

Brazilian bird collections: a decade after Aleixo & Straube (2007)

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ABSTRACT: We compiled the main results of a second diagnosis of Brazilian ornithological collections. Our starting point was the survey by A. Aleixo and F. Straube, with data up to 2005 and published in 2007. Ten years later, in 2015, curators or managers from 35 collections of birds (out of 59) answered 12 questions related to the status of the collection they curate. These collections cover all regions of the country, and many have grown in number of specimens, especially in northeastern Brazil. As verified by Aleixo & Straube, most ornithological Brazilian collections are concentrated in southeastern and southern Brazil (66%). Also, some basic shortcomings persist, such as the lack of specialized curators, taxidermists, and access to digitalized information. The three oldest and biggest collections (Museu Nacional da Universidade Federal do Rio de Janeiro - MN, Museu Paraense Emílio Goeldi - MPEG and Museu de Zoologia da Universidade de São Paulo - MZUSP) together continue to hold more than half of all Brazilian ornithological specimens and 83% of all type specimen. Some collections, (especially new ones) have been actively collecting and preparing specimens in a much-diversified way, saving different body parts of a single individual as distinct types of materials. Government and other online data information systems (*e.g.*, Brazilian Biodiversity Information System - SiBBR and Center for Reference in Environmental Information - CRIA) have been developed, and now provide digital data from some relevant collections. Brazilian ornithological collections are completely or partially digitized (85%), although for most specimens and collections, data are not freely available and is mostly accessed between researchers. Despite the efforts of some researchers and institutions, improvements in the maintenance and protection of the collections are still necessary. Nevertheless, we conclude that the situation of Brazilian ornithological collections has improved in the past 10 years. Finally, herein we propose a rank for Brazilian ornithological collections classifying them according their role for both research and education activities, which are considered in the current bibliography as key roles of natural history collections.

KEY-WORDS: bird biodiversity, classifying criteria, conservation, database, museums, specimens.

INTRODUCTION

Collections of biological specimens, which in the past were the privilege of aristocratic collectors and/or curious people interested in nature, have come to be recognized as repositories of evidence or results of evolution (Joseph 2011). Even today they serve this purpose, supporting research on taxonomy, systematics, distribution and biology, as well as studies of changes in populations, species and the environment, playing a very important role in research and education, defined as key internal scholarly museum functions, and also in the education of the non-specialized public (external museum function) (Allmon 1994, Cracraft 2002, Suarez & Tsutsui 2004, Winker 2004). Museum collections have also been used successfully to analyze declines of many species and are a valuable tool in documenting the changes that have occurred in the planet's biodiversity in the last century (Shaffera *et al.* 1998). Despite the intrinsic value of the collections and their value for research and education,

museum collections are sources of inspiration and other connections that occur when a researcher examines and compares objects “first hand and ponders their significance” (Allmon 1994).

Biological scientific collections traditionally consist of specimens or parts of them stored, hopefully, for perpetuity. Worldwide natural history collections are an enormous and incomparable sampling of global biodiversity of all taxonomic groups. Currently, these collections contain about 3 billion specimens curated in museums and universities (Brooke 2000), which were acquired over the past 500 years thanks to the efforts of generations of naturalists and curators (Rouhan *et al.* 2017). Due to new technological advances (such as sound recordings, photographs, geographic information systems and DNA sequencing) and the development of new disciplines such as genomics and bioacoustics, there is an ever-increasing need to diversify the items to be included, stored, preserved, identified and cataloged in a biological collection. In parallel with the generation of these new

types of data, the development of the World Wide Web (WWW) and its access through the internet allows the sharing, almost instantaneously, of data. Of course, this is accompanied by a growing demand for information availability.

