Article

200 Years of Caprimulgid Records in Southern Brazil: A Comparison between the Literature and Citizen Science Data

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Simple Summary: Citizen science contributes to our scientific knowledge when non−researcher citizens collect information, usually, under the supervision of academics. It has revolutionized how traditional science is developed since it accumulates a great quantity of data over larger areas and within shorter periods of time than single researchers would be able to achieve. Both traditional and citizen science data were used to compare how caprimulgid species have been recorded in southern Brazil. Researchers mentioned 13 species from 1820–2020, and citizen scientists (from 1989–2022) detected one more species never mentioned in the literature. There have been no dialogues between traditional and citizen scientists to come together and develop an integrated approach to investigate common hypotheses. It remains unclear whether traditional and citizen scientists will realize that communicating about mutual interests can help organize and solve questions based on empirical observations. This type of joint effort could improve knowledge of caprimulgids in Paraná and other Brazilian regions.

Abstract: Although the ornithological history of southern Brazil has been amassed over the last 200 years, few attempts have been made to describe how species have accumulated. Furthermore, the collaboration of citizen scientists has considerably changed the way researchers analyze empirical data. Caprimulgidae (Nightjars and Nighthawks) species were used to illustrate how species have been recorded since the 1800s in Paraná State by comparing traditional and citizen science data. In addition, reports from both researchers and citizen scientists on the breeding biology of these caprimulgids have been verified. A literature review was conducted searching for the Caprimulgid species within the territory of Paraná. Regarding citizen science, records were obtained from four ornithological platforms. Overall, 14 species were detected within the state, 13 of which have been described in the literature, including 1 endemic to the Atlantic Forest and 3 threatened species. Citizen scientists detected all 13 taxa, in addition to one undocumented species that has never been recorded by researchers. There were 12 times more records on ornithological platforms in half of the sampling effort accumulated in studies, but most of them date from the last five years. Citizen scientists also visited 4.5 times more locations than researchers. Citizen scientists accumulated more records around September and November, and most (59%) records were from 2020–2022. Researchers mentioned species as early as 1820, while continuous studies only began during the 1980s; they concentrated their fieldwork mostly in September. Only one (2%) study sought to describe the breeding biology of a caprimulgid species, but there were 84 observations on ornithological platforms between 2004–2022 on their reproduction. Because of the evident mismatch between traditional and citizen science data due to a lack of congruence between their actions, it is suggested that ornithology in Paraná, as well as other Brazilian regions, would benefit the most if traditional and citizen scientists improved their networking communication to focus on common purposes instead of acting independently.

Keywords: Caprimulgidae; literature review; observer behavior; ornithological platforms; Paraná State

1. Introduction

Brazil has a relatively recent ornithological history which was initiated during its colonization in the 1500s, but the increase in available information began after the 19th century, when European naturalists visited the country [1,2]. By comparing bird records documented during the 1800s, researchers who recently characterized the avifaunas in areas where naturalists previously visited were able to strongly suggest species extinctions, due to habitat modifications, or the absence of extinctions when an area remained well−preserved [3–5]. In the state of Paraná, in southern Brazil, earlier naturalists like Johann Natterer and Tadeusz Chrostowski collected specimens for museums at irregularly spaced intervals, while other contributors amassed more information later on, until the 1930s [6–12]. It was only during the second half of the 20th century that Paraná birds were once again the objective of scientific collections [13], while during the 1980s, field and ecological data began to be obtained on a more regular basis [14,15].

Recently, academics have started applying citizen science to address empirical and theoretical research in the natural sciences, generating knowledge while producing an important social outcome, i.e., engagement in scientific disciplines like zoology [16,17]. The list of birds from Paraná, for example, represents a successful combination of hundreds of years of field efforts and the help from non−biologists to generate a complete set of species [18]. Because citizen science has the potential to amass a significant amount of information, it is especially important to organize all that has been accumulated over the years so that this new information can be used to update and compare previous data.

In Brazil, some researchers have initiated these approaches using distinct platforms or citizen science projects aligned with particular objectives. They found that urbanization results in alterations to bird community compositions [19]. They also commented on challenges in engaging birdwatchers in bird monitoring programs [20] and on how the particularities of observers or inclement weather strongly influence the number of records per location [21]. With the aid of citizen science, previously unknown breeding and migration patterns have been discovered [22–24]. Traditional and citizen scientists have been compared according to their objectives and behaviors, and recommendations on how to best integrate them have been given [25]. Furthermore, analyses of Atlantic Forest endemic species and threatened species have also been addressed [26,27].

