition, the PECBMS dataset is regularly used for assessments like the Living Planet Index (https://livingplanetindex.org/), helping to shed light on the global biodiversity state of vertebrates;[30,31] for policy purposes by the European Environmental Agency, European Commission, Eurostat (EU headline indicators)[32]; and by Forest Europe and the Organisation for Economic Co-operation and Development to report against national and international environmental and biodiversity frameworks and goals.

Here, we present the database of the between-year and long-term relative population size changes in 170 bird species collected by thousands of volunteers in 28 European countries over the past decades[8]. The publicly available datasets can be used for numerous goals and especially for investigating research questions, conservation efficiency assessments and for policy purposes.

Methods

National breeding bird monitoring schemes. Fieldworkers record all, or a fixed, pre-defined set, of bird species heard or seen in the main breeding season in 28 European countries on an annual basis (Fig. 1). All observations are recorded following a scheme-specific standardized protocol based on established field methods for counting birds: point count transect, line transect, or territory or spot mapping[10,33,34]. Here, we provide a short description of the field methods used, as each scheme provides its fieldworkers with specific fieldwork instructions and training.

1. Point counts: A fieldworker counts all detected birds at census points, often placed along a transect (typically >200 meters apart) during a fixed time period to sample birds in a defined study area. Each point is usually visited twice a year.
2. Line transects: A fieldworker moves along a transect and records all detected birds along the predefined path to sample birds in a defined study area. Each transect is usually visited twice a year.
3. Territory or spot mapping: A fieldworker records all birds showing territorial behaviour in a defined study area and marks their positions and their territorial behaviour on a map. The study area is visited multiple times a year (usually 5–12) to map breeding bird territories based on the individual species-specific behaviour recorded. The species counts reflect the number of present territories.

National scheme coordinators provide all fieldworkers with instructions with the prescribed number and timing of survey visits, and information on how to record observations in terms of sampling effort, time of day, seasonality and weather conditions. This ensures the temporal and spatial consistency of data quality within individual national schemes[35]. The standardization of conditions during counting then enables unbiased comparison of results between years and individual study sites within each country.

For the selection of sampling plots, national monitoring schemes use either random, stratified random, systematic selection, or allow a free choice by fieldworkers[8,34]. Sampling plots are selected randomly within the study boundaries using a random selection method or randomly within the stratum under the stratified random method. Under these methods, study plot selection is conducted by random generators (by computer programs) and stratum is predefined as a region with similar attributes; these might be proportions of habitat types, altitude bands, bird abundance, accessibility of survey sites, or fieldworker density, depending on the local circumstances. Systematic selection predefines a spatial grid for sampling plot selection while free choice enables fieldworkers to select their study areas without restrictions[34]. The use of a free choice, or stratified random selection of sampling plots may result in a biased sampling of specific habitat types (typically species-rich habitats) and regions (remote areas poorly covered), but post-hoc stratification and weighting procedures are generally used to correct for unequal sampling and reduce sampling bias as long as the number of plots per stratum is sufficient[36]. Moreover, national coordinators provide fieldworkers with recommendations or oversee the study plot selection to prevent oversampling of specific habitat types and regions. Detailed information on scheme-specific counting protocols, study plot selection and breeding period specification can be found for each national monitoring scheme[8].

National species indices. A species annual index reflects population size change relative to the population size in the reference year. On an annual basis, coordinators of the national monitoring schemes produce species indices for recorded species using a tailor-made implementation of loglinear regression models (TRIM models – Trends and Indices for Monitoring data) from time series of recorded species counts at the study plots[37,38]. Species counts from a study plot reflect mean (or maximum) of individuals recorded during visits at the study plot when using point counts or line transects. For some species, only the number of individuals recorded on the second visit is used because the period of the first visit coincides with the migratory period and consequently the mean number of recorded individuals might not reflect the number of breeding individuals. The method to estimate the species counts in a plot is constant within a national scheme.