We do not know current complete surveys of the number of specimens deposited in Brazilian collections, but by 2003 its number was about 26 million specimens, being the largest collection in the world of Neotropical biodiversity (Zaher & Young 2003). A complete survey of the Brazilian Bird Collections was published by Aleixo & Straube (2007), which constitutes a general overview of most known collections of birds in Brazil. That study was part of a project on the status of the Brazilian collections promoted by the government-funded Brazilian Biodiversity Research Program (PPBio), with the aim of consolidating an information system of integrated data on biodiversity (Aleixo & Straube 2007). That study compiled data on 22 collections and 250,311 specimens (skins, anatomical and exhibition series). Currently, after 10 years, few government grant calls aimed at enabling the creation and maintenance of collections or parts of them have been put forward. Some of these, such as the “Edital MCT/CNPq No. 35/2012 - PPBio/Geoma - Networks for Research, Monitoring and Modeling in Biodiversity and Ecosystems, Part I” belonging also to the PPBio project, were essentially discontinued, resulting in strong negative impacts to the knowledge of Brazilian biodiversity (Fernandes *et al.* 2017).

While recognizing the efforts of federal, state and private entities, foundations and, especially, researchers in creating and maintaining Brazilian collections, the shortcomings still outweigh the gains. Thus, a survey of the current situation compared to the past is relevant to establish future guidelines for all Brazilian bird collections. Our objectives here are to: (1) list the current Brazilian ornithological collections; (2) compare the information obtained with those of the diagnosis made in 2007 (Aleixo & Straube 2007); and (3) to draw a qualitative and quantitative outline based on criteria related to the management and maintenance of the collections, and the availability of their data for scientific and educational purposes.

METHODS

In October 2014 and from January to March of 2015, an online Google questionnaire was sent to all specialists responsible for maintaining the collections of birds in Brazil, identified in Aleixo & Straube (2007) or found using the keywords “bird collections” and “ornithological collections” within search engines, such as the Lattes platform of the Brazilian National Council of Scientific Development and Technological (CNPq). J.P.S. sent

questionnaires (see Appendix I) that took no longer than 3 minutes to answer, with 12 questions (much smaller than the questionnaire proposed by Aleixo & Straube 2007, with 26 questions). The highest percentage of questionnaires (78%) was answered by 2015 and some were answered in August and September 2016, when questionnaires were re-sent. However, all the results are based on data from collections up to 2015. We tried to correct some inconsistencies observed in the questionnaire responses, by telephone or electronic correspondence, until November 2017. In all, we contacted managers at 59 collections (see list in Table 1). In case of differences of information between the current study and Aleixo & Straube (2007), we placed the older information between parentheses.

Additionally, with the information requested through the questionnaire in hand, in 2017 we searched for bird collections on the Internet, in the databases of the CRIA - Center for Reference in Environmental Information (CRIA 2017) and SiBBR - Brazilian Biodiversity Information System (SiBBR 2017). Both entries had more than 400 collections in 2017, of which 10 were of birds. Some of these collections (eight) are the same ones contacted via questionnaire and three others were opportunistically added to this work. Collections of sounds, videos, photos, tissues, DNA, or collections of microorganisms or other organisms related to birds were not considered when they were not associated with traditional vouchers such as skins and/or, skeletons and deposited in the same collection.

To establish a ranking of the status of Brazilian bird collections we evaluated and compared the answers of the questionnaires on a scale of 0–1 according to the criteria described below. Criteria and weights were based on the assumptions that a collection serves to two main functions - research and education - considering what was asked in the questionnaires and what is cited in the literature as important features and functions for a collection (*e.g.*, Allmon 1994, Lane 1996). Most of these criteria have been considered a good basis for evaluation in previous publications (Allmon 1994, Lane 1996, Dance 2017). Rankings were based on the following parameters:

(A) Total size of the collection - 1, greater than 10,000 specimens; 0.75, from 5000 to 10,000 specimens; 0.5, from 1000 to 5000 specimens; 0.25, from 500 to 1000 specimens; 0, less than 500 specimens;

B) Relationship between the total number of specimens/total years of existence (*i.e.*, annual growth rate) - 1, more than 200 specimens; 0.75, between 200 and 150 specimens; 0.5, between 150 and 100 specimens; 0.25, between 100 and 50 specimens; 0, less than 50 specimens;

