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ORIGINAL ARTICLE

# Are globally threatened, endemic landbirds studied in Brazil? Implications for conservation

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**Abstract**
Globally, about 1500 bird species are considered threatened and the overall conservation status of most species continues to deteriorate. In addition, many endemic birds that inhabit rapidly changing environments also require urgent conservation efforts. Understanding the problems faced by these species, guiding effective conservation actions, and optimizing the use of limited resource are therefore a priority. Effective conservation strategies need to be based on scientific knowledge, so systematically assessing scientific production can help identify species whose conservation may be compromised by limited knowledge. Here, we assess endemic, globally threatened landbirds in Brazil that we identified using the "Country Profiles" of the BirdLife International's database. Scientific production, in the form of published documents, was identified using the SCOPUS bibliometric database between 1870 and 2020. We identified a total of 90 Brazilian endemic landbird species categorized by the International Union for Conservation of Nature as threatened. Scientific production was strongly skewed, with 10 species associated with almost half (46.2%) of all published documents, and 16 species not yet associated with any published document in the database. The number of documents increased significantly from 2005. Keyword analysis indicates that published studies cover a wide range of topics, although there is a lack of information to support conservation decision-making. We conclude that more research on endemic, globally threatened landbirds in Brazil is urgently required. Lack of knowledge of these species is likely to compromise the development of effective conservation actions and we recommend greater investment in targeted research on these species.

**Keywords** Brazilian ornithology · Brazilian scientific production · Research gaps · Research trends · Scientometrics

## Introduction

Birds are one of the best-known vertebrate classes (Lewinsohn and Prado 2002) and are therefore an excellent means through which to "take the pulse" of the planet (BirdLife International 2020). For example, information on the abundance and distribution of bird species has been instrumental in setting conservation priorities (Guisan et al. 2013; Baker et al. 2019). Endemic (geographically localized) birds are particularly important indicators since they have higher extinction rates compared to non-endemic species and are frequently restricted to environments that are undergoing rapid transformations due to human actions (Ribon et al. 2003). These characteristics make them particularly important species for establishing key conservation actions (Burlakova et al. 2011) and defining priority areas for protection (Loyola et al. 2007).

About 1500 bird species worldwide are threatened with extinction (IUCN 2019) and over the years the situation of most species has become increasingly critical (Marini and Garcia 2005; Butchart et al. 2010). The development of effective conservation strategies for these species depends, to a certain extent, on the availability and quality of scientific knowledge (Scott and Csuti 1997; Cook et al. 2009; Doi and Takahara 2016). Such information can be used to

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increase understanding of the complex problems faced by these species, to guide effective actions, and to prioritize limited resources to support sites, species, and management actions (McCarthy et al. 2012). Despite the clear importance of scientific information, many bird species, especially those with small populations, are still poorly known (Marini and Garcia 2005; Chartier 2009; Xiao et al. 2016; Hasui et al. 2018; Develey 2021). It has been estimated that as much as 77% of the data sources used for conservation management are "anecdotal" and only 2% are based on verifiable scientific evidence (Sutherland et al. 2004).

In this context, it is clearly useful to understand the "landscape" of ornithological research, distinguishing which species are well studied from those that are poorly known and which may be more vulnerable due to the difficulties of identifying and implementing effective conservation actions. Specifically, we need to quantify the temporal, spatial, and thematic distribution of scientific knowledge about the threatened and geographically localized bird species (Bautista and Pantoja 2000). In this way, it will be possible to better guide future studies and to increase our understanding of trends and gaps in knowledge production (Nabout et al. 2012; Borges et al. 2015).

The quantitative study of scientific knowledge is termed "scientometrics" (Spinak 1996), and its tools and methods are well suited to study trends in publications about threatened and endemic bird species (Moreno-Opo and Margalida 2014; Yarwood et al. 2014). Such information can potentially be used to support a wide range of conservation, management, and policy actions, and to identify gaps and biases (Mckenzie and Robertson 2015). The objective of this work was to analyze scientific production on endemic, globally threatened landbird species in Brazil, evaluating the quantity and quality of published knowledge in the context of supporting conservation interventions and management.

