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Wanted: A systematic review of the most trafficked songbirds in a Neotropical hotspot

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The illegal wildlife trade is one of the main factors of biodiversity loss worldwide. Brazil, the largest country in South America, is a hub of wildlife trafficking, but availability of information on the issue is constrained to specific regions and to Portuguese speakers. Knowledge gaps hinder the establishment of targeted countermeasures in the fight against the illegal wildlife trade. Thousands of animals are seized from IWT and sent to wildlife centers each year. Here, we reviewed the literature on seized songbirds for the Brazilian Atlantic Forest (BAF), a global hotspot of biodiversity. Using a systematic review approach, we compiled a database with all available papers containing seizure records for the Brazilian Atlantic Forest. We focused on the 10 most seized species in each study to construct a comprehensive view of the main victims of the illegal trade. We reported 23 studies in 20 locations throughout the BAF. In 19 years, 139,000 passerines were recorded, distributed in 47 species – and two genera – across 10 families. Thraupidae was the most important family, with 27 species in the list and comprising 70% of individuals recorded. We highlighted the preference for granivorous birds and birds deemed good singers. There were few threatened species in the top list, but many of the ones included have population trends of decline, indicating a conservation issue that can direly affect even currently common species if the high demand continues. We appointed knowledge gaps within the Brazilian scenario of wildlife trafficking and provided practical recommendations on the issue considering the global scenario of IWT.

KEYWORDS

illegal wildlife trade (IWT), Atlantic Forest, songbirds, systematic (literature) review, Neotropical conservation, bird trade

1. Introduction

The illegal wildlife trade (IWT) is, globally, a major threat to biodiversity. It refers to any and all unlawful activity associated with the commercial exploitation and trade of wildlife (Wyatt, 2013; Sas-Rolfes et al., 2019). Its similar sibling, wildlife trafficking, can be defined as the harvest and trade of protected species (Wyatt, 2013). Here, we will adopt the common stance of using those terms interchangeably (e.g., Agu and Gore, 2020). The IWT is now recognized as one of the largest illegal trades in the world (Zimmerman, 2003; van Uhm, 2016; Wyatt et al., 2020).

It has been pointed out as one of the main factors of biodiversity loss worldwide (Rosser and Mainka, 2002; Scheffers et al., 2019) and cause of population and species extinction (Ceballos et al., 2020). Demand for particular species fall heavily on birds, especially in the Passeriformes order of songbirds, making them a major group featured in the IWT globally (Scheffers et al., 2019). Songbirds are often colorful and pleasing to the eyes (Lišková and Frynta, 2013; de Oliveira et al., 2020), while their singing abilities make them even more attractive for the live pet trade (Alves et al., 2013; Souto et al., 2017; de Oliveira et al., 2020). Although it is recognizable that IWT can severely affect bird populations (Scheffers et al., 2019), information is concentrated in the Southeast Asian region, where population declines of trafficked species has been dubbed the "Asian songbird crisis" (Nijman et al., 2019). The leading organization against global IWT, TRAFFIC, has currently 163 reports for Asia and the Middle East (TRAFFIC, 2021). Considerably less information is available for South America and Africa (22 for the entire American continent, 53 for the latter), although both regions are recognized as hubs of IWT (Baker et al., 2013; Bush et al., 2014; Scheffers et al., 2019).

The continent of South America is recognized as a main source of wildlife to the global illegal market (Scheffers et al., 2019; van Uhm and Nijman, 2022). However, traditionally, Latin America has received limited attention in terms of the IWT (Arroyo-Quiroz and Wyatt, 2019). Limited funding, low priority for environmental crimes and unsafe environment for fieldwork can all be pointed out as factors into this reality (Arroyo-Quiroz and Wyatt, 2019). There are already indicators that a significant portion of birds found in the IWT in Latin America are of wild origins (Thomsen and Brautigam, 1991; RENCTAS, 2001). Nonetheless, it is clear that a prevalent knowledge gap exists on the extent of trade in Latin countries (Alves et al., 2013).

The IWT is an important negative factor on the conservation of Neotropical birds (García-Moreno et al., 2007; Souto et al., 2017), and it is linked with many cultural traditions of bird-keeping throughout the tropics (Jepson and Ladle, 2005; Alves et al., 2010; de Oliveira et al., 2018). The largest country in South America, Brazil, is well known for its avifauna diversity, holding almost a fifth of the 10,000 bird species described to science (Butler, 2019). Birds, especially songbirds, are the most taxonomic group seized from Brazilian IWT in all of the five main regions of the country (e.g., Ferreira and Glock, 2004; Borges et al., 2006; Rocha et al., 2006; Santos et al., 2011; de Oliveira Souza et al., 2014). At least 300–400 songbird species, comprising 15–20% of Brazilian avifauna, are known to be illegally sold throughout the country (Alves et al., 2013), although such numbers can be an underestimate given the high prevalence of hidden figures for wildlife crimes (Cook et al., 2002; Akella et al., 2017). In criminology, hidden figures of crime describe the amount of unreported or undiscovered crime. With the main victims of wildlife crimes being unable to communicate directly with humans, hidden figures are estimated to be quite high (Wellsmith, 2011; Lemieux et al., 2014).

Brazilians have a long cultural history of capturing and keeping birds, set by indigenous tribes that first inhabited the country and followed by European colonizers from the XVI century onward (Silveira and Méndez, 1999; de Oliveira Souza et al., 2014). Capturing and transporting exotic species to the Old World has been a cultural European practice ever since the new continents were "discovered" (Redford, 1992). Up to this day, songbirds are a resource of economic value in various regions of Brazil (de Oliveira et al., 2020), besides being valued for social and aesthetic reasons (Alves et al., 2010; Licarião et al., 2013; de Oliveira et al., 2018).

