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Conservation needs and opportunities drive LIFE funding allocation for European birds

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ABSTRACT

Conservation resources are unevenly distributed among species and this can hamper conservation efforts. Previous research indicates that species popularity can be strongly associated with conservation funding allocation, suggesting conservation outcomes can be partly influenced by subjective human perceptions. We assessed the allocation of European Union LIFE projects targeting species conservation among European birds (548 species) and how it associates with species' conservation priorities, scientific knowledge availability, distribution, popularity and visual aesthetic attractiveness. We modelled how these factors relate to the probability that a species has received EU LIFE funding, and how many projects have targeted it. As expected given LIFE funding regulations, species listed in the EU Birds Directive Annex I are more likely to receive funding than non-listed species, and receive more projects. We also found that knowledge availability, presence in more EU member countries with access to LIFE funding, and higher conservation priority in Europe are positively associated with the probability of receiving funding, and the number of projects received. More popular species are less likely to receive conservation funding, but tend to receive more projects when allocated funding. Visual attractiveness was not associated with funding. These results suggest that pragmatic factors dominate funding allocation, but subjective factors still play a minor role. Our analysis also emphasises the need to consider non-funded species when assessing conservation funding allocation. Our findings underscore a need for targeted research on poorly-known species and opportunities for allocating conservation resources to underfunded species that need conservation action, are well-studied, and relatively popular.

1. Introduction

Taxonomic biases permeate conservation science and practice. From research effort (Adamo et al., 2021; Buechley et al., 2019; Clark and May, 2002; dos Santos et al., 2020; Silva et al., 2020) to funding allocation (Adamo et al., 2022; Davies et al., 2018; Mammides, 2019; Mammola et al., 2020), there is ample evidence that some taxa receive more conservation attention than others. Given the need to prioritize conservation action in the face of limited available resources, these biases can negatively impact the effectiveness of conservation programmes aiming to halt further biodiversity loss. It is therefore essential to understand the factors associated with the tendency to favour certain species over others as a basis to address taxonomic biases in conservation (Langlois et al., 2022; Mammola et al., 2023a; Miralles et al., 2019; Santangeli et al., 2023).

Various factors have been put forward to justify why some species receive more conservation attention and resources than others. These factors include species characteristics such as body size, anthropomorphic and neotenic characters, or colourful phenotypes (Adamo et al., 2022; Chan, 2012; Langlois et al., 2022; Stokes, 2007), which make

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them particularly attractive to humans. Some species may also receive more conservation attention because they are perceived as popular (Brambilla et al., 2013; Davies et al., 2018; Mammola et al., 2020), often as a result of their histories of cultural use and interactions with humans (Ladle et al., 2019). Ideally, however, species should receive more conservation attention and support because research efforts have highlighted their conservation need and provide the evidence-base needed to develop targeted conservation efforts (Sitas et al., 2009). The role of each of the above factors in driving the allocation of conservation funding will inevitably depend on the funding model and institutions involved (Martín-López et al., 2009). For example, non-governmental organisations may be more likely to allocate funding to specific species based on donations or perceived support (Davies et al., 2018). In other instances, funding may be allocated to targeted conservation plans based on the conservation needs of species and the likelihood of project success in addressing them (Santangeli and Sutherland, 2017). Successful conservation actions require knowledge about the most effective interventions (Sutherland et al., 2004), so such funding decisions may at least be partly driven by existing research effort.

One such example is the European Union (EU)'s LIFE programme for environment and climate action. Starting in 1992, the programme is currently on its sixth iteration and has already funded over 5500 projects implementing specific actions towards addressing climate change and biodiversity loss (European Commission, 2024). Its current iteration, LIFE 2021–2027, comprises a total budget of 5.45B€ (an increase of nearly 2B€ compared to the previous iteration) to be distributed across four sub-programmes (European Commission, 2018). Approximately 40 % of the total budget is allocated to the LIFE Nature and Biodiversity sub-programme, which focuses on funding projects that contribute specifically to the implementation of the Birds (79/409/EEC) and Habitats (92/43/EEC) Directives, the Natura 2000 network, and the EU's goal of halting biodiversity loss (e.g., through the Biodiversity Strategy for 2030). LIFE programme funding is allocated based on a competitive selection of the projects submitted each year and reviewed by a specialist committee. Its regulations state that the selection of projects for funding should prioritize both the conservation urgency (e.g. based on Red List status) and existing policy priorities (e.g. species and habitats listed in the annexes of the Birds and Habitats Directives). Some earlier analyses of the LIFE programme have suggested that the allocation of funding for species conservation has disproportionally targeted species from some taxonomic groups, namely vertebrates, among those prioritised in EU legislation, thus omitting many other species of conservation concern (Mammides, 2019). Others have also suggested funding decisions may be associated to some extent with subjective human preferences for certain species and habitats (Adamo et al., 2022; Mammola et al., 2020). A better understanding of these different factors contribute to conservation funding allocation can help identify ways to address existing funding gaps.

One important aspect is that some of the earlier analyses incorporated only species which have been granted funding and may thus suffer from a form of survivor bias. Survivor bias (also referred to as survivorship bias) is a term used to describe the logical fallacy of concentrating our attention exclusively towards entities that passed a selection process and overlooking those that did not (Lockwood, 2021). Failing to consider species that were never considered for funding or those that may have been proposed for funding but did not succeed in securing it can potentially bias inferences about what factors drive funding decisions. Many earlier analyses have also neglected to account for the scientific evidence-base available to support the development of conservation projects, such as estimations about the effectiveness of target conservation measures or information on the life history and autecology of the target species. A more detailed assessment of a wider set of species that are considered a priority for funding allocation can help disentangle and assess the relative importance of multiple factors acting at various stages of conservation funding allocation.

In this study, we aim to investigate the factors associated with conservation funding allocation using European bird species as a case study. We focus on European bird species for three key reasons: i) the EU Birds Directive provides a clear mandate for the conservation of European bird species, including through the allocation of funds within the context of the EU LIFE Programme; ii) birds are a diverse taxonomic group, and while they are generally considered popular and attractive, these aspects vary greatly between species (Ladle et al., 2019; Santangeli et al., 2023); iii) earlier research suggests the allocation of conservation research effort (Ducatez and Lefebvre, 2014; Fischer et al., 2023) and funding (Garnett et al., 2003; Leonard, 2008) for birds varies greatly between species – a pattern also common to other taxonomic groups. We explore how different factors (i.e., conservation status, scientific knowledge availability, distribution, popularity and visual aesthetic attractiveness) associate with the number of LIFE projects allocated to each European bird species. In doing so, we account for survivorship bias and recognize that the absence of funding may originate from different processes. Specifically, we asked whether i) species of conservation priority (i.e., those included in the EU Birds Directive and considered of conservation concern in Europe) receive more funding than non-priority species, ii) more studied species receive more funding than less studied species, iii) species occurring in more EU member states receive more funding than less widespread ones, iv) more popular species receive more funding than species which receive poor attention on the web, and v) visually attractive species receive more funding than less attractive ones.

2. Methods

2.1. Data sources

2.1.1. LIFE funding data

We collected LIFE funding information from the European Climate, Infrastructure and Environment Executive Agency (CINEA), which maintains the online LIFE Project Database (https://webgate.ec.europa.eu/life/publicWebsite/search, accessed July 2022). This database contains data in a standardised format on all LIFE projects funded since the programme started in 1992. From the online LIFE Project Database, we collected the following information: i) the LIFE project reference number, ii) start and end year of the project (expected dates), and iii) the species targeted by the LIFE project. Using these data, we then computed the number of unique LIFE projects that targeted each bird species. We used this latter metric as an indicator of how much funding is allocated to each species through the EU LIFE programme, because number of unique LIFE projects is correlated to the total amount of funding allocated to each species (Adamo et al., 2022; Mammola et al., 2020). The average funding allocated per project and per species was 1.1 million euros (std. dev. = 1.8 million euros).