Caprimulgids, of order Caprimulgiformes, represent a worldwide diversified family of some 90 species of nocturnal birds that occupy several environments and habitat types [28,29]. Their greatest diversity is found in South America, with 34 species [30], 27 of which are known to occur in Brazil [31]. Due to their enigmatic plumage and shy nocturnal behavior [28], most species are seldom recorded during censuses or inventories [32], and even fewer investigators have dedicated their time to comprehending caprimulgid biology [33–35]. Therefore, the group constitutes an excellent case study for comparing and analyzing data obtained from traditional and citizen scientists.

Because it is recommended that citizen science data be integrated with bibliographical searches [23], I aimed to investigate how many published studies accounted for caprimulgid records in Paraná State since the 1800s and how this information was provided by citizen scientists in a more recent scenario. I compared traditional and citizen science data and determined the number of caprimulgid species recorded, the total effort hours employed in censuses or inventorying, the number of localities visited, and how species were detected over the years. Additionally, I sought to verify what scientists and citizen scientists produced concerning the breeding biology of the caprimulgid species. I predicted that species records by naturalists and researchers would have taken longer to accumulate, but that most records from citizen scientists date back to earlier decades. Species richness is likely quite similar for both traditional and citizen scientists, but I suspect total effort hours may be higher over the course of ornithological research. Citizen scientists may concentrate their observations while on vacation, which in Brazil takes place in July and January, and breeding biology data may be almost exclusively recorded by researchers.

2. Materials and Methods

2.1. Study Area

Paraná State is between 22°30′58′′ S, 52°06′47′′ W and 26°43′00′′ S, 51°24′35′′ W in southern Brazil. It is characterized by a humid subtropical climate, without dry seasons, and includes two climates according to Koeppen's classification: hot summers with rainfall concentration (Cfa) and temperate summers (Cfb). The first predominates in the state, mainly across the northern, western, and southwestern regions [36]. Rainfall is homogeneously distributed throughout the year at the highest elevations [37] and ranges from 1134 to 2702 mm with a mean of 1696 mm [38]; the minimum and maximum temperatures are −1.3 °C and 31.1 °C [39].

Some 80% of the state is Atlantic Forest, followed by Cerrado and other vegetation types [40]. Atlantic Forest formations include eastern rainforests, mixed forests in central higher plateaus, and seasonal semideciduous forests, found in eastern and western regions, as well as in the valleys of the rivers that comprise the Paraná River basin [40,41]. The Cerrado is found to the north and northeast [40,41].

2.2. Literature Review

The searches for articles, books, and book chapters published up to 31 December 2022 were conducted in the Directory of Open Access Journals (https://doaj.org, accessed on 30 August 2023), Google Scholar (https://scholar.google.com, accessed on 30 August 2023), JSTOR (https://www.jstor.org, accessed on 30 August 2023), Scielo (https://www.scielo.br, accessed on 30 August 2023), Scopus (https://www.scopus.com, accessed on 30 August 2023), and Web of Science (https://access.clarivate.com, accessed on 30 August 2023) using Boolean operators and the following keywords: 'avian' OR 'avifauna*' OR 'bird*' OR 'ornithol*', OR 'caprimulg*' as well as their Portuguese translations 'avian*', OR 'avifauna*' OR 'ave*' OR 'ornitol*', OR 'caprimulg*', AND 'Paraná'. References were then filtered to exclude unrelated topics, those that did not provide Caprimulgidae species, or those which analyzed previously published databases. All databases were accessed on 30 August 2023. The search resulted in 262 references, of which 56 mention caprimulgid species and were published between 1820–2020 (Supplementary Materials, Section S1).