Brazilian environmental legislation includes the criminalization of capturing and/or keeping any wild animal without governmental permission [Law 9.605 (BRASIL, 1998)]. However, the country is still experiencing a relatively young democracy, with issues of corruption and political leniency for wildlife crimes reported for other developing nations (Toledo et al., 2012; Schaedla, 2016; Levitsky, 2018). High chances of profit with perceived low potential of persecution is one of the main attractions of IWT in developing countries (Elliot, 2009; Regueira and Bernard, 2012; Papathanasiou, 2017). Thus, criminalization has not been an endgame for Brazil's IWT. It is still quite common to see live birds being sold at fairs and street markets, across small villages and metropolitan areas. Such activities are jeopardizing bird populations and their ecosystems (Alves et al., 2013; Reuter and O'Regan, 2017), with at least one species, the Spix's macaw, being declared extinct in the wild due to the illegal trade (Juniper, 2002).

Wild animals illegally captured and kept can be seized by two main enforcement agencies, the Brazilian Institute of Environment and National Resources (IBAMA) and the Environmental Military Police (PAm). Their agents have lawful power to inspect, apprehend, fine and (in the case of PAm) arrest offenders. Raids can be orchestrated by IBAMA and PAm officers or tipped by civilian complaints (de Oliveira Souza et al., 2014). Civilian complaints can lead to birds being rescued from owners' properties or seized at markets, fairs, and national and State border controls. The law also allows citizens to voluntarily deliver animals held captive to avoid prosecution, although the majority of valuable songbird species rescued from the IWT is still seized (Borges et al., 2006). Given the inability to distinguish between rescues and seizures of animals involved in IWT, we used these terms interchangeably.

Once a wild animal is seized, they can be temporarily held in PAm's headquarters, NGOs and private institutions, including Centers for Rehabilitation of Wild Animals (CRAS). However, Wildlife Screening Centers (CETAS) are the main institutions responsible for receiving, identifying, screening, and recovering wild animals (IBAMA, 2008). CETAS are managed by IBAMA or other Environmental Agencies at the State and Provincial level. With 23 centers for 25 states, distribution is not equal, with some states holding more than one CETAS and others with none. Ideally, each individual received by the centers should have their information registered into databases. For the last two decades, there has been an effort in publishing those records for different regions, probably linked with the first reports on Brazilian IWT (RENCTAS, 2001, 2002). The information is thus slowly being made available to the scientific community, although there is not a unified database for all CETAS throughout the country to date.

Given the nature of illegal trades, seizure records are often the most available way of studying these activities, acting as proxies of the scale of the crime (Rosen and Smith, 2010). This is especially relevant considering that the main victims of wildlife crimes, the non-human animals themselves, cannot self-report (Sollund, 2019; Wyatt et al., 2022). The records can thus be used to study the scale of the trade and act as a good comprehension of which species are involved, even if the issue of dark figures is highly prevalent in wildlife crimes (Cook et al., 2002; Wellsmith, 2011). Dark figures refer to crimes which are not reported or detected. Because reporting rates can be extremely low, dark figures of wildlife crimes are comparatively much larger than traditional crimes (Lemieux et al., 2014). The amount of data being

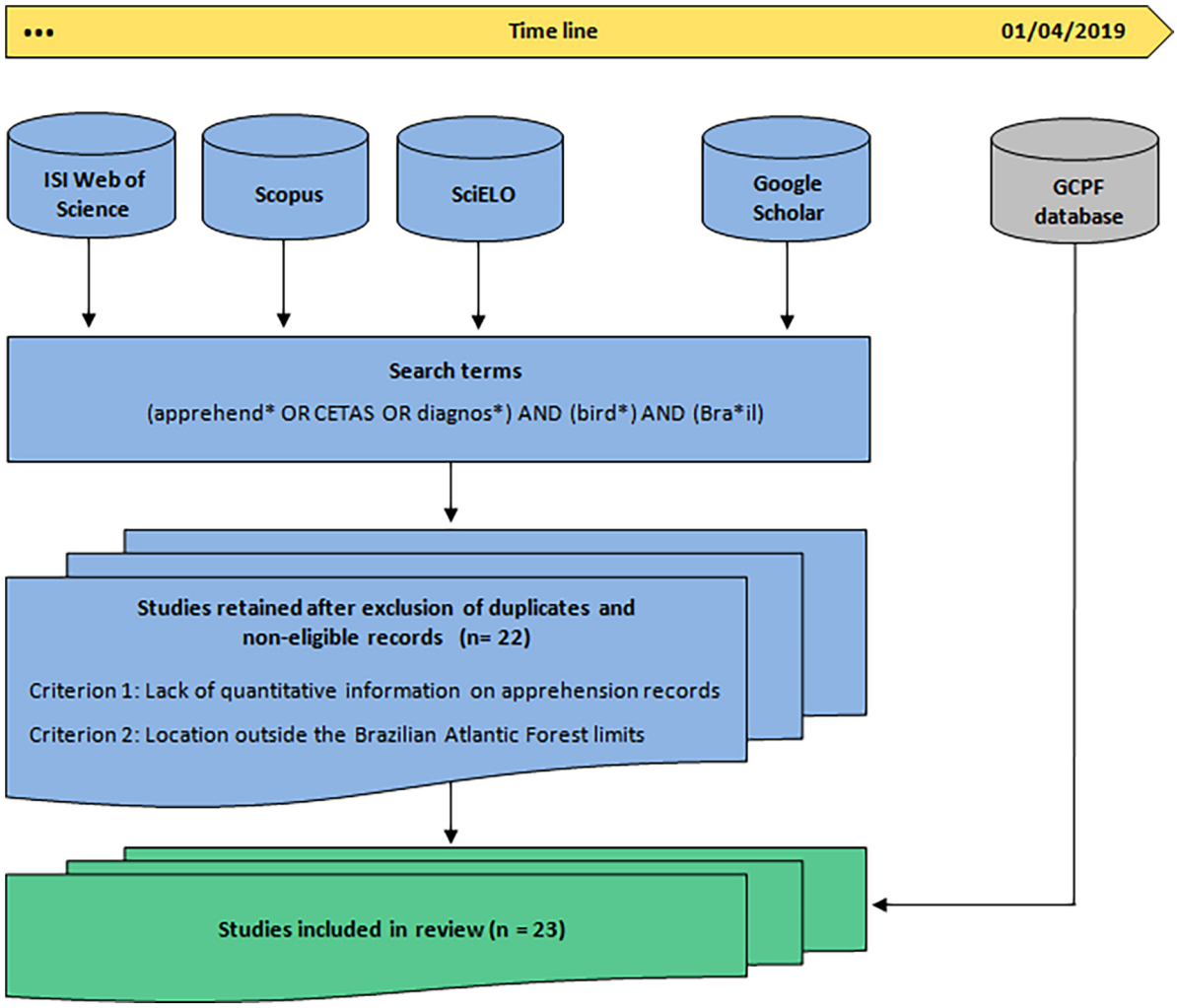

FIGURE 1
Flowchart of the review strategy used to select studies eligible to extract information on trafficked songbirds in the Brazilian Atlantic Forest.

collected worldwide on IWT is of an unprecedented scale; still, the information is scattered and remains underutilized (Gore et al., 2022).