2.1.2. Bird conservation status data

We collected information on the distribution and conservation status of birds in Europe ($n = 548$ species) from the fourth assessment of Species of European Conservation Concern (BiE4; Burfield et al., 2023). Specifically, we collected information for each species on i) its status as a Species of European Conservation Concern ('SPEC' or 'Non-SPEC'), and ii) its inclusion or not in Annex I of the EU Birds Directive ('Yes' or 'No'). Annex I of the EU Birds Directive includes a list of bird species and subspecies which are the subject of special conservation measures as a means to ensure their survival and reproduction in their area of distribution. We considered a species listed in the EU Birds Directive Annex I if it was listed at either the species or subspecies level. We also collected information on the number of current and past EU member states (i.e. including the UK, which had access to the LIFE Programme before Brexit occurred in early 2020) where each species is considered to be extant and native from the IUCN Red List API v4 (IUCN, 2024).

2.1.3. Research publications

We obtained a measure of scientific research dedicated to each species by sampling the number of scientific articles indexed in the Web of Science that refer to that species. This approach has been widely used in previous publications as an estimate of research effort towards individual species (e.g., Adamo et al., 2022, 2021; dos Santos et al., 2020; Mammola et al., 2023a; Tam et al., 2022; Wilson et al., 2007). To collect these data, we used the R package 'wosr' version 0.3.0 (Baker, 2018) to query the Web of Science's Core Collection database. We implemented topic searches ('TS') with the species' currently accepted scientific name and any known synonyms as the search terms, and recorded the total number of references published between 1945 and the date of sampling returned by each query. We selected this approach because we aimed to obtain an estimate of research dedicated to a specific species, and articles mentioning the scientific name on either the title, abstract or keywords are likely focused on that particular species. Furthermore, the use of scientific names returns similar results to searches using vernacular names (Correia et al., 2017; Jarić et al., 2016) but avoids problems associated with the latter, such as some names having multiple meanings (homonyms). However, we did include any known scientific name synonyms as omitting these can limit estimates of available information due to nomenclature changes (Correia et al., 2018). We log-transformed (log10 + 1) data on the number of research articles recorded for each species prior to inclusion in the models based on the visual inspection of the data.

2.1.4. Online interest in birds

We characterised the popularity of each bird species using a measure of the volume of internet searches performed on Google's search engine (Correia et al., 2021). These data were obtained from the Google Trends API using R package gtrendsAPI (Correia, 2024). Specifically, we implemented topic searches for each bird species and collected data on the average monthly relative search volume recorded between January 2004, when data is first available, and December 2022. The data obtained from Google Trends represent a metric of relative search volume because they are scaled in relation to the highest proportion of total searches observed during any given month of the sampled period. The highest observed proportion of searches is assigned the value of 100, and all other values are scaled in relation to it.

Before implementing the searches, we identified and validated species-specific topics (Correia, 2019) using R package 'gkgraphR' (Correia, 2021). Using the identified topics, we ran searches combining multiple species and each search after the first always included one species common to previous searches to allow a recalculation of relative search values that are comparable between searches. As in previous studies (Adamo et al., 2022; Mammola et al., 2020), we used the values returned for the species with repeated searches to estimate a scaling factor between searches using the coefficient of a linear regression between the monthly values of either search. The species included in each search as a reference were selected iteratively to ensure the scaling factor was calculated as accurately as possible based on i) the highest number of non-zero values between searches and ii) a coefficient of determination (R-squared) value above 0.95. We then rescaled the monthly values of search interest for each species using this coefficient so that search volume estimates were comparable between species and averaged across the sampling period (i.e., 216 months of search volume data). We log-transformed (log10 + 1) the values representing relative search volume to homogenise data distribution based on the visual inspection.

2.1.5. Bird attractiveness data

We considered the perceived visual aesthetic attractiveness of individual bird species as a potential additional driver of funding allocation. For this, we used a dataset of the perceived visual aesthetic attractiveness of bird species to humans (Haukka et al., 2023). These data were collected using an internet application available in 21 languages. This application engaged over 6000 users from 78 countries, including many users from countries within the EU, in the scoring of bird photographs. This process produced a dataset comprising over 400,000 scores for >11,000 bird taxonomic units, encompassing both species and subspecies. Succinctly, users were shown an image representing a single bird species and prompted to score the visual aesthetic attractiveness of the bird depicted using a scale ranging from 1 to 10, reflecting an increasing preference for a species' appearance (Haukka et al., 2023). Only highly-quality photos were used for the survey and, where possible, multiple images were used per species to mitigate the influence of individual photos (e.g., varying photo quality). All bird photos were sourced, with permission, from the Cornell Lab of Ornithology's Macaulay Library (https://media.ebird.org/catalog).

The raw attractiveness scores were subsequently employed to predict the visual aesthetic attractiveness of each bird species. To derive the attractiveness values, a regression model was applied to the data, seeking to predict a consensus attractiveness score for each bird species while correcting for a number of confounding factors. Specifically, two confounding covariates were incorporated into the model: (1) variation in photograph quality (rated on a scale of 1–5), and (2) user language as a proxy for culture (Haukka et al., 2023). Furthermore, to address concerns of pseudo-replication due to multiple assessments of the same photograph or species and consider phylogenetic relationships, random factors such as photo identity, species, and family were integrated into the model creating the average attractiveness score per bird species. In this study, we used these predicted scores as the visual aesthetic attractiveness value of the birds to humans.

2.2. Data analysis

We adopted a regression analysis approach to explore the relationship between the number of funded projects for each bird species and variables related to the conservation status, research effort, public interest and perceived visual attractiveness of each species. We carried out all analyses in R version 4.3.3 (R Core Team, 2024), using package 'glmmTMB' version 1.1.8 (Brooks et al., 2017) for regression modelling, and packages 'ggplot2' version 3.4.4 (Wickham, 2016) and 'sjPlot' version 2.8.15 (Lüdecke, 2023) for data visualization. For the analysis, we followed a series of standard steps that included data exploration, model fitting, and validation (Zuur and Ieno, 2016). We started the analysis by calculating summary statistics from the complete dataset and visually inspecting the distribution of each variable, the presence of outliers in the data, and collinearity among the continuous predictors using pairwise Pearson's correlations (Zuur et al., 2010). We identified a strong correlation (Pearson's $r = 0.78$) between the number of scientific articles recorded for each species and online interest, but we retained both variables for the modelling procedure because both contributed importantly to the model's explanatory power and a subsequent analysis of variance inflation factors (VIF) did not reveal any issues (VIF scores <3).