Missing data occur in the species counts at specific sites in individual years for various reasons, such as severe weather conditions during the counting period, abandonment of the study site, restricted access, or where counts are repeated in multi-year intervals. The TRIM model imputes missing data using species counts either from surveyed sites with similar environmental characteristics (stratified imputing) or all other sites with available data[37,39]. This process is based on the assumption that changes in populations at non-counted sites are similar to those at counted sites within the same stratum. To derive expected between-year changes in species population sizes, the program fits a log-linear regression model assuming Poisson distribution to time series from counted plots. Finally, we use this model to calculate missing species-specific counts for individual years[37,39]. The resulting time series of species counts with imputed missing values cover the whole period of counts in the national monitoring scheme. These imputed data are then used to estimate annual population sizes from all study plots and to derive population size indices for species[11].

European species indices and trends. The individual national indices for a given species are combined to create the European species indices. Subsequently, long-term population size changes (trends) are calculated as the multiplicative linear slopes from species indices and represent an average between-year relative population size change over a predefined period.

The European combination process is very similar to the production of national scheme species indices, but with three differences[40]. Firstly, the indices are calculated using national TRIM output data, consisting of imputed species counts, standard errors per year and covariance matrices. Secondly, species counts are weighted by the most recent species population size estimates (updated every three years) in a given country derived from national bird atlases, official data reports and national experts (http://datazone.birdlife.org/) to account for the

Class	Description
Steep decline	A trend slope of <0.95 (a decline of more than 5% per year), with the upper confidence limit of the slope <0.95
Moderate decline	A trend slope of ≥0.95 and 1.00 (a decline of no more than 5% per year), with the upper confidence limit of the slope between 0.95 and 1.00.
Stable	A trend slope where the confidence intervals overlap 1 (no significant change), with the lower confidence limit of change >0.95 and upper confidence limit of change <1.05
Uncertain	A trend slope where the confidence intervals overlap 1 (no significant change), with the lower confidence limit of change <0.95 and/or the upper confidence limit of change >1.05
Moderate increase	A trend slope between 1.00 and ≤1.05 (an increase of no more than 5% per year), with the lower confidence limit of the slope between 1.00 and 1.05.
Strong increase	A trend slope of >1.05 (an increase of more than 5% per year), with the lower confidence limit of the slope >1.05

Table 1. Classification of the European bird species trends based on the magnitude and uncertainty of the estimates (using 95% confidence intervals).

Field name	Description
species	scientific name (HBW and BirdLife International 2018)
euring_code	EURING species code (EURING 2018)
year	the year
index	relative population change relative to the reference year
se	standard error of the index value

Table 2. Fields of the European bird population size indices dataset (indices.csv).

country-specific population sizes and thus the unequal contribution of national indices on the European index. Thirdly, missing national time totals due to different start years of the schemes[8] are imputed using species counts from a set of countries from the same geographical region[6,11]. For this purpose, we divided all national schemes into seven geographic regions – Central & East Europe, East Mediterranean, North Europe, South Europe, Southeast Europe, West Balkan and West Europe[8]. We then use a set of national indices from a given region to impute missing national indices. Therefore, the earliest periods of population size changes are based on data from a reduced number of study plots and schemes.

The species trends are then imputed from species indices for four periods: 1980 onwards, 1990 onwards, 2000 onwards and using only the last ten years of data if the data are available. Despite higher uncertainty of the earliest estimates, we do provide the population index estimates for this period as no alternative and continuous measures of bird population size changes exist for this period.

The uncertainty estimates of indices and trends are presented by the standard error[11,37] allowing a calculation of 95% confidence limits ($\pm 1.96 \times$ standard error). The magnitude of the trend estimates together with their 95% confidence intervals are then used for trend classification into six classes facilitating communication and interpretation of the outputs[37] (Table 1).

Finally, European species indices and trends are presented only for a group of common and widespread bird species (hereafter 'common bird species') meeting two criteria:

1. The estimated breeding population (http://datazone.birdlife.org/) is at least 50 000 pairs in PECBMS Europe (EU countries, Norway, Switzerland and the United Kingdom; Fig. 1). Additionally, Red-billed Chough (*Pyrrhocorax pyrrhocorax*) and Spotted Redshank (*Tringa erythropus*) with population sizes below 50 000 pairs are included, as large parts of their breeding populations are covered in the PECBMS Europe.
2. The estimated breeding population in PECBMS countries providing data for a given species[8] covers at least 50% of the whole PECBMS Europe breeding population (http://datazone.birdlife.org/).

The resulting datasets of European population size indices and trends consist of relative population changes for 170 common bird species.