## Methods

Endemic, globally threatened Brazilian landbirds were selected using the "Country Profile" of BirdLife's data zone (BirdLife International 2020). Published documents (including inventories) relating to these species for the years 1870 and 2020 were then collected in the SCOPUS database using the following search terms: (i) the scientific name of the species (including synonyms), and (ii) the common name in English (available on the Avibase platform, https://avibase.bsc-eoc.org/avibase.jsp). Retrieved documents were downloaded in BibTeX format containing the following information: (i) authors; (ii) document title; (iii) year; (iv) journal title; (v) source and document type (e.g., papers, notes, reviews, letters, erratum, book chapter); (vi) affiliations; (vii) publisher; (viii) abstract; (ix) index keywords.

Publications were collated and analyzed in Microsoft Excel® and R software (R Core Team 2020) using Bibliometrix package (Aria and Cuccurullo 2017). This package allowed quantification of the number of publications related to each species, the number of papers published per year, and the frequency of each keyword used in papers. The total number of papers published each year was analyzed by a linear regression, using the year as an explanatory variable, to identify the possible pattern of total paper increase through time. To place the growth patterns of published documents in a more general context, we calculated the average percentage increase in the number of documents in relation to the results of a search on SCOPUS for [Birds OR Bird OR Aves], including results from all countries, hence giving a relative number of papers. In order to identify possible patterns of keywords usage through time, we also summarized the total keyword frequency per year and used these results to perform a principal component analysis (PCA) using vegan package (Oksanen et al. 2013). Since there is no standard for keywords usage between different authors and journals, we manually checked all of them and replaced each keyword with a broader term (e.g., replacing species names with the corresponding Order – Suppl. Material S1). In addition to the keywords, we analyzed titles and abstracts to identify publications with topics related to broad areas of conservation science, such as ecology, reproduction, population, distribution, protected areas, and environmental education, among others (Suppl. Material S2).

## Results

Brazil has 90 endemic, globally threatened landbird species (Suppl. Material S2). As a result of searching the SCOPUS database, we identified 289 published documents until 2020. However, some approached more than one species. Therefore, for some analyses, the repeated publications were adjusted and 253 published documents were considered (236 papers, eight notes, four reviews, two letters, two errata, and one book chapter).

We observed high levels of taxonomic bias. Our results show that 10 species account for 46.2% of all research: the most studied species were *Guaruba guarouba* (24 published documents), *Crax blumenbachii* (22 published documents), and *Anodorhynchus leari* (18 published documents). However, 16 species were not associated with any published documents indexed in the database (Suppl. material S2), including *Columbina cyanopis*, which is classified as "Critically Endangered," and other species, such as *Amazona diadema*, *Formicivora erythronotos*, *Rhopornis ardesiacus*, *Automolus lammi*, *Cranioleuca muelleri*, *Iodopleura pipra*, and *Phylloscartes beckeri*, that are classified as "Endangered." Among the species without

published studies are also those considered "Vulnerable": *Rhegmatorhina gymnops*, *Celeus tinnunculus*, *Hemitriccus mirandae*, *Myrmotherula minor*, *Myrmotherula urosticta*, *Neopelma aurifrons*, *Pionus reichenowi*, *Tangara fastuosa*, and *Touit surdus*.

Scientific production remained low between 1870 and 1990 (Fig. 1a): only one or two published articles in 10 years within this period (an average of 0.09 published documents). However, there was a statistically significant increase from 1990 to 2020 ($R^2 = 0.77$; $P < 0.001$), with an average of 1.98 published documents each year during this period (Fig. 1b). Finally, when we analyzed the relative number of publications (i.e., the number of papers found with our search terms comparing with the total output of bird research) with a linear regression, we still find a statistically significant increase in the same period, with an average increase of 0.41 published documents per year (relative to every 10,000 documents on birds), although the relationship is weaker ($R^2 = 0.45$; $P < 0.001$) (Fig. 1c).

A total of 663 keywords were extracted from the articles and were replaced by 1184 standardized terms (Table 1). Some items were very general and indicate more specific search patterns such as conservation ($n = 74$), species characteristics ($n = 67$), ecology ($n = 47$), genetic ($n = 45$), taxonomy ($n = 41$), and health ($n = 40$).