We proceeded to model the relationship between the number of projects funded per species and variables representing i) SPEC status, ii) inclusion in the Annex I of the EU Birds Directive, iii) species occurrence in Europe only, iv) research effort, v) online interest, and vi) attractiveness. Seven species were missing values for one or more variables considered and were removed from the analysis, so the final sample used for modelling contained data from 541 species. We scaled all continuous variables to a mean of zero and a standard deviation of 1 to facilitate the comparison of effect sizes (Schielzeth, 2010). For the regression models, we included a zero-inflation component due to the large number of species for which no project funding has been allocated (315 out of 548 species; see Results section). We consider that some species that have not received funding emerge because they were considered for funding but not selected (i.e., they can be considered 'random' zeros), whereas others may have never been considered for funding for example due to lack of scientific information to develop a conservation plan (i.e., they can be considered ‘structural’ zeros emerging from a different process) (Blasco-Moreno et al., 2019). The selected modelling approach allowed us also to estimate the effect of each explanatory variable on the ‘structural’ zeros. We then explored the use of zero-inflated Poisson and Negative Binomial distributions with linear (‘nbinom1’ family in glmmTMB) and quadratic (‘nbinom2’ family in glmmTMB) parametrization for regression models containing all the mentioned response variables. We used the suite of functions available in package ‘performance’ version 0.10.5 (Lüdecke et al., 2021) to assess model fit based on a visual inspection of residuals, and to evaluate overdispersion and multicollinearity in the final model. An analysis of the outcomes of each model suggested the Poisson distribution model showed issues related with overdispersion, so this distribution was rejected. Both Negative Binomial distributions showed no issues with multicollinearity, but the one using quadratic parametrization returned a lower Akaike information criterion (AIC) score and was thus selected for further analysis. We used the results of this model to visualise the relationship between the various explanatory variables and the number of projects funded per species, and to calculate the number of predicted funded projects per species based on these relationships as a means to identify underfunded species. We report summary model statistics (see Appendix Table S1) but for interpreting and discussing model results, we adopted an evidence-based approach by emphasising effect sizes and directions of effects (Muff et al., 2022; Wasserstein et al., 2019).

3. Results

We identified a total of 620 EU LIFE projects targeting 233 European bird species. The vast majority (609 out of 620, 98 %) of the LIFE projects targeting bird species included at least one species listed in the Annex I of the EU Birds Directive (156 species in total). Furthermore, 56 of these projects also included at least one species that is not listed in Annex I (75 species in total). The remaining 11 projects were allocated to 9 bird species that do not feature in Annex I of the EU Birds Directive. On the other hand, we found no record of funded EU LIFE projects for 315 bird species (approximately 58 % of the species in our sample; *N* = 548 species), including 33 species listed in Annex I of the EU Birds Directive. The allocation of funding through the EU LIFE Programme therefore varies greatly between species (Fig. 1); most species received no funding, some funding from only a few projects, and only 18 species were targeted by 30 or more projects. The species targeted by most projects was the Eurasian Bittern (*Botaurus stellaris*), featuring in 86 projects.

Our models suggest that whether or not a species is listed in Annex I of the EU Birds directive is a major factor associated with EU LIFE funding allocation (Fig. 2). Species listed in Annex I are more likely to receive funding as these species were negatively associated with zero-inflation (Zero-inflation estimate = −2.87, conf. int. = −3.86 to −1.89). Species listed in Annex I also tend to be funded more often than species that are not listed (Count estimate = 2.49, conf. int = 2.10–2.89; Appendix Table S1). Similarly, the models also suggest that species considered of European conservation concern are somewhat more likely to receive funding (Zero-inflation estimate = −0.51, conf. Int. = −1.30–0.28) and tend to be funded more often (Count estimate = 0.25, conf. Int. = −0.03–0.23), but this effect was weaker than that of being listed in EU Birds Directive Annex I.

Factors other than conservation status also seem to be positively associated with EU LIFE funding allocation to different bird species (Fig. 2). The number of scientific publications focusing on a given species contributes positively to the likelihood of receiving a project (Zero-inflation estimate = −0.77, conf. int. = −1.45 to −0.10), and species with more publications also tend to receive more projects (Count estimate = 0.47, conf. int. = 0.20–0.74; Appendix Table S1). Similarly, species that occur in more EU member states are also more likely to receive funding (Zero-inflation estimate = −0.87, conf. int. = −1.42 to −0.32) and be funded more often (Count estimate = 0.61, conf. int. = 0.40–0.82; Appendix Table S1). While both research and presence in member states are positively associated with funding allocation, these

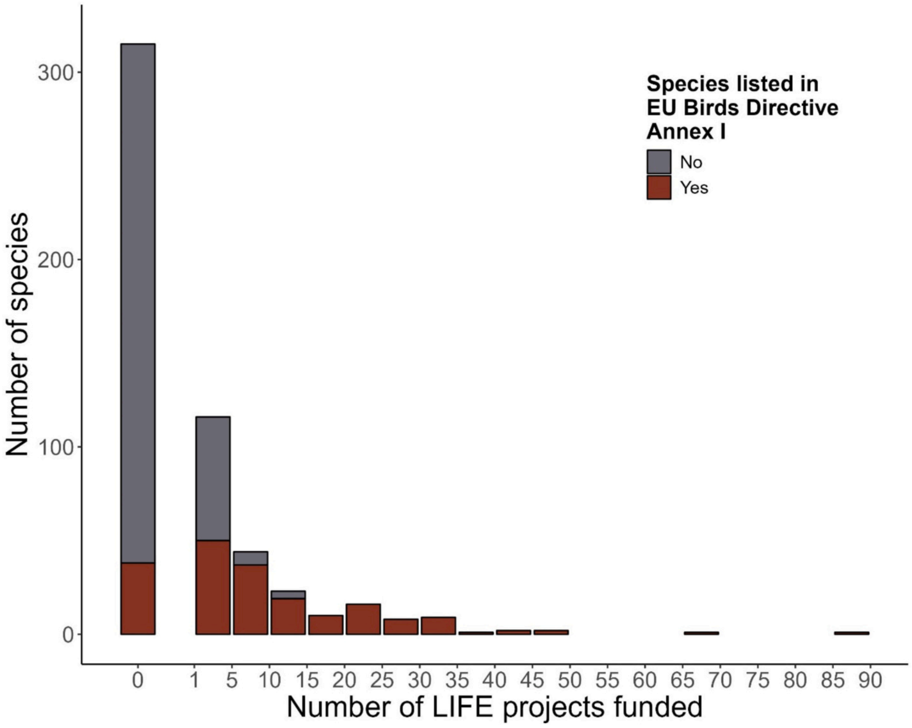

Fig. 1. Frequency distribution of European Union (EU)'s LIFE projects allocated per species (*N* = 541). Bars are binned in intervals of five projects, with the exception of the first bar which represents species that have not been targeted by any project. The number of species included in the Annex I of the EU Birds Directive is marked in red, and those not included are marked in grey. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

relationships are stronger for species included in the EU Birds Directive Annex I when compared to those that are not (Fig. 3).

On the other hand, species that generate more online interest are less likely to receive funding (Zero-inflation estimate = 1.28, conf. int. = 0.38–2.18). Yet, among the species that have received funding, popular species tend to receive more funding than less popular ones (Count estimate = 0.24, conf. int. = −0.04–0.52; Appendix Table S1). Species perceived visual attractiveness had a relatively small association with the likelihood of receiving funding (Zero-inflation estimate = −0.06, conf. int. = −0.40–0.31), and the number of projects funded (Count estimate = −0.10, conf. int. = −0.25 to −0.04).

Some species showed considerable differences when comparing the funding received with the number of projects predicted to have been funded by the model. We used differences in the number of predicted and funded projects to identify a set of species that can be considered underfunded based on their characteristics and could be prioritised for future projects. Specifically, we identified ten species listed in Annex I of the EU Birds Directive and considered of highest conservation concern in Europe (SPEC 1) that have received at least 4 fewer projects than expected (Fig. 4). The species with a wider gap between funded and predicted projects include the Bar-tailed godwit (*Limosa lapponica*; 6 projects funded, 20 predicted), Horned grebe (*Podiceps auritus*; 4 projects funded, 16 predicted), Pallid harrier (*Circus macrourus*; 1 project funded, 9 predicted), and Leach's Storm-petrel (*Hydrobates leucorhous*; 0 projects funded, 8 predicted).