In this paper we present a systematic review of the published literature on records of songbirds seized or rescued from the IWT in the Brazilian Atlantic Forest (BAF). Focus was set on this particular biome given (1) lack of published information for some Brazilian biomes, which could create bias in the data, and (2) the importance of the BAF as a global hotspot for biodiversity (Myers et al., 2000; Marques et al., 2021) and IWT (Scheffers et al., 2019). The BAF is a rich tropical biome with levels of endemism, affected by drastic anthropogenic impacts (Dean, 1996; Marques et al., 2021). It holds more than 900 bird species, 24% endemic to the biome, with a majority (476) included in the order Passeriformes (Piacentini, 2015). Commonly known as songbirds, a high diversity of species from this group is included in the IWT (Scheffers et al., 2019). However, a comprehensive view on the species and their numbers captured within the trade is virtually unknown. Here, we seek to answer the following questions: What is the size and composition of the IWT on songbirds in the BAF? What species of songbirds are more targeted? Are the species being seized inside or outside its native range?

As our review demonstrates, thousands of songbirds of a few selected species are seized within the BAF annually, indicating them as the most targeted species for the IWT. By collecting available data through a systematic review, we present a comprehensive report on the most trafficked songbird species in the biome, both regionally and locally. The aim of this study was to contribute to the understanding of IWT in a biodiversity hotspot, identifying the targeted species to thus suggest the development of efficient counter-trafficking measures.

2. Materials and methods

To identify documents related to trafficked songbirds in the BAF, we conducted the data collection through a systematic review of papers and gray literature. The flowchart in **Figure 1** summarizes the review strategy used to select studies eligible to extract information on birds seized from IWT. We used two main tools, Portal CAPES and Google Scholar, to conduct the search. Portal CAPES is a Brazilian official virtual library (CAPES, 2020), allowing access to hundreds of national and international journals and databases, including SciELO, Web of Science, and Scopus. It is particularly useful to search for documents published in Portuguese. The search protocol was as follows. All available content was searched in two separate occasions,

using the equivalent terms in Portuguese and English, from the first available document to April 2019. Search terms were: "(seiz* OR diagnos* OR CETAS OR CRAS) AND (bird*) AND (Bra*il)." Search was not limited to peer-reviewed articles, including other publications such as books and dissertations. Duplicate and non-eligible records were excluded. We used two criteria to flag records as non-eligible: (1) documents that did not present quantitative information on seized individuals, and (2) records located outside the BAF limits (**Figure 1**).

We found 23 documents reporting on species and their numbers of seized individuals for the BAF biome (**Supplementary Table 1**). For each study, we gathered information on spatial and temporal scope – Brazilian state/province, start and end dates for the records comprising the study length, and the recorded songbird species. There was no overlap among the studies, being it temporal or spatial (**Supplementary Table 1**). Localities that were surveyed more than once were done so in different time periods; e.g., the same CETAS in the MG State was surveyed in 2008 (Freitas et al., 2015) and 2011 (de Oliveira Souza et al., 2014). Some municipalities were surveyed more than once, but done so in different localities; e.g., the municipality of São Paulo had the CETAS of Animália and Depave surveyed from 2003 to 2008 (Morita, 2009), while its Environmental Police Center was surveyed from 2012 to 2015 (Reis et al., 2017). In total, we compiled information for 20 localities (**Figure 2**).

Data from the 10 most seized species were compiled separately for each study, following two reasons: firstly, the intent of this project was to understand the main victims of the IWT in the BAF; secondly, most papers lacked information on all species seized for each study. In fact, to consider more than the 10 most seized species would make 62% of the studies (n = 15) not eligible, greatly reducing the sources available to review, and losing data for most areas of the BAF (**Supplementary Table 2**). We compiled four different tables for the studies including the top 10 species (23 studies), top 20 species (eight studies), top 50 species (three studies), and 100 (with one study) and compared them side by side (**Supplementary Table 2**).

To test if the rank position of the top 10 seized species would be affected by the number of species considered in each study, we applied a Spearman rank correlation to compute correlations between two groups of rank scores (Kumar and Abirami, 2018). Firstly, we used the same approach to compute position scores for the top 10 species for each available study that had information on the top 20 (Hundertmarck, 2004; Morita, 2009; de Moura et al., 2012; Matias and Rodrigues, 2012; Freitas et al., 2015; Anastacio, 2017; Pinto, 2018), 50 (Morita, 2009; Freitas et al., 2015), and 100 seized species (Morita, 2009; **Supplementary Table 2**). Spearman rank correlation analysis revealed statistically significant strong positive correlations (mean rs = 0.847, $p < 0.001$) between the rank position scores produced with the top 10, 20, 50, and 100 species.

We also compared the proportion of threatened species among the top 10, 20, 50, and 100 seized species, aiming to investigate whether considering only the top 10 would cause biases toward common and widespread species in detriment to more localized but commonly traded species. Threatened species encompass those classified within IUCN Red List categories of Critically Endangered (CR), Endangered (EN), and Vulnerable (VU). We found a low and similar proportion of threatened species (~4–5%) among all sets. Spearman coefficient indicated positive correlations (mean rs = 0.974, p = 0.1) between the proportion of EN, VU, and non-threatened species produced with the top 10, 20, 50, and 100 species. Both the strong positive correlations between the rank position scores and the similar proportions of threatened species in the different sets allowed us to conduct the review considering the top 10 species, including therefore all 23 studies retrieved in the search.