The principal component analysis using the standardized keywords frequency explained 74.7% of data variation within the first two principal components. Since many keywords have a small contribution to the ordination, we chose to display only the words with loadings that summed more than 0.75 in the first two components (Fig. 2).

Analysis of titles and abstracts of all 289 publications revealed that 94.8% of the indexed studies addressed at least one theme applied or directly applicable to conservation to 74 species (Suppl. Material S2). Most of the species in the study occur in the Atlantic and Amazon Forests (Table 2). The taxonomic orders most representatives among the species studied were Passeriformes ($n = 55$), and Psittaciformes ($n = 15$) (Table 3).

**Table 1** Main researched areas investigated worldwide (number of published documents = 253) with SCOPUS indexed publications between 1870 and 2020, on endemic, threatened Brazilian landbird species

| Terms | Frequency |
|---|---|
| Local | 251 |
| Passeriformes | 119 |
| Psittaciformes | 117 |
| Group | 91 |
| Conservation | 75 |
| Species characteristics | 70 |
| Method | 58 |
| Ecology | 48 |
| Genetic | 47 |
| Taxonomy | 42 |
| Health | 42 |
| Galliformes | 29 |
| Piciformes | 21 |
| Population | 22 |
| Threat | 22 |
| Distribution | 18 |
| Biogeography | 17 |
| Evolution | 17 |
| Parasite | 17 |
| Biota | 15 |
| Inventory | 14 |
| Apodiformes | 7 |
| Accipitriformes | 6 |
| Gruiformes | 5 |
| Falconiformes | 3 |
| Author | 2 |
| Charadriiformes | 2 |
| Strigiformes | 2 |
| People | 2 |
| Abiotic factors | 1 |
| Columbiformes | 1 |
| Pelecaniformes | 1 |

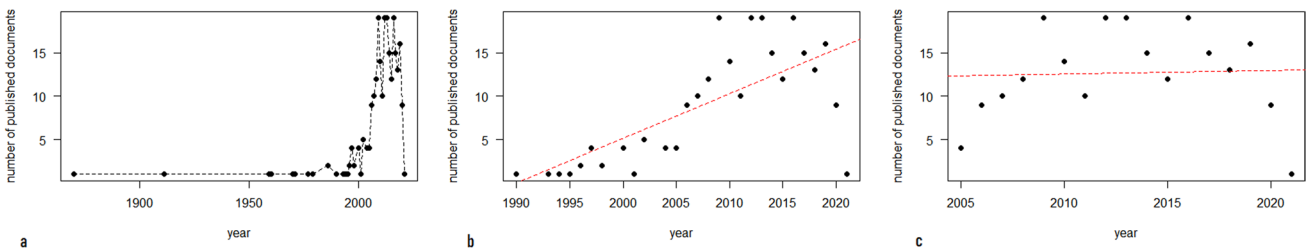


**Fig. 1** **a** Total number of published documents ($n = 253$) about endemic, globally threatened Brazilian landbirds indexed in SCOPUS between 1870 and 2020; **b** linear regression of the number of publications in response of years from 1990 to 2020; **c** linear regression of the relative number of publications in response to years from 1990 to 2020

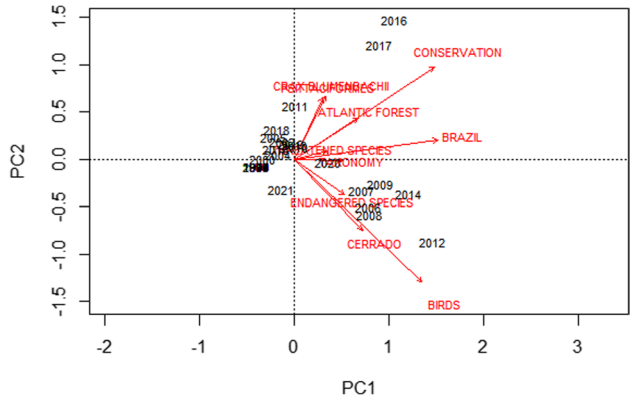


**Fig. 2** Ordination of keywords used per year on the analyzed papers performed by a PCA (number of published documents = 253) with SCOPUS indexed between 1870 and 2020, on endemic and threatened Brazilian landbird species. The first and second axes explain 57.0 and 17.7% of the data variation, totaling 74.7%