4. Discussion

Our results suggest that conservation status, scientific knowledge, presence in EU member states and species popularity are positively associated with EU LIFE funding allocation for bird species conservation. While not all EU LIFE funding has been allocated to bird species of conservation priority, and many priority species have not yet received support, EU conservation priorities do seem to be the most important factor driving EU LIFE funding allocation. Indeed, most bird species that have received funding from the EU LIFE programme are listed in Annex I

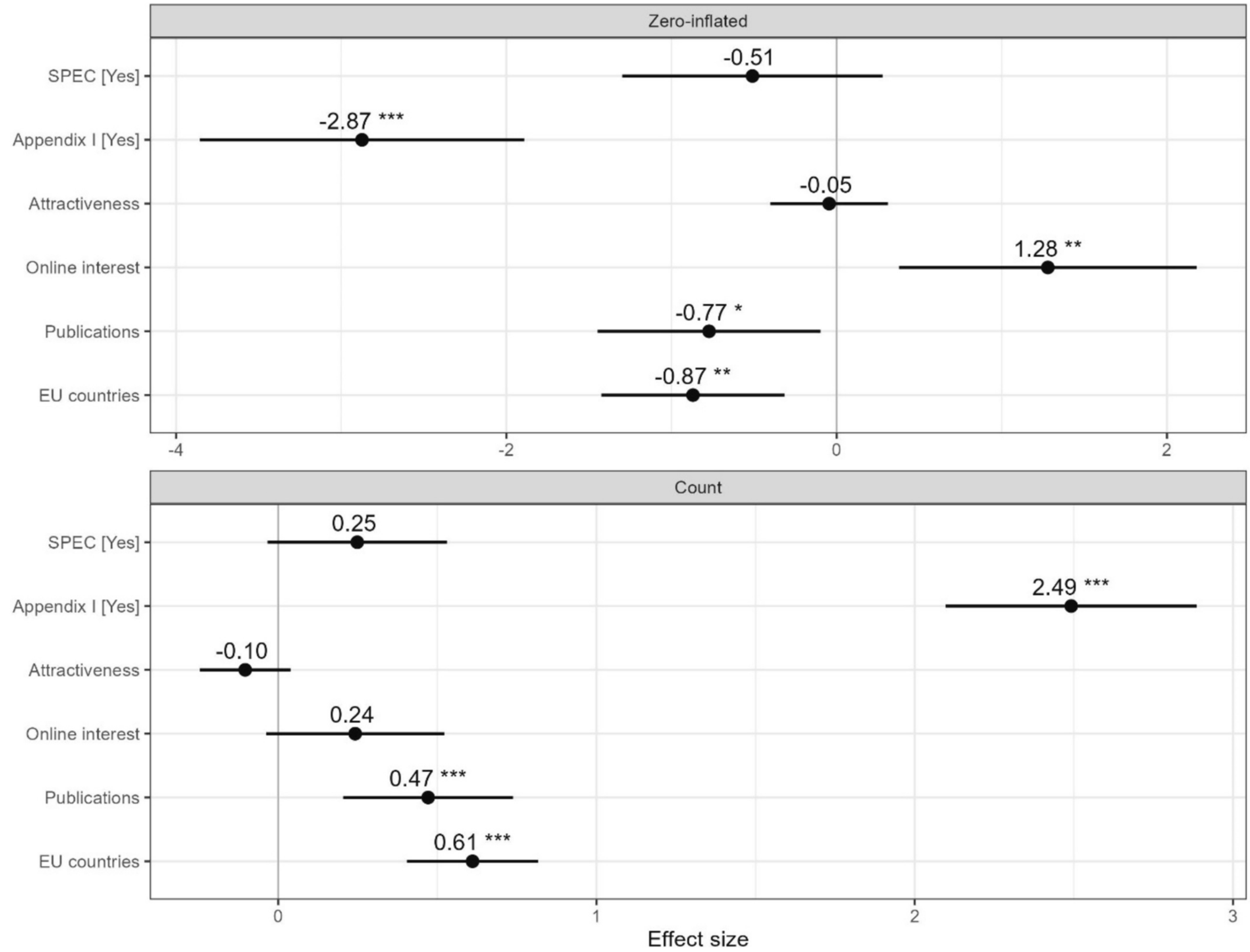

Fig. 2. Parameter estimates of the relationship between species-level variables and the number of projects allocated through the European Union's LIFE programme based on a zero-inflated negative binomial model. The zero-inflated component of the model (top) refers to the effects of each variable on likelihood that a species has not been considered for funding (e.g., because no projects have been submitted for consideration). The count component of the model (bottom) represents the effects of each variable on the number of projects per species selected for funding. ‘SPEC’ indicates European bird species of conservation concern. ‘Annex I’ refers to whether or not a species is included in the first appendix of the EU Birds Directive. ‘Attractiveness’, ‘Online interest’, and ‘Publications’ represent, respectively, estimates of species' attractiveness to humans, species' relative search volume online, and the number of recorded scientific publications featuring a species. ‘EU countries’ represents the number of EU member states where a species is considered native and extant. Dots represent the parameters estimates and horizontal lines their respective 95 % confidence intervals. Asterisks mark significant effects according to the estimated p-value (* ≤ 0.05; ** ≤ 0.01; ** ≤ 0.001). Estimated regression parameters are provided in Supplementary Table 1.