(C) Curator - 1, presence of a curator and/or professional ornithologist in the collection (based on Lattes CV; www.lattes.cnpq.br); 0.5, without a curator but with a head researcher with a degree in any area of Zoology, based on

the *Lattes* CV; 0, Museum general manager, even with an academic degree in a different area or who answered “no curator” in the questionnaire;

(D) Taxidermist - 1, presence of a taxidermist; 0, absence of a taxidermist;

(E) Diversification of the Collection - 1, six or more preparation forms (*e.g.*, skins, skeletons, tissues, nests, eggs, carcasses, syringes, stomachs, etc.); 0.5, between three and five types of preparation; 0, only one or two types of forms;

(F) Presence of type specimens reported (*e.g.*, Holotypes, Paratypes, Syntypes) - 1, presence; 0, absence;

(G) Average proportion of digitalization of the collection, such as: total digitalization (1), partial digitization (0.5) and non-digitalization (0), and the availability of the database to the public (1), to researchers (0.5), or only to the internal public (0);

(H) Average between the number of visits/year (1, more than 13 visits; 0.5, 1 to 12 visits; 0, no visit) and the number of loans per year (1, more than 12 loans; 0.5, 12 loans; 0, no loans);

(I) Geographical representativeness of the collection - 1 (Global); 0.5, regional (Brazil, regions); 0, state where the collection is located;

(J) Known citations of the collection in scientific articles - 1, 13 or more articles; 0.5, 1 to 12 articles; 0, no articles.

RESULTS

Thirty-eight of 59 curators/managers (64%) answered the electronic questionnaire in full (35) or partially (3) (Table 1). Additionally we received electronic correspondence, updating us on the current situation of four other collections as followed.

In October 2014, we were informed that the Museu de História Natural da Universidade Estadual do Centro-oeste (MEHS) in Guarapuava (Paraná state - PR) was closed, but that few specimens are stored, and that the skins were only for didactic purposes, since they did not have data of origin. However, we recently discovered that the museum was reopened in December 2015 (Prefeitura de Guarapuava 2015). The Zoology Collection of the Delta do Parnaíba, of the Universidade Federal do Piauí (UFPI), Parnaíba campus, contains fish, reptiles, amphibians and insect specimens from the Parnaíba region, but only three birds. The Bird Collection of the Museu de História Natural (MHN) of the Universidade Estadual Paulista (UNESP), at Botucatu (São Paulo state - SP), has a didactic collection of animals. The collection UCG (Universidade Católica de Goiás) held in Goiânia, cited in Aleixo & Straube (2007), is currently known as the Bird Collection of CEPB (Centro de Estudos e Pesquisas Biológicas) of Pontifícia Universidade Católica de Goiás in the same city. It is a research nucleus of the Escola de

Ciências Agrárias e Biológicas, which unites the biological collections of each individual laboratory. According to the curator, this collection is being reorganized and re-inventoried, and currently has 518 specimens belonging to 212 bird species from Goiás, Minas Gerais, Mato Grosso do Sul, Rondônia, and Tocantins states (W. Vaz, *in litt.*).

Concerning the three collections that managers answered partially the questionnaire, we find that the Museu de Ornitologia de Goiânia (MOG) lists over 15,000 specimens in its catalogue. However, of this total, thousands of specimens were taken to foreign collections and it is currently estimated that the collection of birds has between 5000 and 8000 skins, distributed in the serial and expository collections (information received through the questionnaire, without identification of the author, forwarded to J.P.S. on 20 September 2016). Apparently, MOG has an excellent didactic collection, although the origins of many of its specimens are questionable. In relation to this collection, we still found that the Legislative Assembly of the state of Goiás approved the decree number 3652/17, which authorizes the transfer of financial resources to the *Sociedade Goiana de Cultura*, responsible for the PUC-GO for the creation and construction of the Museum of Zoology of this university (Assembleia Legislativa do Estado de Goiás 2017a). According to the source, this museum will be built to house the collection donated by José Hidasí, which has more than 27,000 specimens (invertebrates, reptiles, birds and mammals) (Assembleia Legislativa do Estado de Goiás 2017b). The information on the total number of specimens and presence of type specimens were absent in the reply from the Museu das Culturas Dom Bosco (MCDB), Campo Grande, Mato Grosso do Sul state - MS. The number of specimens of the Bird Collection of the Museu Oceanográfico da UNIVALI (MOVI), Itajaí, Santa Catarina state - SC, was also mistakenly informed (200,000) and after no reply to our attempt to correct it we decided do not consider this number. On the website of this Museum, there is a citation indicating that 650 specimens of oceanic birds are housed in the bird collection. For the purpose of this work, MOG, MCDB, MOVI were considered only in the ranking of the collections.