Therefore, for each study, we gathered information on the 10 most recorded songbird species. Species were listed from the first position to the last, with the number of individuals per species, the total number of all bird species included in the study, and the proportion of each songbird species to the total bird species recorded (**Supplementary Table 1**). In the studies that surveyed more than 1 year, the number of songbirds is given as a sum of the number of individuals through the duration of the study. Species in each study received a position score following the equation:

$$\text{Score} = \sum[\text{position} \times \log(\text{individuals})] \times \left[\frac{\text{records}}{\text{total records}}\right]$$

where position = 1 for the first position on a given study, trickling down to a 0.1 for the 10th species listed; log(individuals) = base 10 logarithm of the number of individuals registered for each species; records = number of studies a species appears in; and total records = the entirety of studies compiled (N = 23). By transforming the raw number of individuals per species into logarithms, we can equate all studies in a single scale. The transformation was chosen to avoid bias in the score, giving that some studies recorded thousands of birds (e.g., de Oliveira Souza et al., 2014), and others only a couple hundred (e.g., Pinto, 2018).

To investigate whether species were being rescued (and therefore traded) outside its native range, we evaluated the localities of studies with records of a given species in relation to the limits of its geographical distribution. We represented the geographical distribution of each species through their extent of occurrence (EOO) provided by the IUCN Red List database (IUCN, 2021). For each species, we investigated if the localities reporting a given species fell within or outside of their EOO. We considered a record to be outside of a species' native range if it was outside the area delimited by a buffer of 150 km around the EOO of the species. We mapped such events using the ArcMap program (ESRI, 2020) to identify potential geographical patterns.

3. Results

The review assembled 23 sources listing songbirds seized or rescued from IWT within the BAF, comprising of published papers and monographs (**Supplementary Table 1**). One paper reported on two separated facilities (Morita, 2009) and was counted as two studies. The geographic coverage of the records encompassed 10 (58.9%) of the 17 Federal States within the BAF (**Figure 2**). The records ranged from 1997 to 2018, with an average of 3 years per study. The most prevalent States were São Paulo, with five studies, followed by Santa Catarina and Minas Gerais with four each, all in Southeast Brazil. Although we looked for documents in English, studies available were solely published in Portuguese.

Nine studies looked at data from CETAS (Morita, 2009; Pagano et al., 2009; Matias and Rodrigues, 2012; de Oliveira Souza et al., 2014; Freitas et al., 2015; Silva, 2015; de Mello, 2016; Anastacio, 2017). Seven looked at data from IBAMA facilities other than CETAS (Ferreira and Glock, 2004; Hundertmarck, 2004; Bastos et al., 2008;

FIGURE 2
Distribution of the 20 localities containing seizure or rescue records for the Atlantic Forest (limits in green shade) throughout the 23 studies reviewed. Some localities were surveyed more than once in different time periods, with no overlap. Number of localities per region: Southern states (7), Southeastern (9), Central-Western (1), and Northeastern (3).

Araujo et al., 2010; Gogliath et al., 2010; de Moura et al., 2012; Nunes et al., 2012). Five studies analyzed data from PAm facilities (Preuss and Schaedler, 2012; Viana and Zocche, 2013; de Medeiros, 2014; Reis et al., 2017; Pinto, 2018), with only two looking at data from CRAS (de Brito, 2017; Neto, 2018; **Supplementary Table 1**).

Forty-seven passerine species are reported as the most seized or rescued species on the BAF (**Table 1**), with a total of 138,905 songbirds recorded. Additional two genera not identified at species level were also included: *Sporophila* sp. and *Turdus* sp. (16th and 24th positions, respectively). *Crithagra mozambica* (42nd position), the yellow-fronted canary, was the only exotic species included in the list. A total of 138,905 passerines were recorded in the review. The top five species most trafficked in the BAF were the saffron finch (*Sicalis flaveola*) with 39,781 individuals; the double-collared seedeater (*Sporophila caerulescens*) with 22,019; the green-winged saltator (*Saltator similis*) with 21,263; the ultramarine grosbeak (*Cyanoloxia brissoni*), with 4,922; and the chestnut-bellied seed-finch (*Sporophila angolensis*), with 6,553 (**Table 1**).

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TABLE 1 List of most seized or rescued passerine species from the illegal wildlife trade reported in the 23 studies focusing on the Brazilian Atlantic Forest.