2.3. Citizen Science

All records of the Caprimulgidae species within Paraná State which were available up to 31 December 2022 were downloaded from four ornithological platforms: eBird (https://ebird.org/, accessed on 30 August 2023), iNaturalist (https://www.inaturalist.org/, accessed on 30 August 2023), Wikiaves (https://www.wikiaves.com.br/, accessed on 30 August 2023), and Xeno−canto (https://xeno-canto.org/, accessed on 30 August 2023). All ornithological platforms were accessed on 30 August 2023. From eBird, the raw data were downloaded by filtering by locality (Paraná State). These results were then filtered to exclude any other taxa. Four records of "Caprimulgidae sp." were discarded, for a total of 2727 records. The iNaturalist and Wikiaves platforms allowed filtering simultaneously by family and state. The first resulted in 56 records, of which 29 met the search criteria, while the latter included 1332 photographs and 260 recordings. The Xeno−canto platform required the species to be searched individually, filtering by locality (Paraná State). This search resulted in 34 sound records. Citizen scientists obtained records of the caprimulgid species from 1989–2022.

2.4. Data

Differences in the nomenclature adopted by each ornithological platform were standardized according to the suggestions of the Brazilian Ornithological Records Committee [31]. Endemic species were assigned to the Atlantic Forest [42], and threatened species were assigned according to the State Red List [43]. The total field effort was calculated in hours (when this information was available in the literature) or directly obtained from eBird (the other platforms do not provide sampling efforts). Evidence of breeding activities

was classified into two categories: nests with eggs (NE) and nests with young (NY). The latter was further subdivided into having downy−feathered young or young with more developed plumage. Because I wished to quantitatively compare the number of records obtained from traditional and citizen science data, all records of any given species were computed. This means that series of records from the same individual (i.e., duplicates from identical dates and localities) were deliberately included.

2.5. Analyses

A Jaccard Similarity Index was used to measure the similarity between the Caprimulgidae species' composition according to traditional or citizen science data. Monthly counts were obtained by summing all individuals of all species reported on a given month over the years until 31 December 2022. Analyses were developed within the R 4.1.3 environment [44].

3. Results

3.1. Number of Species and Records

The 56 published references (Supplementary Materials, Section S1) accounted for 13 species (median 4.0 ± 2.2 SD species per study) in 372 records (5.5 median $\pm$ 7.2) obtained between 1820 and 2020 (Figure 1). One species is endemic to the Atlantic Forest, while three are threatened (one vulnerable and two endangered) at the state level (Table 1). Citizen scientists detected 14 species in 4402 individual records between 1989–2022 (Figure 1).
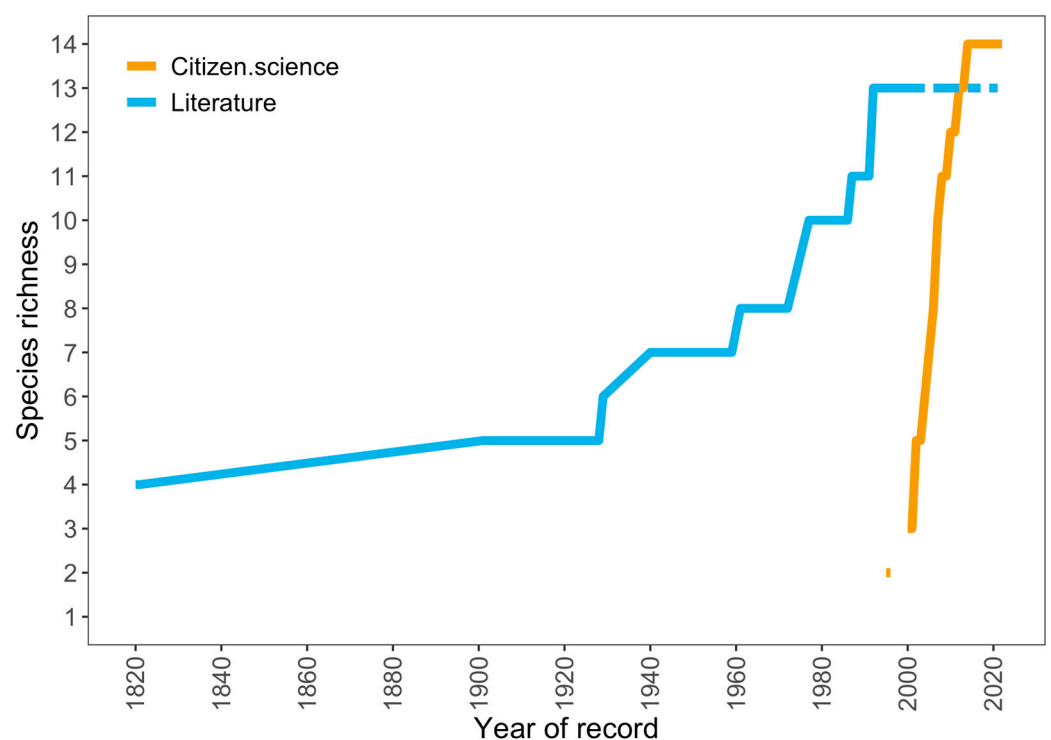