From the answers of the questionnaires, searches on the Internet and the full collection's list mentioned by Aleixo & Straube (2007), we were able to list 62 collections of birds, or collections that may potentially contain birds, in Brazil (Table 1). Except for the four collections mentioned above, plus the MOG, MCDB and MOVI collections, which partially answered questionnaires, the remaining 35 respondents answered the full questionnaire (collections C), eight of which have databases available on the Internet (collections D). Sixteen collections did not answer the questionnaire (collections NC) and two

Table 1. List of currently known Brazilian bird collections. State: Brazilian state abbreviations. Region: N – north, NE – northeast, CO – midwest, SE – southeast, S – south. Jurisdiction/funding: S – State, F – Federal, M – Municipal, P – Private. Abbreviations on column Aleixo & Straube (2007) and column This study: A – Checked, C – Included in analysis, CNC – contacted, but not considered (information in the text), D – Data in online database (CRIA or SiBBR), NA – Not investigated, NC – Not considered, questionnaire response not obtained, or collection created after 2005. The data in parentheses are from Aleixo & Straube (2007), different from the current data.

Acronym	Collection	City	State	Region	Jurisdiction	Aleixo & Straube (2007)	This study
CGFA	Coleção Científica Fauna do Amapá, Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá, IEPA	Macapá	AP	N	S	C	NC
CRAR	Coleção de Referência da Avifauna de Rondônia, Fundação Universidade Federal de Rondônia, UNIR	Porto Velho	RO	N	F	NA	D
INPA	Coleção de Aves, Instituto Nacional de Pesquisas da Amazônia, INPA	Manaus	AM	N	F	C	C
MPEG	Coleção Ornitológica Fernando da Costa Novaes, Museu Paraense Emílio Goeldi	Belém	PA	N	F	C	C, D
NZT (UNITINS)	Núcleo de Zoologia e Taxidermia, Universidade Estadual do Tocantins, UNITINS	Palmas	TO	N	P	C	C
UFAC	Coleção Ornitológica, Universidade Federal do Acre, UFAC	Rio Branco	AC	N	F	NA	C
ZEE-AVI	Zoneamento Ecológico-Econômico do Acre, Avifauna, Secretaria do Meio Ambiente	Rio Branco	AC	N	M	NA	D
CAHZ (UFPB)	Coleção de Aves Heretiano Zenaide, Universidade Federal da Paraíba, UFPB	João Pessoa	PB	NE	F	C	C
CHNUFPI	Coleção de História Natural Universidade Federal do Piauí, UFPI, Campus Amílcar Ferreira Sobral	Floriano	PI	NE	F	NA	C
MCNC	Coleção Ornitológica, Museu de Ciências Naturais da Cetrel. Cetrel: Empresa de Proteção Ambiental S.A.	Camaçari	BA	NE	S	C	NC
MHN	Museu de História Natural, Universidade Federal de Alagoas, UFAL	Maceió	AL	NE	F	NA	C
MHNU	Museu de História Natural da Urca, Universidade Regional do Cariri, UHC	Crato	CE	NE	P	A	NC
MMOL	Museu do Mar Onofre Lopes, Universidade Federal do Rio Grande do Norte, UFRN	Natal	RN	NE	F	A	C
MZFS	Divisão de Aves do Museu de Zoologia, Universidade Estadual de Feira de Santana, UEFS	Feira de Santana	BA	NE	S	NA	C
UFPE	Coleção Ornitológica, Universidade Federal de Pernambuco, UFPE	Recife	PE	NE	F	NC	C