Updates.   We aim to maintain the PECBMS database with annual updates. The annual updates will be available through the PECBMS database deposited at the Zenodo repository[8] to ensure long-term public availability of the data.

Data Records

The Pan-European Common Bird Monitoring Scheme database is organised into five datasets: (1) European species indices, (2) European species trends, (3) European species trends for three short periods, (4) a list of details on the national monitoring schemes and (5) a matrix of countries providing data for population size estimates of individual species[8]. Individual fields are described in Tables 2–6 and the whole database is freely available at the Zenodo data repository[8]. National-level species indices and uncertainty estimates are also available in the PECBMS database. Due to specific privacy ownership rights, the most recent (2016–2017) Spanish[41] and Cypriot[42] data are under Restricted Access and researchers interested in these most recent updates are required to provide a brief description of the data use. The Austrian and Portuguese datasets are publicly available but

Field	Description
species	scientific name (HBW and BirdLife International 2018)
euring_code	EURING species code (EURING 2018)
base_year	the reference year
trend	multiplicative slope of the between-year population change
se	standard error of the trend value
class	trend value classification based on its magnitude and uncertainty estimate (Table 1)
note	the note

Table 3. Fields of the European bird population size trends dataset (trends.csv).

Field	Description
species	scientific name (HBW and BirdLife International 2018)
euring_code	EURING species code (EURING 2018)
base_year	the reference year
trend	multiplicative slope of the between-year population change
se	standard error of the trend value
class	trend value classification based on its magnitude and uncertainty estimate (Table 1)

Table 4. Fields of the European bird population size trends dataset for 1990 onwards, 2000 onwards and for the last ten years of the data (trends_short.csv).

Field	Description
country	country
collaborators	sample size in last year of survey
scheme_name	national monitoring scheme name
count_method	field methods for counting birds
plot_selection	method used for selection of study plots
initial_year	the first year of the data collection
end_year	the last year of the data collection
region	geographic region of the national scheme
reference	reference to the national scheme monitoring program

Table 5. Fields of the list of the national monitoring schemes (monitoring_schemes.xlsx).

Rows	species
Columns	country

Table 6. Dimensions of the matrix of species and countries providing data to the PECBMS (species_country.csv).

researchers using these datasets are kindly requested to notify the national scheme coordinators of their use. A list of regularly updated contacts to all national scheme coordinators is provided at the PECBMs website (https://pecbms.info/country/).

Technical Validation

Coordinators of the national monitoring schemes provide all fieldworkers participating in national monitoring schemes with detailed information on counting methods and selection of study plots. Fieldworkers also receive detailed instructions on counting procedures with recommendations to follow guidelines on weather conditions during counts, and time and duration of counts to ensure between-year consistency in bird abundance estimates. Coordinators routinely offer and run practical training sessions and workshops on national fieldwork methods. Moreover, coordinators oversee study plot selection in cases where observers are free to choose their study plots, to prevent oversampling of certain habitat types or regions. Finally, all fieldworkers are advised to carefully check all their records prior to data transfer to the national coordinators. Use of standardized counting protocols, standardized counting conditions[10] and randomization or supervised study plot selection should yield unbiased year-to-year changes in bird abundances.

The national coordinators carefully check received data for errors caused by data transcription and run TRIM models[37] combining data records from all study plots and estimating the species' abundance for the whole scheme. The model outputs are evaluated for credibility using outlier control and a consistency evaluation. Firstly, national coordinators check an outlier report of a national index for each species that indicates very low (<0.5)

or very high (>1000) annual index values, very low (1 individual) or very high species counts (>1 × 10⁶ individuals), the number of zero-count sites, the number of sites with missing counts, and the number of sites with more than 10% of the total national species count. The outlier check indicates possible discrepancies in raw data and transcription errors. Secondly, index and trend estimates, species counts, uncertainty estimates and trend classification for a given year are compared to the information from the previous (or any other) year. After evaluating the data credibility, the whole national dataset including indices, trends and uncertainty estimates for each species is transferred to the PECBMS coordination unit. The quality check at the PECBMS level consists of similar steps. Finally, species recorded at very few study plots (i.e. some nocturnal species, rare species, species with a small distribution ranges) are filtered out from the final PECBMS datasets.