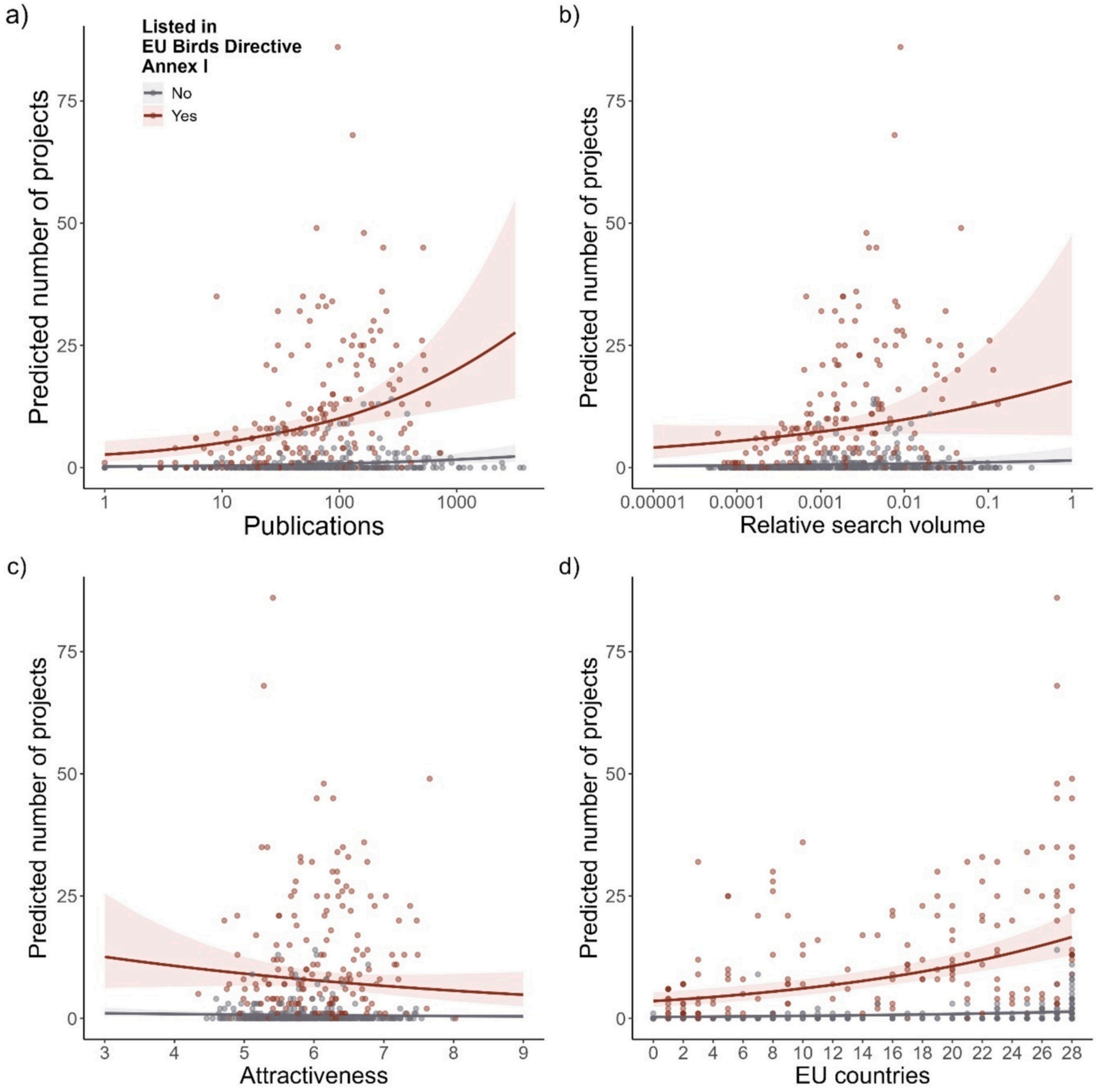

Fig. 3. Predicted relationship between (a) the number of publications, (b) online search interest, (c) bird attractiveness, and (d) number of past and present EU member countries with access to LIFE funding (EU 27 + UK) on the number of LIFE funding projects awarded per species. In each plot, the shown relationships are those predicted by the model while holding the non-focal variables constant.

of the EU Birds Directive and are thus subjected to specific conservation provisions within Europe. Species considered of conservation concern in Europe were somewhat also more likely to receive funding, and to be targeted by more projects. Species that occur in more EU member states were also more likely to receive funding and secured more projects. These results are to be expected given that EU LIFE programme regulations mandate that species of conservation concern and listed in conservation policy such as the EU Birds and Habitats Directives should be prioritised, and presence in more EU member states may allow more people and institutions to develop conservation efforts and secure funding for them. Still, they do provide a somewhat more positive outlook than earlier studies that have found little relationship between conservation status and EU LIFE funding allocation (e.g., Adamo et al., 2022; Mammola et al., 2020). There are a few possible explanations for the contrasting results. One is the different taxonomic coverage of the various studies. The fact that our study was restricted to bird species, which have specific conservation legislation in Europe and are already favoured in conservation funding allocation when compared to other taxa (Mammides, 2019), could help explain why funding allocation and conservation needs align better for this group. However, another important factor may be that our study explored funding allocation among all European bird species, not just those that have received funding, thus potentially accounting for a survivorship-bias effect (Lockwood, 2021) in the analysis. Indeed, the contrast between species listed in the EU Birds Directive Annex I and those that are not listed seems to be clearer among the species that have not received any funding than among those that did (Fig. 1). This stresses the need for future studies exploring the factors associated with conservation funding allocation to consider also species that have not been the recipients of any funding in order to account for survivor bias in the analysis.

The other factor that was positively related to conservation funding allocation was the volume of published scientific research focusing on a species. It may seem logical that existing scientific knowledge about the conservation needs of individual species and possible actions to address them may influence funding allocation given the need and importance of evidence based conservation (Sutherland et al., 2004). This factor was only seldom considered in earlier assessments of conservation funding allocation but our results align with the growing recognition that both

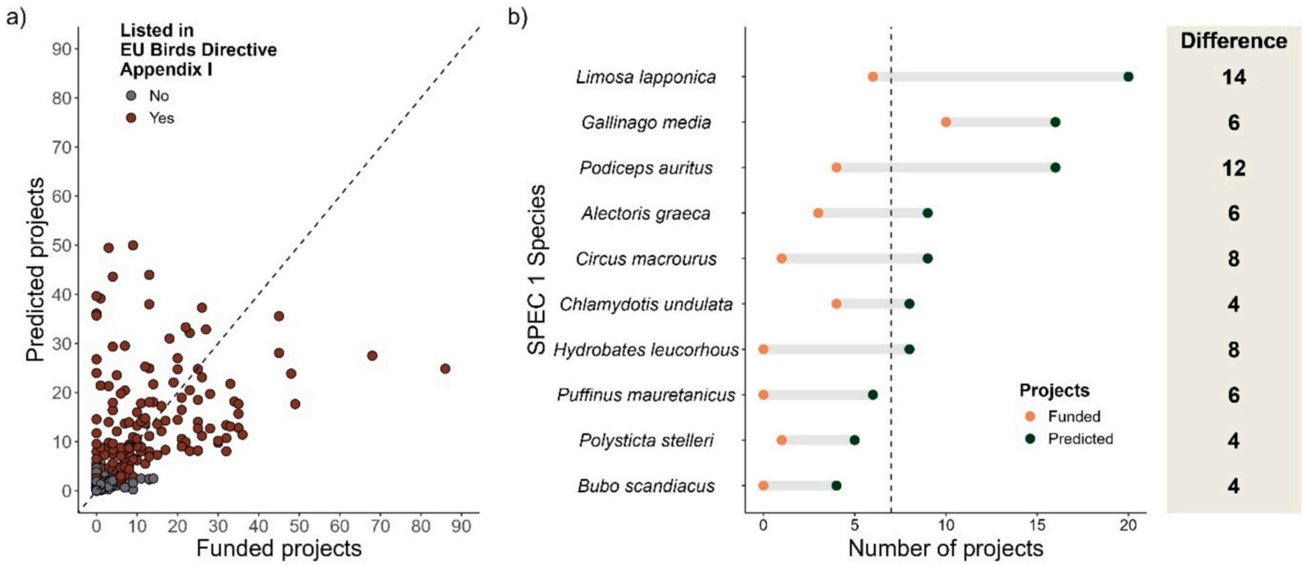

Fig. 4. Differences between the number of European Union (EU)'s LIFE projects funded per species and the number of projects per species predicted by the model. The figures represent (a) the relationship between observed and predicted projects for all species, and (b) the top-10 species listed in the Annex I of the EU Birds Directive and considered of European conservation concern (SPEC 1) showing the highest difference between observed and predicted projects. The dashed line in figure (a) represents an equal number of funded and predicted projects; species falling above the line are predicted to have more funded projects than they have received, and species falling below the line have received more funded projects than predicted by the models. The dashed line in figure (b) represents the median number of projects funded (median = 7) for species listed in EU Birds Directive Annex I.

biological and cultural processes drive efforts to avoid species extinctions (Ladle et al., 2023; Ladle and Jepson, 2008) and help to emphasise the importance of conservation scientists in this context. This result also stresses the need to address the existing biodiversity knowledge gaps and biases that plague conservation research (Clark and May, 2002; Mammola et al., 2023b; Troudet et al., 2017). Research biases affect all branches of the tree of life, including well-studied or popular vertebrates such as birds (Ducatez and Lefebvre, 2014; Fischer et al., 2023), amphibians (Silva et al., 2020) and mammals (dos Santos et al., 2020); however, knowledge gaps are particularly evident and troublesome for non-vertebrate groups such as plants (Adamo et al., 2021), invertebrates (Grodsky et al., 2015), and fungi (Gonçalves et al., 2021; Mueller et al., 2022). Addressing taxonomic research gaps will therefore be an important first step towards ensuring a solid knowledge basis exists to ensure conservation support and action across the tree of life (Mammola et al., 2020).