Acronym	Collection	City	State	Region	Jurisdiction	Aleixo & Straube (2007)	This study
UFPI	Coleção Zoológica Delta do Parnaíba, Universidade Federal do Piauí, UFPI, Campus Parnaíba	Parnaíba	PI	NE	F	NA	CNC
CEPB (UCG)	Centro de Estudos e Pesquisas Biológicas, Pontifícia Universidade Católica de Goiás, PUC-Goiás	Goiânia	GO	CO	P	C	CNC
COMB	Coleção Ornitológica Marcelo Bagno, Museu de Zoologia, Universidade de Brasília, UnB	Brasília	DF	CO	F	C	C
COUFMT	Coleção Ornitológica, Universidade Federal de Mato Grosso, UFMT	Cuiabá	MT	CO	F	NA	C, D
MCDB (MDB)	Museu das Culturas Dom Bosco, Universidade Católica Dom Bosco, UCDB	Campo Grande	MS	CO	P	NC	CNC
MOG (FMOG)	Museu de Ornitologia de Goiânia, Prefeitura Municipal de Goiânia	Goiânia	GO	CO	M	C	CNC
DZUFMG	Coleção Ornitológica, Departamento de Zoologia, Universidade Federal de Minas Gerais, UFMG	Belo Horizonte	MG	SE	F	C	C
IAL	Coleção de Aves, Instituto Adolfo Lutz, Secretaria Estadual de Saúde, Governo de São Paulo	São Paulo	SP	SE	S	NC	NC, D
IB/UFRJ (UFRJ)	Museu de Zoologia, Coleção Ornitológica, Instituto de Biologia, Universidade Federal Rural do Rio de Janeiro, UFRJ	Seropédica	RJ	SE	F	A	NC
MBML	Coleção Ornitológica, Museu de Biologia Prof. Mello Leitão, Instituto Nacional da Mata Atlântica	Santa Teresa	ES	SE	F	C	C, D
MCN-UNESP	Coleção de Aves, Museu de Ciências da Natureza, Universidade Estadual Paulista, UNESP, Campus de Rio Claro	Rio Claro	SP	SE	S	NC	NA
MCNA (MCNP)	Museu de Ciências Naturais, Pontifícia Universidade Católica de Minas Gerais, PUC-Minas	Belo Horizonte	MG	SE	P	NC	C
MHNB	Coleção de Aves, Museu de História Natural, Universidade Estadual Paulista, UNESP, Campus Botucatu	Botucatu	SP	SE	S	NC	CNC
MHNPAP	Museu de História Natural Professor Antônio Pergola	Atibaia	SP	SE	M	NA	NC
MHNT	Coleção de Aves, Museu de História Natural de Taubaté, Fundação de Apoio à Ciência e Natureza, FUNAT	Taubaté	SP	SE	P	C	C
MHN-UFJF	Museu de História Natural, Universidade Federal de Juiz de Fora, UFJF	Juiz de Fora	MG	SE	F	A	NC