**Table 2** Number of publications indexed in SCOPUS between 1870 and 2020 and endemic and threatened Brazilian landbird species by biomes

| Biome | Species | Number of studies |
|---|---|---|
| Atlantic Forest | 59 | 134 |
| Amazon Forest | 20 | 80 |
| Cerrado | 14 | 56 |
| Caatinga | 12 | 47 |
| Campos Sulinos | 2 | 6 |
| Pantanal | 2 | 2 |

**Table 3** Number of publications indexed in SCOPUS between 1870 and 2020 and endemic and threatened Brazilian landbird species by taxonomic order

| Order | Species | Number of studies |
|---|---|---|
| Passeriformes | 55 | 118 |
| Psittaciformes | 15 | 92 |
| Galliformes | 5 | 38 |
| Piciformes | 5 | 19 |
| Apodiformes | 3 | 3 |
| Acciptriformes | 2 | 13 |
| Gruiformes | 2 | 2 |
| Columbiformes | 1 | 0 |
| Galbuliformes | 1 | 2 |
| Strigiformes | 1 | 2 |

## Discussion

Our scientometric analysis identified key research trends, as well as some significant gaps in research on endemic, threatened Brazilian landbird species. Our results show a trend of increasing research production over the years as has been reported in similar studies centered on diverse knowledge areas (King 2004; Carneiro et al. 2008; Nabout et al. 2012). However, it is important to note that despite this increasing trend (especially since 2005), the number of studies on endemic, threatened Brazilian landbird species is still low. Similar patterns have been shown across other threatened birds (Ducatez and Lefebvre 2014; Buechley et al. 2019). In the current study, most species (approximately 90%) have less than six published documents, despite the species' ecological and cultural importance (Bracken and Low 2012). In addition, although most indexed works address important specific issues for the conservation, the fact that most of these endemic and threatened species are occasionally recorded in studies, bringing only this isolated information, is not enough for the planning of their conservation. Most of them have their populations reduced and are dependent on specific environments, making it a priority to produce strong knowledge about their population dynamics, genetic variability, evolutionary patterns, reproductive characteristics, biotic interactions, and abiotic tolerances (Hortal et al. 2015) to define actions efficient to the conservation of these species, improving their status and decreasing risk of extinction (Plaza and Lambertucci 2020; Buxton et al. 2021).

Keywords help search engines identify the topics that papers cover and have been widely utilized to reveal the basic elements covered in the research (Su and Lee 2010). Moreover, these terms should broadly reflect the content of the main study. It is noteworthy that we only analyzed works published and indexed in the SCOPUS database, and we know that unpublished information is also used as input in local conservation strategies. However, the lack of knowledge published about this important group of birds, verified in our analysis, is likely to compromise the development and application of efficient conservation actions at a global level, especially in access by conservation practitioners (Pullin and Knight 2001, 2003). For example, published studies detailing nest building or feeding behavior in one location would be important for the design of artificial nests and feeders in another; two efficient and low-cost interventions for species conservation in multiple locations.

The low levels of knowledge production about endemic, threatened species may be related to the inherent difficulty of finding rare species with small populations or the difficulty of access to their areas of occurrence (Kunin and

Shmida 1997; Novotný and Basset 2000; Caro and Sherman 2011). Moreover, even if a rare species can be found and studied, the difficulties of generating sufficient data to publish the results of the study in a peer-reviewed journal may preclude researchers from focusing on such species (Caro 2007). Consequently, bird research is often focused on the largest, most visible, and/or "charismatic" species in the regions where most researchers live and where there is more funding available (Martín-López et al. 2011; Griffiths and Santos 2012). Such cultural impacts on research effort lead to taxonomic bias, even when species have an important role in the maintenance of ecosystem functions and contribute to the maintenance of the entire ecosystem diversity (Doi and Takahara 2016).