Score	P	Species	Family	EN	Status	Pop	*N*
53.87	1	*Sicalis flaveola*	Thraupidae	Saffron finch	LC	S	39,781
32.79	2	*Sporophila caerulescens*	Thraupidae	Double-collared seedeater	LC	I	22,019
30.53	3	*Saltator similis*	Thraupidae	Green-winged saltator	LC	D	21,263
15.50	4	*Cyanoloxia brissoni*	Cardinalidae	Ultramarine grosbeak	LC	U	4,922
7.77	5	*Sporophila angolensis*	Thraupidae	Chestnut-bellied seed-finch	LC	I	6,553
7.42	6	*Gnorimopsar chopi*	Icteridae	Chopi blackbird	LC	S	5,576
5.53	7	*Turdus rufiventris*	Turdidae	Rufous-bellied thrush	LC	S	3,443
5.49	8	*Carduelis magellanica*	Fringillidae	Hooded siskin	LC	S	2,958
4.76	9	*Sporophila nigricollis*	Thraupidae	Yellow-bellied seedeater	LC	I	5,928
4.42	10	*Sporophila lineola*	Thraupidae	Lined seedeater	LC	S	3,954
3.02	11	*Paroaria dominicana*	Thraupidae	Red-cowled cardinal	LC	S	3,998
2.88	12	*Zonotrichia capensis*	Passerellidae	Rufous-collared sparrow	LC	S	2,082
1.79	13	*Sporophila frontalis*	Thraupidae	Buffy-fronted seedeater	VU	D	5,211
1.49	14	*Paroaria coronata*	Thraupidae	Red-crested cardinal	LC	S	1,594
0.95	15	*Coryphospingus cucullatus*	Thraupidae	Red-crested finch	LC	S	369
0.82	16	*Sporophila* sp.	Thraupidae	NA	NA	NA	3,997
0.39	17	*Stephanophorus diadematus*	Thraupidae	Diademed tanager	LC	S	168
0.33	18	*Sporophila albogularis*	Turdidae	White-throated seedeater	LC	S	873
0.23	19	*Turdus leucomelas*	Thraupidae	Pale-breasted thrush	LC	U	382
0.22	20	*Volatinia jacarina*	Thraupidae	Blue-black grassquit	LC	U	2,102
0.22	21	*Tangara sayaca*	Thraupidae	Sayaca tanager	LC	S	269
0.10	22	*Tachyphonus coronatus*	Thraupidae	Ruby-crowned tanager	LC	S	34
0.08	23	*Pitangus sulphuratus*	Tyrannidae	Great kiskadee	LC	I	386
0.06	24	*Turdus* sp.	Turdidae	NA	NA	NA	205
0.06	25	*Chrysomus ruficapillus*	Icteridae	Chestnut-capped blackbird	LC	S	69
0.06	26	*Saltatricula atricollis*	Thraupidae	Black-throated saltator	LC	U	25
0.05	27	*Sporophila bouvreuil*	Thraupidae	Copper seedeater	LC	D	135
0.04	28	*Sporophila plumbea*	Thraupidae	Plumbeous seedeater	LC	S	115
0.03	29	*Icterus jamacaii*	Icteridae	Campo troupial	LC	S	38
0.03	30	*Estrilda astrild*	Estrildidae	Common waxbill	LC	S	49
0.02	31	*Mimus saturninus*	Mimidae	Chalk-browed mockingbird	LC	S	49
0.02	32	*Cacicus cela*	Icteridae	Yellow-rumped cacique	LC	D	37
0.02	33	*Ramphocelus bresilius*	Thraupidae	Brazilian tanager	LC	S	12
0.02	34	*Sporophila collaris*	Thraupidae	Rusty-collared seedeater	LC	S	23
0.02	35	*Furnarius rufus*	Furnariidae	Rufous homero	LC	I	5
0.01	36	*Saltator maxillosus*	Thraupidae	Thick-billed saltator	LC	U	47
0.01	37	*Icterus pyrrhopterus*	Icteridae	Variable oriole	LC	S	37
0.01	38	*Euphonia violacea*	Fringillidae	Violaceous euphonia	LC	D	11
0.01	39	*Cyanocorax chrysops*	Corvidae	Plush-crested jay	LC	D	10
0.01	40	*Agelasticus thilius*	Icteridae	Yellow-winged blackbird	LC	S	22
0.01	41	*Sporophila maximiliani*	Thraupidae	Great-billed seed-finch	EN	D	5
0.01	42	*Crithagra mozambica*	Fringillidae	Yellow-fronted canary	LC	D	10
0.01	43	*Tangara seledon*	Thraupidae	Green-headed tanager	LC	S	10
0.01	44	*Sicalis luteola*	Thraupidae	Grassland yellow-finch	LC	I	84
0.01	45	*Turdus flavipes*	Turdidae	Yellow-legged thrush	LC	S	37
0.00	46	*Cacicus chrysopterus*	Icteridae	Golden-winged cacique	LC	S	10
0.00	47	*Saltator fuliginosus*	Thraupidae	Black-throated grosbeak	LC	U	10

Position of each species was set following the equation described in the methods, with the total score for each species represented in the first column and its subsequent position (P). Species are noted with their respective families and common names in English (EN). Species conservation status (status) and population trends (Pop) were retrieved from the IUCN Red List (S, stable; I, increasing; D, decreasing; U, unknown). The total number of individuals recorded for each species is reported in the last column (*N*). Bird nomenclature follows BirdLife International's taxonomy (http://birdlife.org/datazone/species/taxonomy.html). A comprehensive table of all localities and species is provided on **Supplementary Table 1**.

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The 47 species and two genera were distributed among 10 families. Thraupidae holds the majority, with 27, followed by Icteridae (8), Turdidae (4), Fringillidae (3); and Cardinalidae, Corvidae, Furnariidae, Mimidae, Passerellidae, and Tyrannidae with one species each. In numbers of individuals recorded, Thraupidae is also at first place, with 118,113 birds, followed by Icteridae (5,790), Cardinalidae (4,922), Turdidae (4,558), Fringillidae (2,979), Passerillidae (2,082), Tyrannidae (386), Mimidae (49), Corvidae (10), and Furnariidae (5).

Most species (n = 44) were classified as Least Concern (LC) in the last IUCN Red List assessment, two as VU (*Sporophila frontalis* and *Sporophila falcirostris*) and one as EN (*Sporophila maximiliani*) (IUCN, 2021). For species status and population trends, we only analyzed the records that could be reported on species level (N = 47), excluding the two genera. On population trends, there are 25 species considered Stable by IUCN Red List, comprising of 65,570 individuals. This group represents 53.2% of the species in the list and 48.7% of all individuals. Nine species (19.1%) are considered Decreasing, with 26,707 individuals (19.8%). Seven species (14.9%) are considered Increasing with 34,976 individuals (26%). Six species do not have population trend assessments (Unknown, 12.8%), with 7,488 individuals (5.6%).

Out of the 47 species, 10 (21.27%) were reported in localities outside their EOOs (in order of higher to lower score): *S. similis, Paroaria dominicana, Paroaria coronata, Coryphospingus cucullatus, Saltatricula atricollis, Icterus jamacaii, Ramphocelus bresilius, Agelasticus thilius, S. maximiliani*, and *Sicalis luteola* (Figure 3). As the only species not native to the region, *C. mozambica* was not included in this analysis.

Most seized animals found outside their EOO were found in South and Southeastern states of Brazil. *P. dominicana, I. jamacaii*, and *S. maximiliani* were moved to Southeastern states (Figures 3A–C). Meanwhile, *P. coronata, S. atricollis, R. bresilius*, and *A. thilius* were moved to Southern states (Figures 3D–G). Out of the 12 species, only *S. similis, C. cucullatus*, and *S. luteola* (Figures 3H–J) were moved toward Northeastern states.