Figure 1. Collector curves of the Caprimulgidae species based on the literature and citizen science data in Paraná State, southern Brazil.

Table 1. Caprimulgidae species records according to source and the span of years in which they were detected by traditional and citizen scientists in Paraná State, southern Brazil. Longer (>25 years) time intervals are separated by semicolons. VU = vulnerable; EN = endangered. AF = Atlantic Forest endemic species. The sequence of species follows that of CBRO [31].

Species	Literature	eBird	iNaturalist	Wikiaves	Xeno−Canto
Nyctiphrynus ocellatus[EN]	1961; 2011	2005–2022	–	2005–2022	2008–2015
Antrostomus rufus	1992–2015	2014–2022	–	2014–2022	2021
Antrostomus sericocaudatus[VU]	1940; 2004	2006–2022	2020–2021	2006–2022	2007–2013
Lurocalis semitorquatus	1820; 1982–2019	1995–2022	2015–2021	2009–2022	1995–2021
Nyctidromus albicollis	1901; 1982–2020	2000–2022	2018–2021	2006–2022	2015–2020
Hydropsalis parvula	1820; 1983–2017	2010–2022	2021	2010–2022	2012–2013
Hydropsalis anomala[EN]	1820; 1959; 1986–2012	2002–2022	–	2012–2022	2002–2019
Hydropsalis longirostris	1987–2012	2002–2022	2012	2004–2022	2002
Hydropsalis maculicaudus	–	2004	–	–	–
Hydropsalis torquata	1977–2015	2007–2022	2021	2008–2022	–
Hydropsalis forcipata[AF]	1929–2012	2008–2022	2011–2021	2008–2022	2012–2020
Podager nacunda	1820–1821; 1929; 1959; 1984–2017	1989–2022	2018	2010–2022	–
Chordeiles minor	1992–2003	2007–2022	2021	2009–2022	–
Chordeiles acutipennis	1977–1997	2012–2021	–	2012–2017	2016–2017

The Jaccard similarity index between the records from the literature and the citizen scientists' records indicated J = 0.93, in which case one species was exclusively recorded by the former and 13 species were common to both (Table 1).