Consideration of species that have not received any funding was also important to reveal a more nuanced picture of the role of species popularity in conservation funding (Adamo et al., 2022; Davies et al., 2018; Mammola et al., 2020). Previous studies have shown a positive association between species popularity and funding allocation but our results show a more nuanced picture and somewhat contrasting effects on species that have never received funding when compared to those that did. In our study, popularity was negatively associated with the likelihood of species receiving funding, but was positively associated with the number of projects funded among species that had received funding. This was particularly true among the species listed in EU Birds Directive Annex I (Fig. 3). In other words, popularity alone does not seem to drive the allocation of conservation funding per se, but species that are of conservation concern and also happen to be popular may benefit from enhanced support Examples of such species include the Peregrine Falcon (*Falco peregrinus*), Golden Eagle (*Aquila chrysaetus*) and Western Capercaillie (*Tetrao urogallus*), which have been the target of several funded projects. In contrast, highly popular species present in our sample that have not received any EU LIFE funding include for example the Eurasian Blackbird (*Turdus merula*), European Goldfinch (*Carduelis carduelis*) and the Common Raven (*Corvus corax*). The latter species are widespread in Europe and not considered of conservation priority, and popularity alone should obviously not be a factor to justify conservation funding allocation. Nevertheless, the factors that shape species popularity are complex and understanding them may provide important clues towards how they interplay with conservation funding allocation. For example, our results suggest that aesthetic attractiveness is unlikely to be a relevant driver of conservation funding allocation as visual attractiveness was only weakly associated with the likelihood and number of projects allocated. A more plausible explanation relates to the specific roles that certain species occupy in human culture (Schuetz and Johnston, 2019). Species that are widespread and occur in a broad range of habitats, including urban areas, tend to be highly visible and popular among humans (Correia et al., 2016; Mittermeier et al., 2021). However, popularity had a positive effect even when accounting for the number of EU member states a species occurs in, suggesting that chances for interacting with humans may not be the only factor at play. Some species are also highly popular because they possess certain traits that afford something unique to humans, such as large sizes or unique behaviours, and are thus kept as pets, hunted for food, or broadly considered as charismatic (Ladle et al., 2019; Schuetz and Johnston, 2019). Popular species in our sample that have received conservation funding seem to align more with the latter group and this suggests that more contextual and species-specific drivers of species popularity may contribute to funding allocation decisions, and this topic should be investigated further.

Unveiling gaps in funding allocation can also help to ensure a more balanced distribution of conservation resources across species given existing resource constraints. Among the bird species analysed, we identified a set of ten species that have received less conservation support through the EU LIFE programme than expected based on their conservation status, distribution, availability of scientific knowledge and popularity (Fig. 4). Importantly, not only are these species included in the Annex I of the EU Birds Directive, they are also considered of highest conservation priority in Europe (SPEC 1) given their global threat status and Europe's responsibilities towards their conservation (Burfield et al., 2023). Three of the ten species identified have not received any targeted project through the EU LIFE programme and two others have been targeted by one project only. While it is not clear if these species lack conservation support due to the absence of funding requests (i.e., no projects submitted targeting them) or due to lack of selection (i.e., projects were submitted but not approved), they seem to gather some of the conditions required to develop successful projects towards securing funding to improve their conservation status. Some of these underfunded species, such as the Rock Partridge (*Alectoris graeca*) or Pallid Harrier, also have important populations in eastern Europe where many countries have received lower EU LIFE funding support in the past (Sánchez-Fernández et al., 2018). Targeting them may therefore help address both taxonomic and geographical biases in funding allocation. We also acknowledge that many of these species show certain characteristics, such as restricted distributions or nomadic habits, that may pose important challenges to their study and conservation, and may thus require more tailored efforts. Still, failing to allocate adequate resources to their conservation may risk the extinction of these species in Europe. A growing body of evidence suggests that the careful allocation of conservation resources to targeted and evidence-based conservation action can be effective in improving the conservation status of species (Bolam et al., 2021; Langhammer et al., 2024) and we hope our analysis can help to identify opportunities for further enhancing bird conservation resource allocation and actions in Europe.

CRediT authorship contribution statement

Ricardo A. Correia: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jon E. Brommer:** Writing – review & editing, Data curation, Conceptualization. **Anna Haukka:** Writing – review & editing, Data curation, Conceptualization. **Leonie Jonas:** Writing – review & editing, Data curation, Conceptualization. **Aleksi Lehikoinen:** Writing – review & editing, Data curation, Conceptualization. **Stefano Mammola:** Writing – review & editing, Data curation, Conceptualization. **Andrea Santangeli:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2024.110833.

Data availability

The data and code used for the analysis are available online in the following Github repository: https://anonymous.4open.science/r/EU_LIFE_funding_birds_submission.

References

Adamo, M., Chialva, M., Calevo, J., Bertoni, F., Dixon, K., Mammola, S., 2021. Plant scientists’ research attention is skewed towards colourful, conspicuous and broadly distributed flowers. Nat. Plants 7, 574–578. https://doi.org/10.1038/s41477-021-00912-2.

Adamo, M., Sousa, R., Wipf, S., Correia, R.A., Lumia, A., Mucciarelli, M., Mammola, S., 2022. Dimension and impact of biases in funding for species and habitat conservation. Biol. Conserv. 272, 109636. https://doi.org/10.1016/j.biocon.2022.109636.

Baker, C., 2018. wosr: Clients to the ’Web of Science’ and ’InCites’ APIs. In: R package version 0.3.0. https://CRAN.R-project.org/package=wosr.

Blasco-Moreno, A., Pérez-Casany, M., Puig, P., Morante, M., Castells, E., 2019. What does a zero mean? Understanding false, random and structural zeros in ecology. Methods in Ecology and Evolution 10, 949–959. https://doi.org/10.1111/2041-210X.13185.

Bolam, F.C., Mair, L., Angelico, M., Brooks, T.M., Burgman, M., Hermes, C., Hoffmann, M., Martin, R.W., McGowan, P.J.K., Rodrigues, A.S.L., Rondinini, C., Westrip, J.R.S., Wheatley, H., Bedolla-Guzmán, Y., Calzada, J., Child, M.F., Cranswick, P.A., Dickman, C.R., Fessl, B., Fisher, D.O., Garnett, S.T., Groombridge, J. J., Johnson, C.N., Kennerley, R.J., King, S.R.B., Lamoreux, J.F., Lees, A.C., Lens, L., Mahood, S.P., Mallon, D.P., Meijaard, E., Méndez-Sánchez, F., Percequillo, A.R., Regan, T.J., Renjifo, L.M., Rivers, M.C., Roach, N.S., Roxburgh, L., Safford, R.J., Salaman, P., Squires, T., Vázquez-Domínguez, E., Visconti, P., Woinarski, J.C.Z., Young, R.P., Butchart, S.H.M., 2021. How many bird and mammal extinctions has recent conservation action prevented? Conserv. Lett. 14, e12762. https://doi.org/10.1111/conl.12762.

Brambilla, M., Gustin, M., Celada, C., 2013. Species appeal predicts conservation status. Biol. Conserv. 160, 209–213. https://doi.org/10.1016/j.biocon.2013.02.006.

Brooks, M.E., Kristensen, K., Benthem, K.J. van, Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Mächler, M., Bolker, B.M., 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9, 378–400.