More than a third of the birds (4 out of 10) were found up to 200 km outside their EOO: *A. thilius, S. similis, S. luteola*, and *S. maximiliani*. Other species were moved through greater distances. *R. bresilius* has the smallest geographic distribution of the birds in this set, but individuals were found 500 km away from their EOO (Figure 3F). *C. cucullatus* had the highest distance recorded, with individuals found almost 1,000 km away from their EOO's closest edge (Figure 3I). *P. dominicana* was found in five external record localities, ranging from 400 to 850 km away from species EOO (Figure 3A). *S. atricollis* was found in two external localities more than 600 km away (Figure 3E), while the remaining six species were found in one external locality each.

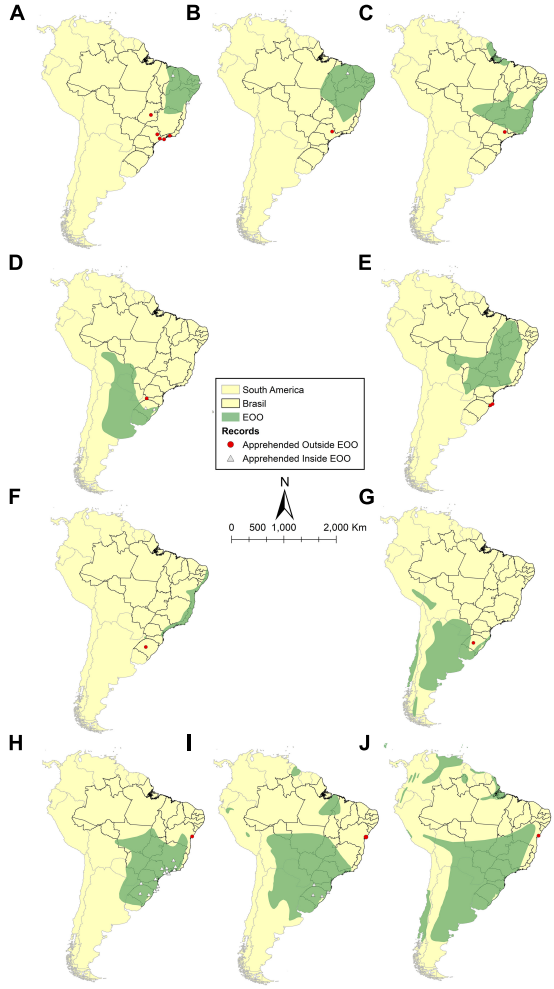

FIGURE 3
Songbird species moved from their native extent of occurrence (EOO) to different regions of the Brazilian Atlantic Forest. The first group **(A–C)** corresponds to species moved to Southeastern states. The second group **(D–G)** corresponds to species moved to Southern states. The third group **(H–J)** corresponds to species moved to Northeastern states. The EOO of each species is shaded in dark green. Localities that reported the species inside their EOO are represented in white triangles, while localities that reported the species outside their EOO are represented in red circles. A comprehensive table of all localities and species is provided on **Supplementary Table 1**. {[group I: **A**, *Paroaria dominicana* (11th); **B**, *Icterus jamacaii* (29th); **C**, *Sporophila maximiliani* (41st)], [group II: **D**, *Paroaria coronata* (14th); **E**, *Saltatricula atricollis* (26th); **F**, *Ramphocelus bresilius* (33rd); **G**, *Agelasticus thilius* (40th)], and [group III: **H**, *Saltator similis* (3rd); **I**, *Coryphospingus cucullatus* (15th); **J**, *Sicalis luteola* (44th)]}.

4. Discussion

Our study demonstrates that, on a yearly basis, seized songbirds in the BAF encompasses thousands of individuals belonging to a few targeted species. Out of the 476 songbird species present in the biome (Piacentini, 2015), we found that 47 (9.87%) were the most targeted for the IWT. They are well known throughout the country, with thousands of individuals of these species arriving at the 20 surveyed localities. The common saffron finch (*S. flaveola*), holds the first position on the list, being found in all 23 studies and totalizing 39,781 seized birds in a 12-year span. Given that dark figures are a common phenomenon in illegal activities (Mosher et al., 2002), it is reasonable to expect that at least many hundreds more, likely thousands, of individuals of those species are removed from the wild every year. However, none of these species are listed in CITES Appendices.

When considering population trends through species' IUCN assessments, we can distinguish some patterns. The species deemed to be increasing within IUCN Red List, such as *S. caerulescens, S. angolensis, Sporophila nigricollis, Pitangus sulphuratus, Furnarius rufus, Molothrus bonariensis*, and *S. luteola* are all distributed in open habitats, such as shrubland, grassland and even arable and

pasture lands and degraded forests (Billerman et al., 2020). They are mostly granivorous and insectivorous and some, such as the great kiskadee (*P. sulphuratus*) and the rufous hornero (*F. rufus*) are known members of the urban avifauna (Clements, 2007). This scenario could indicate ecological release for these species, with more open habitat available due to deforestation or even adaptation to more urban environments.

Species with trends of population decrease include the LC species *S. similis, Sporophila bouvreuil, Cacicus cela, Cyanocorax chrysops*, and *Euphonia violacea*; the EN *S. maximiliani*; and the VU *S. frontalis* and *Sporophila falcirostris*. This subgroup is composed mainly of forest, wetland, or shrubland dweller birds (Clements, 2007). Those habitats within the BAF are already severely affected by anthropogenic activities (Ribeiro et al., 2009; Lira et al., 2021). The BAF is currently an ecological archipelago of small islands of forests within a matrix of degraded areas (Ribeiro et al., 2009). Unsustainable levels of exploitation, combined with the habitat loss, fragmentation and degradation, are strong factors motivating population declines (Rosser and Mainka, 2002; Symes et al., 2018), and can lead to even LC species becoming threatened, with the already Endangered ones subjected to higher risks of extinction.

Relating to the geographical scale, our results indicate that most songbirds seem to be traded locally or regionally. Even the exotic yellow-fronted canary (*C. mozambica*) can be included in this scenario, given that breeding of this species is allowed by IBAMA (2011). These results could support the hypothesis that the main purpose for illegally captured wild animals in Brazil is to feed the internal trade (Destro et al., 2012, 2019). Nonetheless, we are aware of Brazilian birds being found in markets as distant as Southeast Asia and the Middle East (e.g., Su et al., 2015; Abi-Said et al., 2018) and the global reach of IWT (Schneider, 2012; Bush et al., 2014).