3.2. Spatio−Temporal Records and Field Efforts

The temporal records of each species ranged from the beginning of the last two centuries until the 2000s and 2010s, but eBird and Wikiaves consistently had records from the 2000s until 2022. The ornithological platforms used the least by Brazilians (iNaturalist and Xeno−canto) had fewer species, and their records spanned for shorter periods of time (Table 1). Traditional researchers obtained records as early as 1820 from 195 locations throughout the state (Figure 2a) over a span of 2633 h. Some 75 locations were visited at least once until the 1970s but never visited again (Figure 2a). Citizen scientists visited 876 localities (Figure 2b, Supplementary Materials, Section S2) in 1175 h, but their first record was made in 1989. In the published literature, the number of species was somewhat low, with a maximum of four species recorded by year and with several gaps of information across the years. Later, publications were more constant and reported more species per year between 1980–2020. The initial number of observed species by citizen scientists was low (*n* = 6) in the late 1980s but was higher in the early 2000s than in other periods, with it remaining homogeneous at 12 species detected per year (Figure 3a). Regarding the number of species records, citizen science data amassed a greater quantity of observations, peaking in 2019 onwards, with most (59%) records from 2020–2022 (Figure 3b) when the coronavirus pandemic hit worldwide. Both sources of information obtained records across the years, but citizen scientists tended to accumulate more records around September–November, with a peak in October (Figure 4). Researchers, on the other hand, obtained more records in March, April, October, and especially in September (Figure 4).
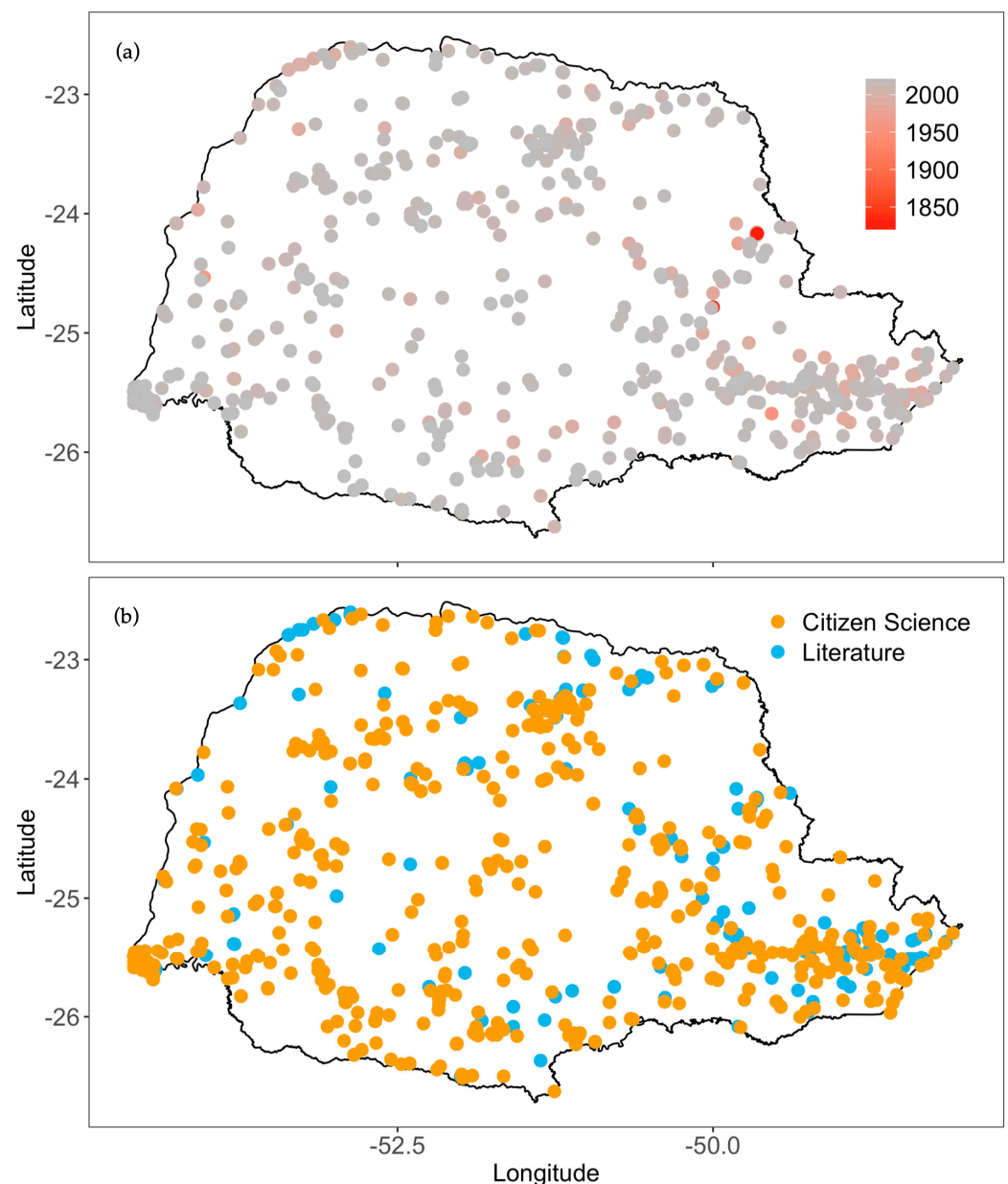
Figure 2. Spatio−temporal distribution of records of the Caprimulgidae species accumulated by traditional and citizen scientists over 200 years in Paraná State, southern Brazil. (**a**) Temporal variation of records and (**b**) spatial distribution of records.