Buechley, E.R., Santangeli, A., Girardello, M., Neate-Clegg, M.H.C., Oleyar, D., McClure, C.J.W., Şekercioğlu, Ç.H., 2019. Global raptor research and conservation priorities: tropical raptors fall prey to knowledge gaps. Divers. Distrib. 25, 856–869. https://doi.org/10.1111/ddi.12901.

Burfield, I.J., Rutherford, C.A., Fernando, E., Grice, H., Piggott, A., Martin, R.W., Balman, M., Evans, M.I., Staneva, A., 2023. Birds in Europe 4: the fourth assessment of Species of European Conservation Concern. Bird Conservation International 33, e66. https://doi.org/10.1017/S0959270923000187.

Chan, A.A.Y.-H., 2012. Anthropomorphism as a conservation tool. Biodivers. Conserv. 21, 1889–1892. https://doi.org/10.1007/s10531-012-0274-6.

Clark, J.A., May, R.M., 2002. Taxonomic bias in conservation research. Science 297, 191–192. https://doi.org/10.1126/science.297.5579.191b.

Correia, R., 2021. gkgraphR: accessing the official “Google Knowledge Graph” API. R package version 1.0.2. doi:https://doi.org/10.5281/zenodo.4569962.

Correia, R.A., 2019. Google trends data need validation: Comment on Durmuşoğlu (2017). Hum. Ecol. Risk Assess. Int. J. 25, 787–790. https://doi.org/10.1080/10807039.2018.1446322.

Correia, R.A., 2024. gtrendsAPI: an R wrapper for the Google Trends API. Software Impacts 20, 100634. https://doi.org/10.1016/j.simpa.2024.100634.

Correia, R.A., Jepson, P.R., Malhado, A.C.M., Ladle, R.J., 2016. Familiarity breeds content: assessing bird species popularity with culturomics. PeerJ 4, e1728. https://doi.org/10.7717/peerj.1728.

Correia, R.A., Jepson, P., Malhado, A.C.M., Ladle, R.J., 2017. Internet scientific name frequency as an indicator of cultural salience of biodiversity. Ecol. Indic. 78, 549–555. https://doi.org/10.1016/j.ecolind.2017.03.052.

Correia, R.A., Jarić, I., Jepson, P., Malhado, A.C.M., Alves, J.A., Ladle, R.J., 2018. Nomenclature instability in species culturomic assessments: why synonyms matter. Ecol. Indic. 90, 74–78. https://doi.org/10.1016/j.ecolind.2018.02.059.

Correia, R.A., Ladle, R., Jarić, I., Malhado, A.C.M., Mittermeier, J.C., Roll, U., Soriano-Redondo, A., Veríssimo, D., Fink, C., Hausmann, A., Guedes-Santos, J., Vardi, R., Di Minin, E., 2021. Digital data sources and methods for conservation culturomics. Conserv. Biol. 35, 398–411. https://doi.org/10.1111/cobi.13706.

Davies, T., Cowley, A., Bennie, J., Leyshon, C., Inger, R., Carter, H., Robinson, B., Duffy, J., Casalegno, S., Lambert, G., Gaston, K., 2018. Popular interest in vertebrates does not reflect extinction risk and is associated with bias in conservation investment. PloS One 13, e0203694. https://doi.org/10.1371/journal.pone.0203694.

dos Santos, J.W., Correia, R.A., Malhado, A.C.M., Campos-Silva, J.V., Teles, D., Jepson, P., Ladle, R.J., 2020. Drivers of taxonomic bias in conservation research: a global analysis of terrestrial mammals: conservation research bias. Anim. Conserv. https://doi.org/10.1111/acv.12586.

Ducatez, S., Lefebvre, L., 2014. Patterns of research effort in birds. PloS One 9, e89955. https://doi.org/10.1371/journal.pone.0089955.

European Commission, 2018. The new LIFE programme: investing more in environment and climate action.

European Commission, 2024. History of LIFE. https://cinea.ec.europa.eu/programmes/life/history-life_en#ref-30-years-of-bringing-green-ideas-to-life (accessed 9.21.24).

Fischer, S.E., Otten, J.G., Lindsay, A.M., Miles, D.B., Streby, H.M., 2023. Drab and distant birds are studied less than their fancy-feathered friends. https://doi.org/10.1101/2023.10.26.560707.

Garnett, S., Crowley, G., Balmford, A., 2003. The costs and effectiveness of funding the conservation of Australian threatened birds. BioScience 53, 658–665. https://doi.org/10.1641/0006-3568(2003)053[0658,TCAEOF]2.0.CO;2.

Gonçalves, S.C., Haelewaters, D., Furci, G., Mueller, G.M., 2021. Include all fungi in biodiversity goals. Science 373, 403. https://doi.org/10.1126/science.abk1312.

Grodsky, S.M., Iglay, R.B., Sorenson, C.E., Moorman, C.E., 2015. Should invertebrates receive greater inclusion in wildlife research journals? J. Wildl. Manag. 79, 529–536. https://doi.org/10.1002/jwmg.875.

Haukka, A., Lehikoinen, A., Mammola, S., Morris, W., Santangeli, A., 2023. The iratebirds citizen science project: a dataset on Birds' visual aesthetic attractiveness to humans. Sci Data 10, 297. https://doi.org/10.1038/s41597-023-02169-0.

IUCN, 2024. IUCN Red List of Threatened Species. Version 2024–1 <www.iucnredlist.org>.

Jarić, I., Courchamp, F., Gessner, J., Roberts, D.L., 2016. Data mining in conservation research using Latin and vernacular species names. PeerJ 4, e2202. https://doi.org/10.7717/peerj.2202.

Ladle, R.J., Jepson, P., 2008. Toward a biocultural theory of avoided extinction. Conserv. Lett. 1, 111–118. https://doi.org/10.1111/j.1755-263X.2008.00016.x.

Ladle, R.J., Jepson, P., Correia, R.A., Malhado, A.C.M., 2019. A culturomics approach to quantifying the salience of species on the global internet. People and Nature 1, 524–532. https://doi.org/10.1002/pan3.10053.

Ladle, R.J., Alves-Martins, F., Malhado, A.C.M., Reyes-García, V., Courchamp, F., Minin, E.D., Roll, U., Jaric, I., Correia, R.A., 2023. Biocultural aspects of species extinctions. Cambridge Prisms: Extinction 1–21. https://doi.org/10.1017/ext.2023.20.

Langhammer, P.F., Bull, J.W., Bicknell, J.E., Oakley, J.L., Brown, M.H., Bruford, M.W., Butchart, S.H.M., Carr, J.A., Church, D., Cooney, R., Cutajar, S., Foden, W., Foster, M.N., Gascon, C., Geldmann, J., Genovesi, P., Hoffmann, M., Howard-McCombe, J., Lewis, T., Macfarlane, N.B.W., Melvin, Z.E., Merizalde, R.S., Morehouse, M.G., Pagad, S., Polidoro, B., Sechrest, W., Segelbacher, G., Smith, K.G., Steadman, J., Strongin, K., Williams, J., Woodley, S., Brooks, T.M., 2024. The positive impact of conservation action. Science 384, 453–458. https://doi.org/10.1126/science.adj6598.

Langlois, J., Guilhaumon, F., Baletaud, F., Casajus, N., Braga, C.D.A., Fleuré, V., Kulbicki, M., Loiseau, N., Mouillot, D., Renoult, J.P., Stahl, A., Smith, R.D.S., Tribot, A.-S., Mouquet, N., 2022. The aesthetic value of reef fishes is globally mismatched to their conservation priorities. PLoS Biol. 20, e3001640. https://doi.org/10.1371/journal.pbio.3001640.