The Northern to Southern movement of birds outside of their geographic distribution detected by the analysis of the species' EOO has been pointed out by other researchers (RENCTAS, 2002; Destro et al., 2012, 2019). In general, Brazilian avifauna appears to be trafficked from Northern, Northeastern, and Central-Western regions, mainly by federal highways, to urban centers of the Southeastern and Southern regions, where the biggest cities are located (RENCTAS, 2002; Destro et al., 2012). Our results reinforce the role of Brazilian Southern and Southeastern regions as hubs of IWT, and the importance of stronger road inspections to detect and intercept interstate smuggling routes, besides cracking down on known wildlife markets operating within the metropolitan areas. It has been suggested that large cities with airports and ports can also act as a sink of individuals by allowing smuggling into other countries (RENCTAS, 2001; Ferreira and Glock, 2004; Destro et al., 2012). Capturing, housing, and transporting the animals in often very precarious conditions can lead to the spread of diseases, including zoonoses (Karesh et al., 2007; Swift et al., 2007). A local example of this issue of IWT and disease outbreaks was illustrated by the frequency of *Salmonella* sp. in Atlantic Forest birds rescued from IWT (Matias et al., 2016).

Our findings highlight a strong social preference for species in the Thraupidae family, composed of tanagers and related species, in the IWT. It was the family with the most species and the largest number of individuals recorded (27 and approximately 118,000, respectively). The three top songbirds of the list (**Table 1**) – *S. flaveola*, *S. caerulescens*, and *S. similis* – are all Thraupidae species, comprising 70.3% of individuals recorded of this family. Thraupidae birds occupied the main position in most studies reviewed and could compose up to 90% of birds recorded in a study (Gogliath et al., 2010). The prevalence of Thraupidae species among seized songbirds in the BAF is in accordance with the pattern indicated in reports on Brazilian IWT (Destro et al., 2012, 2019). Thraupidae birds are often colorful and aesthetically attractive, with many species recognized as good singers (Hilty and Bonan, 2017). Ethnozoographic studies have already pointed out the preference of bird-keepers in Brazil for Thraupidae species (Souto et al., 2017); many species of this family are often used in singing contests, being valued at very high prices (de Oliveira et al., 2020). Species of this family are also relatively small, ranging from 9 to 29 cm (Hilty and Bonan, 2017). Small animals are commonly sought for the IWT, given that smugglers can crowd cages with many individuals for a discreet transport with higher potential of profit (Gama and Sassi, 2008; Souto et al., 2017). Highly sought out species such as the ones in the *Sporophila* genus, the most prevalent group in the review, are also granivorous, a diet that is cheaper and easier to maintain when compared with insectivores (Rocha et al., 2006). However, when compared with a global review on IWT, Thraupidae is not one of the main families represented (Figure 2A in Scheffers et al., 2019). Given that Thraupidae is a Neotropical family of Passeriformes (Hilty and Bonan, 2017), its restricted distribution might explain its low prevalence in global records. Nonetheless, our results present a clear conservation issue to species of this family, and the importance of proper public awareness and the need for targeted measures within the country.

The Brazilian environmental law is quite robust, but many of its citizens see wildlife crimes as minor crimes, with low probability of severe punishment, with some even unaware of its issues (Regueira and Bernard, 2012; Mackenzie, 2014). In a country stricken with social inequalities, keeping birds in cages can present a financial opportunity to breeders. As a clear example, male green-winged saltators (*S. similis*) can be sold for up to 500 USD, in a country where minimum wage does not exceed 240 (de Oliveira et al., 2020). Furthermore, the historical tradition of keeping songbirds as pets, present in Brazil as in many tropical countries (Schaedla, 2016), allows for a sense of cultural legitimacy (Sollund, 2011) that keeps these activities alive even within the context of their illegality. Political lenience and high perceived profits, with low risks of persecution, are a disastrous recipe, leading to the persistence of IWT even with international bans and regulations in place (Pires and Moreto, 2011; Nijman, 2017).

Seizure records are the backbone of IWT studies (Rosen and Smith, 2010; Bush et al., 2014; Reuter and O'Regan, 2017). Still, many seizure records for the BAF were unavailable for analysis, and an all-inclusive database for the whole country was not feasible due to the aforementioned gaps for regions (e.g., Amazon and Pantanal) and some Federal States. This situation might reflect the relatively recent concern with environmental crimes, not only in Brazil (RENCTAS, 2001) but as an international effort (Chang, 1997). In 2019, the Brazilian government launched a platform to centralize records from all CETAS to consolidate a national database, but the data is of yet unavailable. Furthermore, all papers and documents containing pertinent information on birds seized were published in Portuguese, meaning only Portuguese speakers would be able to retrieve the data. Information should be publicly available in Portuguese and English, allowing facilitation of cooperation and management decisions at national and international levels. When discussing adding species to CITES Appendices for their protection, and establishing international cooperation groups against IWT, it

becomes clear the importance of having data readily available in English.

We demonstrated that at least 139,000 songbirds were seized in 20 years of surveyed localities, but these numbers represent an underestimate of the IWT in BAF. Firstly, many endangered species are trafficked and might not show on records due to the already low population numbers. Nonetheless, demand can shift to highly abundant taxa when rarer sources "dry up" (Marshall et al., 2019), meaning more of the common birds can be caught *in lieu* of the rare ones. It is also important to note that we do not have updated population estimates for these highly trafficked species. Therefore, we can only assume those numbers to be potentially dangerous and use anecdotal indications of decline. Secondly, the animals recorded in the review are the ones that were rescued, seized, or voluntarily delivered. It does not account for the thousands more killed on capture, transport, or captivity. Mortality within IWT is extremely high, besides serious injuries, diseases, and intense emotional stress for its victims (Rocha et al., 2006; Fernandes-Ferreira et al., 2010; Godoy and Matushima, 2010). Even when hold in buyer's houses, the often lack of adequate care and companionship from conspecifics leads many of the surviving animals to get sick and die, prompting again a demand for wild birds (Weston and Memon, 2009). Animals perishing at captivity are often quickly discarded to avoid "bad business" (Regueira and Bernard, 2012). Because one only often sees the animals being sold at fairs and the ones being seized, the majority of trafficked animals remains invisible (Petrossian et al., 2016). The extreme amounts of suffering, and the sheer extent of the problem, raises important ethical considerations (Donovan, 1996; Moorhouse et al., 2017).