3.3. Breeding Activity Records

One study (2%) was specifically designed to investigate the breeding biology of one Atlantic Forest endemic caprimulgid species [33]. Another study verified the molecular identification of blood meals in mosquitos, but the remainder mostly encompassed either censuses, inventories, or noteworthy records (96%). Contrastingly, citizen scientists obtained 84 (2%) records with evidence of breeding activities for eight species between 2004–2022. Most breeding activities refer to the Common Pauraque *Nyctidromus albicollis* (*n* = 52), followed by the Short−tailed Nighthawk *Lurocalis semitorquatus* (*n* = 12) and the Band−winged Nightjar *Hydropsalis longirostris* (*n* = 6). There were more records of nests with eggs (*n* = 36), followed by nests with developed young (*n* = 25) and nests with downy−feathered young (*n* = 21). The overall number of localities with breeding activities was 82, in most of which (*n* = 36) the reproduction of the Common Pauraque was detected (Table 2).
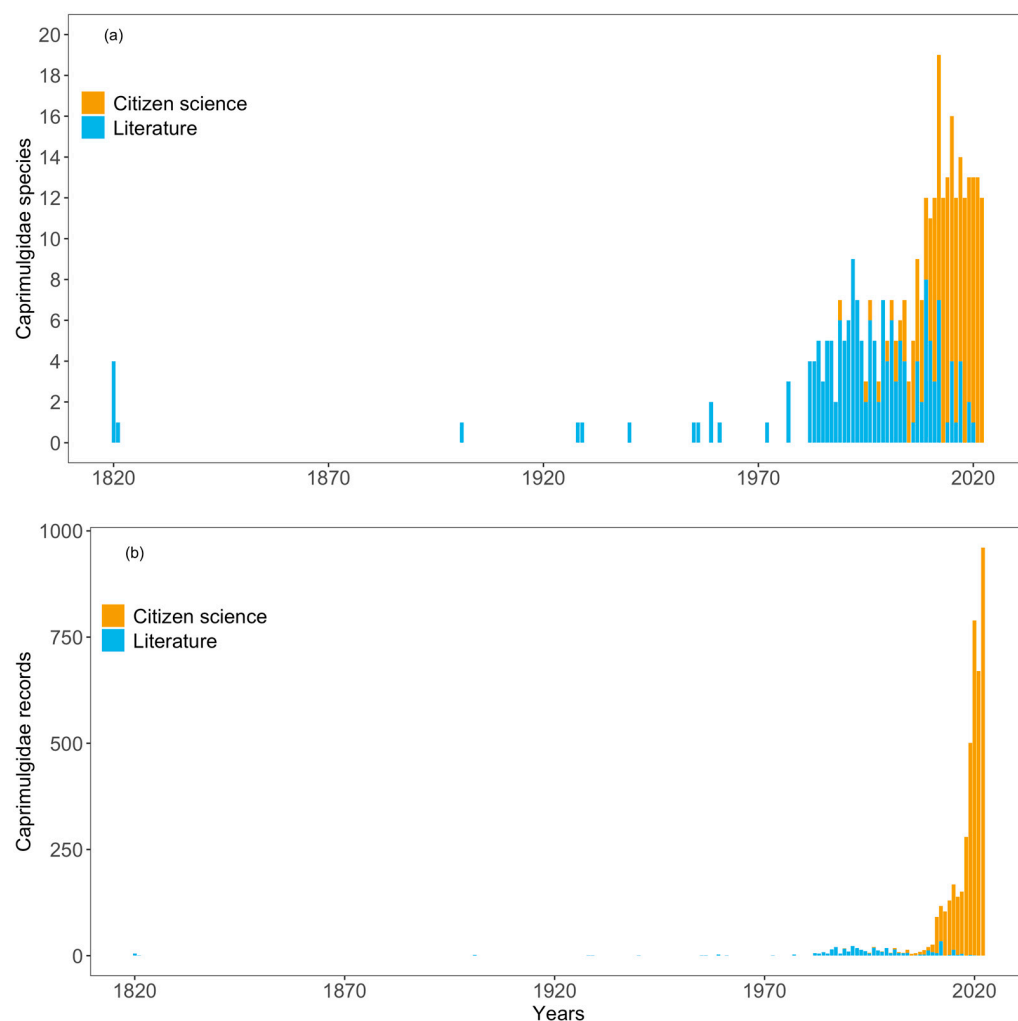
Figure 3. Number of Caprimulgidae (**a**) species and (**b**) records obtained over 200 years in Paraná State, southern Brazil, according to the literature and citizen science data (duplicates are present).
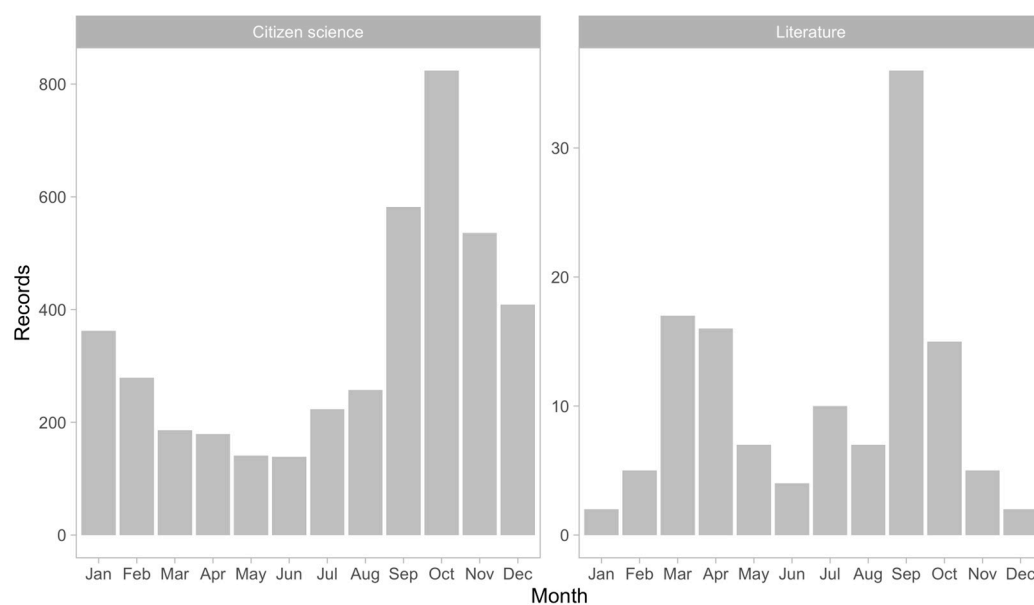