Leonard, D.L., 2008. Recovery expenditures for birds listed under the US Endangered Species Act: the disparity between mainland and Hawaiian taxa. Biol. Conserv. 141, 2054–2061. https://doi.org/10.1016/j.biocon.2008.06.001.

Lockwood, D., 2021. Fooled by the Winners: How Survivor bias Deceives us. Greenleaf Book Group Press, Austin, Texas.

Lüdecke, D., 2023. sjPlot: Data Visualization for Statistics in Social Science.

Lüdecke, D., Ben-Shachar, M.S., Patil, I., Waggoner, P., Makowski, D., 2021. Performance: an R package for assessment, comparison and testing of statistical models. Journal of Open Source Software 6, 3139. https://doi.org/10.21105/joss.03139.

Mammides, C., 2019. European Union's conservation efforts are taxonomically biased. Biodivers. Conserv. 28, 1291–1296. https://doi.org/10.1007/s10531-019-01725-8.

Mammola, S., Riccardi, N., Prié, V., Correia, R., Cardoso, P., Lopes-Lima, M., Sousa, R., 2020. Towards a taxonomically unbiased European Union biodiversity strategy for 2030. Proc. R. Soc. B 287, 20202166. https://doi.org/10.1098/rspb.2020.2166.

Mammola, S., Adamo, M., Antić, D., Calevo, J., Cancellario, T., Cardoso, P., Chamberlain, D., Chialva, M., Durucan, F., Fontaneto, D., Goncalves, D., Martínez, A., Santini, L., Rubio-Lopez, I., Sousa, R., Villegas-Rios, D., Verdes, A., Correia, R.A., 2023a. Drivers of species knowledge across the tree of life. eLife 12, RP88251. https://doi.org/10.7554/eLife.88251.

Mammola, S., Fukushima, C.S., Biondo, G., Bongiorni, L., Cianferoni, F., Domenici, P., Fruciano, C., Giudice, A.L., Macías-Hernández, N., Malumbres-Olarte, J., Miličić, M., Morganti, M., Mori, E., Munévar, A., Pollegioni, P., Rosati, I., Tenan, S., Urbano-Tenorio, F., Fontaneto, D., Cardoso, P., 2023b. How much biodiversity is concealed in the word 'biodiversity'? Curr. Biol. 33, R59–R60. https://doi.org/10.1016/j.cub.2022.12.003.

Martín-López, B., Montes, C., Ramírez, L., Benayas, J., 2009. What drives policy decision-making related to species conservation? Biol. Conserv. 142, 1370–1380. https://doi.org/10.1016/j.biocon.2009.01.030.

Miralles, A., Raymond, M., Lecointre, G., 2019. Empathy and compassion toward other species decrease with evolutionary divergence time. Sci. Rep. 9, 19555. https://doi.org/10.1038/s41598-019-56006-9.

Mittermeier, J.C., Roll, U., Matthews, T.J., Correia, R., Grenyer, R., 2021. Birds that are more commonly encountered in the wild attract higher public interest online. Conservation Science and Practice n/a e340. https://doi.org/10.1111/csp2.340.

Mueller, G.M., Cunha, K.M., May, T.W., Allen, J.L., Westrip, J.R.S., Canteiro, C., Costa-Rezende, D.H., Drechsler-Santos, E.R., Vasco-Palacios, A.M., Ainsworth, A.M., Alves-Silva, G., Bungartz, F., Chandler, A., Gonçalves, S.C., Krisai-Greilhuber, I., Iršėnaitė, R., Jordal, J.B., Kosmann, T., Lendemer, J., McMullin, R.T., Mešić, A., Motato-Vásquez, V., Ohmura, Y., Næsborg, R.R., Perini, C., Saar, I., Simijaca, D., Yahr, R., Dahlberg, A., 2022. What do the first 597 global fungal red list assessments tell us about the threat status of fungi? Diversity 14, 736. https://doi.org/10.3390/d14090736.

Muff, S., Nilsen, E.B., O'Hara, R.B., Nater, C.R., 2022. Rewriting results sections in the language of evidence. Trends Ecol. Evol. 37, 203–210. https://doi.org/10.1016/j.tree.2021.10.009.

R Core Team, 2024. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Sánchez-Fernández, D., Abellán, P., Aragón, P., Varela, S., Cabeza, M., 2018. Matches and mismatches between conservation investments and biodiversity values in the European Union. Conserv. Biol. 32, 109–115. https://doi.org/10.1111/cobi.12977.

Santangeli, A., Sutherland, W.J., 2017. The financial return from measuring impact. Conserv. Lett. 10, 354–360. https://doi.org/10.1111/conl.12284.

Santangeli, A., Haukka, A., Morris, W., Arkkila, S., Delhey, K., Kempenaers, B., Valcu, M., Dale, J., Lehikoinen, A., Mammola, S., 2023. What drives our aesthetic attraction to birds? npj biodivers 2, 1–7. https://doi.org/10.1038/s44185-023-00026-2.

Schielzeth, H., 2010. Simple means to improve the interpretability of regression coefficients. Methods in Ecology and Evolution 1, 103–113. https://doi.org/10.1111/j.2041-210X.2010.00012.x.

Schuetz, J.G., Johnston, A., 2019. Characterizing the cultural niches of North American birds. PNAS 116, 10868–10873. https://doi.org/10.1073/pnas.1820670116.

Silva, A.F. da, Malhado, A.C.M., Correia, R.A., Ladle, R.J., Vital, M.V.C., Mott, T., 2020. Taxonomic bias in amphibian research: are researchers responding to conservation need? J. Nat. Conserv. 56, 125829. https://doi.org/10.1016/j.jnc.2020.125829.

Sitas, N., Baillie, J.E.M., Isaac, N.J.B., 2009. What are we saving? Developing a standardized approach for conservation action. Anim. Conserv. 12, 231–237. https://doi.org/10.1111/j.1469-1795.2009.00244.x.

Stokes, D.L., 2007. Things we like: human preferences among similar organisms and implications for conservation. Hum. Ecol. 35, 361–369. https://doi.org/10.1007/s10745-006-9056-7.

Sutherland, W.J., Pullin, A.S., Dolman, P.M., Knight, T.M., 2004. The need for evidence-based conservation. Trends Ecol. Evol. 19, 305–308. https://doi.org/10.1016/j.tree.2004.03.018.

Tam, J., Lagisz, M., Cornwell, W., Nakagawa, S., 2022. Quantifying research interests in 7,521 mammalian species with h-index: a case study. GigaScience 11, giac074. https://doi.org/10.1093/gigascience/giac074.

Troudet, J., Grandcolas, P., Blin, A., Vignes-Lebbe, R., Legendre, F., 2017. Taxonomic bias in biodiversity data and societal preferences. Sci. Rep. 7, 9132. https://doi.org/10.1038/s41598-017-09084-6.

Wasserstein, R.L., Schirm, A.L., Lazar, N.A., 2019. Moving to a World Beyond "$p < 0.05$." Am. Stat. 73, 1–19. doi:https://doi.org/10.1080/00031305.2019.1583913.

Wickham, H., 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York.

Wilson, J.R., Procheş, Ş., Braschler, B., Dixon, E.S., Richardson, D.M., 2007. The (bio) diversity of science reflects the interests of society. Front. Ecol. Environ. 5, 409–414. https://doi.org/10.1890/060077.1.

Zuur, A.F., Ieno, E.N., 2016. A protocol for conducting and presenting results of regression-type analyses. Methods Ecol. Evol. 7, 636–645. https://doi.org/10.1111/2041-210X.12577.

Zuur, A.F., Ieno, E.N., Elphick, C.S., 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1, 3–14. https://doi.org/10.1111/j.2041-210X.2009.00001.x.