Conservation perspectives on population status also raises further concerns. An extreme cautionary tale of common birds going extinct is of the passenger pigeon (Stanton, 2014), but history is repeating itself in current times (Eaton et al., 2015). Newer examples tell similar stories in this direction, such as the black-winged myna *Acridotheres melanopterus* (Shepherd et al., 2015); the snowy-owl *Bubo scandiacus* (Nijman and Nekaris, 2017); the Spix's macaw *Cyanopsitta spixii* (Juniper, 2002); and the Red Siskin *Spinus cucullatus* (Sánchez-Mercado et al., 2020). All endangered or CR bird species due largely to overexploitation, in which wildlife trafficking takes a main role. In fact, a positive correlation between species' rarity and their value creates a dangerous self-feeding loop that has been called the "anthropogenic Allee effect" (Courchamp et al., 2009). The demand for rarity can be especially hard to counteract (Chen, 2016), since there are no economic constraints to harvesting and exploiting highly valuable species at extremely low densities, increasing their threat of extinction (Low, 2003; Angulo et al., 2009).

As habitat loss, fragmentation and degradation are serious current issues on tropical forests and wetlands, it is reasonable to assume that for the common, highly trafficked species, the forest- and wetland-dwelling ones are at a greater risk of decline given the combined threats. Thus, we pointed out that highly trafficked species, even the ones considered abundantly common, are likely facing important population declines, possibly only noticeable when the situation has already become troublesome. Directing attention toward those highly trafficked species that are apparently at low risk of extinction is needed, especially in a world of rapid changes, in an effort to "keep common species common" (Frimpong, 2018). And for the more endangered species, even if they are less prevalent in the BAF IWT, fewer individuals removed from wild populations can still significantly affect the conservation of these species.

Results from this review also point to a need for structured approaches toward rescued animals. Thousands of seized animals (often in a single facility) mean a similar number of indiscriminate releases each year, given that Screening Centers have limited capacity and are recurrently receiving more animals than it would be able to properly hold (Efe et al., 2006). The quantity of animals seized or rescued is already substantial even though they represent only a fraction of the real number affected by animal trade. In addition to being often released indiscriminately (Efe et al., 2006), individuals may also be introduced in populations with different genetic and phenotypical makeup. This is a clear warning of a conservation issue, and we need to strive for comprehensive information and better policies for dealing with wildlife trafficking and animals rescued from IWT.

5. Implications for conservation of BAF songbirds

This study pointed to the possibility that the IWT can generate consequences for populations of passerine birds, especially for Thraupidae species. Based on our findings and previous surveys conducted in other regions, we conclude the present study with recommendations to the specific scenario of Brazilian wildlife trafficking.

We advocate for the availability of an online integrated database for CETAS across Brazil to amass a better understanding of the national situation, not limited by region or state. Currently, there is an attempted integration of CETAS databases for the whole country, but to this date the information is not yet available.

Accurate population estimates for the species highly trafficked are needed, so one can accurately account for the risks of removing thousands of individuals each year. Lack of information on what is the proportion of removed individuals from their wild populations is a serious gap that needs to be urgently and properly filled.

Individuals are found hundreds of kilometers away from the limits of their geographical distribution, indicating a strong component of wildlife trafficking at regional level. However, currently we can only track movements across states from species found outside their natural habitats. In that scenario, genetic markers are bound to be important tools in combating animal trafficking, and their development should be encouraged by proper governmental and private funding. With genetic fingerprints for each animal, it would be possible to track its origins and have a geographical understanding of the flow of species to and from Federal States, and even at an international level. A species' song can also be used to identify birds' origins and improve the management of seized birds released into the wild (Magroski et al., 2017).

Finally, indiscriminate releases of seized animals forbids evaluating the success of releasing these individuals (Efe et al., 2006) and do not conform to existing guidelines (IUCN/SSC, 2013). Brazilian stakeholders should then benefit from policies targeted at their specific fauna, with proper care being considered for appropriate releases of focal species with the goal of restoring natural populations at risk of extinction. We suggest the adoption of a Structured Decision Making approach (Gregory et al., 2012, 2013) to join park managers, governmental agencies, and legal bird breeders into making decisions that will ensure a better and safer future for birds released from captivity.

Brazil has crowded wildlife markets with hundreds of species being sold, alive without proper sanitary care, or dead in the form of "products." As seen for other regions, sanitary conditions of wildlife markets are a clear public health issue (Brooks-Moizer et al., 2008; Zhang et al., 2020). Notwithstanding the risks of further zoonotic disease outbreaks, the poor conditions in which songbirds are kept in the IWT represents a reasonable potential of significant impacts to the conservation of species. By investigating the extent of the issue and clearly stating the ecological, ethical and health issues rising from the IWT, we can move toward an integrated movement of not only considering the illegality of the activities, but also the harms to the individuals, populations and species involved (Wyatt, 2020). With this review, we present a more holistic perspective of the issue that can contribute to setting of political and management decisions to tackle targeted points of IWT within the BAF.

Data availability statement

The original contributions presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding author.

Author contributions

GCPF initiated the research, compiled the data set from the review, produced the **Figures 2**, **3**, **Tables 1**, and **Supplementary Tables 1**, **2**, and held the role of primary writer of the manuscript. MR had expanded the discussion on the final section of the manuscript. ML produced the **Figure 1** and supervised the ArcMap projects for **Figures 2**, **3**, and performed the correlation analysis using the data from **Supplementary Table 2**. HR supervised the taxonomic data curation. All authors had contributed to the design of the study, and write and review the manuscript, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2023.930668/full#supplementary-material

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