Figure 4. Number of monthly Caprimulgidae records in Paraná State, southern Brazil, according to the citizen science data (1989–2022) and the literature (1820–2020).

Table 2. Information about the breeding biology of the Caprimulgidae species obtained from the literature [33] and citizen scientists in Paraná State, southern Brazil. N refers to the number of activity codes, and localities refer to the number of localities in which breeding biology activities were documented. NE = nest with eggs; NY = nest with developed young; NYd = nest with downy−feathered young.

Source	Species	Code (N)	Localities
Citizen science	*N. ocellatus*	NE (2)	2
		NY (1)	1
	A. rufus	NE (1)	1
		NY (3)	1
	L. semitorquatus	NY (3)	2
		NYd (9)	4
	N. albicollis	NE (26)	18
		NY (15)	11
		NYd (11)	7
	H. parvula	NE (1)	1
	H. longirostris	NE (4)	3
		NY (2)	1
	H. torquata	NE (1)	1
		NYd (1)	1
	P. nacunda	NE (1)	1
		NY (1)	1
Literature	*H. forcipata*	−	1

4. Discussion

Researchers reported species more homogeneously over 200 years and, consequently, accounted for a wider span of years of records. There was an 80−year gap without any caprimulgid record until one more species was mentioned in 1900. Then, field surveys were intensified during the 1980s [45] and the accumulation of records gradually increased until 2020. From 1989 onwards, citizen scientists rapidly recorded more species, reaching the asymptote after 2004. These differences probably reflect the inherent tendencies of researchers, who search for particular species and in particular habitats, while citizen scientists apparently target species of interest or prefer to observe birds in more easily accessible locations [25]. Also, groups of observers tend to produce several records of the same targeted individual, or duplicates, a characteristic that must be taken into account if researchers are to consider species' abundances. At least two species may be rarer (less than 100 records) or habitat−specialists, in Paraná (Rufous Nightjar *A. rufus* and *Lesser Nighthawk C. acutipennis*). In addition, 75 locations have never been revisited since the 1970s, crucial information that could only be retrieved by combining bibliographic and citizen science data [23]. While citizen scientists made significant contributions by adding thousands of inventoried locations in Paraná, the communication between these sources seemed to hinder the effectiveness of their combination [46].