Although there has been substantial research over the last few decades on how to conserve specific species or communities at ecosystem and global scales (Primack 1993), only a few bird species are actually well studied, such as *G. guarouba*, *C. blumenbachii*, *Amazona pretrei*, and *A. leari*. These species are notable for being traded in Brazil and internationally (Costa et al. 2018), and are frequently the focus of conservation projects (Marini and Garcia 2005; Hammer and Watson 2012; Bernardo and Locke 2014). We also found that 60 species had less than five published documents and 16 species were not associated with any published documents indexed in the database, among them *C. cyanopis*, recently rediscovered and with extremely small populations.

Globally, most ornithological literature at the beginning of the twentieth century dealt with breeding biology, population dynamics, biological conservation, and wildlife management (Bautista and Pantoja 2000). However, in Brazil, our data indicates that recent studies cover a wide range of topics, with a significant proportion focused on the conservation of Passeriformes and Psittaciformes from the Atlantic Forest. There were few studies that focused on ecological and life history traits, essential information to assess the vulnerability of species to extinction threats (Jennings et al. 1998; Ferguson and Lariviere 2002). Such a lack of basic ecological information further limits evidence-based assessment of management options in conservation efforts (Cisneros-Mata et al. 1995). Such feedback between evidence and actions maintains a vicious cycle which hinders the effective protection of species, decreases the value of conservation research, and potentially diverts scientific efforts and funds to other areas (Doi and Takahara 2016). As with other disciplines, economics and the availability of research funds are important for increasing the scientific production in conservation/ecological fields (Doi and Takahara 2016). In this context, the financial crisis in Brazil has been severely affecting the support for science in general (Barbuy 2018), and the conservation of biodiversity in particular.

It should be noted that we are relying on published and indexed works in the SCOPUS database only. However, there may be publications indexed in other databases or even without being indexed. In addition, there are recently elevated species for the species category that may have their number of articles underestimated, but with important information about them in articles where they appear as subspecies.

Our database indicates that the Atlantic and Amazon Forests are the biomes where most studies took place. This might be related to the fact that the Atlantic Forest is a biodiversity hotspot (Myers et al. 2000) and the Amazon a biome of world interest, and, therefore, priority areas for conservation research. The fact that the southeastern and southern regions concentrate a large number of bird researchers, banders, and research institutions (Alves et al. 2008) may also be influencing the major number of studies in the Atlantic Forest, especially in the south and southeast regions. In the Amazon, traditional research institutions such as the Instituto Nacional de Pesquisas da Amazônia (INPA) and the Museu Paraense Emílio Goeldi (MPEG), in partnership with universities in the southeast, expanded their studies in the region, mainly concerned with the potential impacts due to strong degradation that the biome has been suffering from agricultural expansion.

Furthermore, since field studies are always costly in time and resources, they will always be in limited supply (Doi and Takahara 2016; Santos 2018; Escobar 2019). On the other hand, the importance of long-term studies is recognized as fundamental for conservation planning (Miranda et al. 2020). It is known that environmental variables influence how species differ, and depend on the time scale over which they are evaluated (Willis and Whittaker 2002). In addition, temporal datasets have the potential to identify and quantify trends in ecological processes, which are difficult to detect in short-term studies (Callahan 1984; Haase et al. 2018). It is therefore necessary to increase investment in long-term research and priority themes, thereby maximizing research effort on endemic, globally threatened species.

In conclusion, we show an increasing trend of research on endemic, threatened landbird species in Brazil, though the volume of studies is still low and they are clearly not a research priority, even among conservation scientists. Only ten species account for almost half of all published research and we clearly still lack information on basic biology and ecology for many species in this group. Studies in our database covered a wide range of topics, but many lack pertinent information to support decision-making on management and conservation. The lack of knowledge about this group compromises the effective conservation of these species and it should be a policy priority to increase research effort of national researchers.

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**Author contribution** K.J.S.B.C. and M.A.E. conceived the idea, designed the collected data, and analyzed the data; L.M.S.O and M.V.C.V analyzed the data; all the authors authored or reviewed drafts of the paper and approved the final draft.

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## Declarations

**Conflict of interest** The authors declare no competing interests.

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