The European species' indices and trends are calculated for the period since 1980; however, the start years differ between schemes (see Methods for details). Therefore, we annually prepare a trend dataset using three additional, shorter periods – 1990 onwards, 2000 onwards and using the last ten years of the data. This yields more robust trend estimates for those periods and allows the comparison of trend estimates between different periods by omitting the earliest years of counts in which only a limited number of schemes were in place and a limited number of fieldworkers recorded data. Despite a higher uncertainty, we present population size change estimates for the earliest periods because there are no alternative data available describing large-scale population size changes in breeding birds for the past four decades.

Usage Notes

The resulting population indices and trends reflect changes in relative population size, which is our main goal. Our data do not reflect true population estimates because the actual numbers of birds, as assessed at site-level, may be biased in a number of ways. The bias may arise from imperfect detection of birds by fieldworkers, the use of multiple survey protocols in different countries, or the imputation of missing values. But given the fact that within each country the same methods are used at the same sites over time, the data allow us to estimate temporal trends in population sizes.

We advise all PECBMS database users to check notes associated with trend estimates. These notes were added when e.g. a high variation in between-year population sizes was detected, or the trend estimates may have been affected by human activities such as hunting or releasing of captive-bred individuals. For Bluethroat (*Luscinia svecica*), the population indices and trends represent population change of the subspecies *Luscinia svecica svecica* only.

Raw bird counts as well as additional details on the sampling sites can be requested from national scheme coordinators. The updated list of their contact information is available at the PECBMS website (https://pecbms.info/country/). Finally, we encourage anyone planning to use the PECBMS datasets in their study to contact the PECBMS coordination team (https://pecbms.info/) with any questions, especially on the possibilities and limitations of these datasets in relation to the aims of the planned study.

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Author contributions

V. Brlík formatted the database, drafted and led writing of the manuscript. E. Šilarová checked aggregated schemes' data quality, analysed aggregated schemes' data, computed supra-national population indices and trends, and commented on the manuscript. J. Škorpilová checked aggregated schemes' data quality, analysed aggregated schemes' data, computed supra-national population indices and trends, and commented on the manuscript. H. Alonso checked national scheme's data, analysed national scheme's data and commented on the manuscript. M. Anton checked national scheme's data, analysed national scheme's data and commented on the manuscript. A. Aunins checked national scheme's data, analysed national scheme's data and commented on the manuscript. Z. Benkö checked national scheme's data, analysed national scheme's data and commented on the manuscript. G. Biver checked national scheme's data, analysed national scheme's data and commented on the manuscript. M. Busch checked national scheme's data, analysed national scheme's data and commented on the manuscript. T. Chodkiewicz checked national scheme's data, analysed national scheme's data and commented on the manuscript. P. Chylarecki checked national scheme's data, analysed national scheme's data and commented on the manuscript. D. Coombes checked national scheme's data, analysed national scheme's data and commented on the manuscript. E. de Carli checked national scheme's data, analysed national scheme's data and commented on the manuscript. J.C. del Moral checked national scheme's data, analysed national scheme's data and commented on the manuscript. A. Derouaux checked national scheme's data, analysed national scheme's data and commented on the manuscript. V. Escandell checked national scheme's data, analysed national scheme's data and commented on the manuscript. D.P. Eskildsen checked national scheme's data, analysed national scheme's data and commented on the manuscript. B. Fontaine checked national scheme's data, analysed national scheme's data and commented on the manuscript. R.P.B. Foppen checked national scheme's data, analysed national scheme's data and commented on the manuscript. A. Gamero checked aggregated schemes' data quality, analysed aggregated schemes' data and commented on the manuscript. R.D. Gregory supervised the project, conceived the aims of the manuscript, checked aggregated schemes' data quality, analysed aggregated schemes' data and commented on the manuscript. S. Harris checked national scheme's data, analysed national scheme's data and commented on the manuscript. S. Herrando checked national scheme's data, analysed national scheme's data and commented on the manuscript. I. Hristov checked national scheme's data, analysed national scheme's data and commented on the manuscript. M. Husby checked national scheme's data, analysed national scheme's data and commented on the manuscript. C. Ieronymidou checked national scheme's data, analysed national scheme's data and commented

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Competing interests

The authors declare no competing interests.

Additional information

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