Interestingly, the reduced number of records in the literature did not necessarily mean a lower number of species recorded [47]. In the case of Paraná, despite the increased number of records, there was only one addition (see below) to species richness. Most of the citizen science reports were concentrated in the last five years, suggesting a strongly biased distribution. Although thousands of locations were inventoried in Paraná across 200 years, there are still large areas in the state where no information is available.

The citizen science tool in Brazil is recent, and this is evident from records dating back to 1989, with an increase in 2018. Most of the records were accumulated in 2022, just after the worldwide coronavirus pandemic. As a result, it was expected that some habitat−specialist species might go undetected, as citizen scientists focused their observations more on urban areas [48] or highly disturbed regions [49]. This led to a lower sampling effort, resulting in fewer priority species being recorded [49]. However, contrary to patterns observed in South [49] and North America [47], citizen scientists in Brazil increased their observations. This trend was also observed on another ornithological platform [21].

eBird (the only platform that provides field efforts) logged only half the effort hours in sampling compared to the literature. However, the exclusive caprimulgid that citizen scientists detected has no recent nor historical records for the state [18,32,50,51], making it a probable misidentification that merits documentation. It was sighted by a group of birdwatchers on 9 November 2004 at Vila Velha State Park, in the municipality of Ponta Grossa, approximately 100 km northwest of Curitiba, the state capital. Once again, supervision between peers could have been beneficial. Nevertheless, both traditional and citizen scientists demonstrated no extinctions of caprimulgid species according to both historical and recent records in Paraná.

Citizen scientists did not concentrate their observations during leisure time; instead, they observed more birds in October. Researchers conducted most of their field observations in March, April, and October, but especially in September, the month in which boreal migrants arrive [52] and the breeding season starts [53] in southern Brazil. Lower numbers of counts may reflect precipitation [21] which, in Paraná, is highest from March–December [36], or simply reduced birdwatching activities [21]. Thus, different from what has been shown for another ornithological platform, in which citizen scientist records proved homogeneous throughout the year [21], citizen science data on caprimulgids may not be appropriate for studying aspects of bird biology that require data−hungry observations.

This is the case for breeding biology, as information was almost exclusively recorded by one researcher. Apart from the detailed description of the breeding biology of the Long−trained Nightjar (*H. focipata*) conducted between 1996–1998 [33], the information presented by citizen scientists is reduced. Only 84 (2%) observations denoted the reproduction of eight species, given the presence of nests with eggs or nestlings. Considering the importance of breeding biology studies and the fact that this type of natural history has been neglected in the Neotropics [54], citizen science users should be oriented when detailing aspects of the breeding biology of species they may encounter. This simple procedure will enable researchers using that platform to collect accurate information, as is successfully carried out elsewhere [21].

Shortcomings are inevitable, but citizen science, similar to traditional science, must improve from previous learning. I recommend that researchers and birdwatchers engage in creating a network that promotes swift and accurate communication. This can easily be accomplished with simple messenger apps. If citizen science is to aid in scientific progress, empirical data could be made available by researchers, instructing some standardized methods to follow, locations to visit, and species to search for. Large collaborative efforts have been successfully employed worldwide, such as the Global Big Day (https://ebird.org/globalbigday; accessed on 30 August 2023), with nocturnal species [55], and in Paraná State [19,56], contributing technically to understanding bird distribution patterns while extracting the highest potential of citizen science.

5. Conclusions

Knowledge of the caprimulgid species in Paraná State began to be formalized in 1820, went through a gap of 80 years without records, and stabilized during the 1980s when standardized surveying methods were introduced in Brazil. Citizen science had its first followers in 1989, but most records date from 2018 onwards, especially in 2022. Therefore, the historical knowledge of caprimulgids is spatially and temporally biased.

Both traditional and citizen sciences have greatly contributed with relevant and exclusive data. However, without proper communication and integration between them, they tend to work independently, unaware of possible shared goals. To ensure that citizen science truly contributes to the scientific development of Brazilian ornithology, researchers and citizen scientists must comprehend the urgency of integrating their efforts as soon as possible.

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