Acronym	Collection	City	State	Region	Jurisdiction	Aleixo & Straube (2007)	This study
MN	Coleção de Aves. Setor de Ornitologia, Departamento de Vertebrados, Museu Nacional, Universidade Federal do Rio de Janeiro, UFRJ	Rio de Janeiro	RJ	SE	F	C	C, D
MZUFU	Museu de Zoologia, Universidade Federal de Uberlândia, UFU	Uberlândia	MG	SE	F	A	NC
MZUFV	Museu de Zoologia João Moojen de Oliveira, Universidade Federal de Viçosa, UFV	Viçosa	MG	SE	F	C	C
MZUSP	Coleção Ornitológica, Museu de Zoologia da Universidade de São Paulo, USP	São Paulo	SP	SE	S	C	C
UENF	Universidade Estadual do Norte Fluminense	Campos	RJ	SE	S	A	NC
ZUEC	Coleção Ornitológica, Museu de Zoologia Adão José Cardoso, Universidade Estadual de Campinas, UNICAMP	Campinas	SP	SE	S	C	C, D
ANCHIETA	Museu Anchieta de Ciências Naturais, Colégio Anchieta	Porto Alegre	RS	S	P	NA	C
CZFURB	Coleção Zoológica, Universidade Regional de Blumenau, FURB	Blumenau	SC	S	P	C	NC
MCN	Coleção Ornitológica, Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul	Porto Alegre	RS	S	S	C	C
MCNCR	Museu de Ciências Naturais Carlos Ritter, Universidade Federal de Pelotas, UFPEL	Pelotas	RS	S	F	A	C
MCNCS	Museu de Ciências Naturais, Universidade de Caxias do Sul, UCS	Caxias do Sul	RS	S	P	A	C
MCN-UFPR	Museu de Ciências Naturais, Universidade Federal do Paraná, UFPR	Curitiba	PR	S	F	NC	NC
MCP	Coleção de Ornitologia, Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul, PUCRS	Porto Alegre	RS	S	P	C	C, D
MEHS	Coleção de Aves, Museu de Ciências Naturais, Universidade Estadual do Centro-Oeste, UNICENTRO, Campus Cedeteg	Guarapuava	PR	S	S	NC	CNC
MGS	Museu Guido Straube, Colégio Estadual do Paraná	Curitiba	PR	S	S	A	NC
MHNCI	Coleção Ornitológica, Museu de História Natural Capão da Imbuia, Secretaria Municipal de Meio Ambiente, Prefeitura Municipal de Curitiba	Curitiba	PR	S	M	C	C, D

Acronym	Collection	City	State	Region	Jurisdiction	Aleixo & Straube (2007)	This study
MHNLTS	Museu de História Natural Prof. Luiz Trajando da Silva, Universidade Estadual do Norte do Paraná, UENP	Cornélio Procopio	PR	S	S	NC	NC
MLE	Museu Luiz Englert, Universidade Federal do Rio Grande do Sul, UFRGS	Porto Alegre	RS	S	F	A	NA
CAFURG ¹ (MOEGR)	Coleção de Aves da Universidade Federal do Rio Grande, FURG	Rio Grande	RS	S	F	A	C
MOVI	Coleção Ornitológica, Museu Oceanográfico, Universidade do Vale do Itajaí, UNIVALI	Itajaí	SC	S	P	C	CNC
MSQ	Museu Sete Quedas, Prefeitura Municipal de Guaíra	Guaíra	PR	S	M	NC	NC
MUCIN (MOUFRGS)	Museu de Ciências Naturais, Centro de Estudos Costeiros, Limnológicos e Marinhos, CECLIMAR, Universidade Federal do Rio Grande do Sul, UFRGS	Imbé	RS	S	F	A	C
MUCPEL	Museu de História Natural, Universidade Católica de Pelotas, UCPel	Pelotas	RS	S	P	NA	C
MuRAU (MRAUM)	Coleção de Aves, Museu Regional do Alto Uruguai, Universidade Regional Integrada do Alto Uruguai, URI, Campus de Erechim	Erechim	RS	S	P	NC	C
MUZAR	Coleção de Aves, Museu Zoológico Augusto Ruschi, Universidade de Passo Fundo, UPF	Passo Fundo	RS	S	P	NC	C
MZPUCPR	Coleção de Aves, Museu de Zoologia, Pontifícia Universidade Católica do Paraná, PUCPR	Curitiba	PR	S	P	C	C
MZUEL	Coleção de Aves, Museu de Zoologia, Universidade Estadual de Londrina, UEL	Londrina	PR	S	S	NC	C, D
UFSC	Coleção de Aves, Universidade Federal de Santa Catarina, UFSC	Florianópolis	SC	S	F	A	NC
ULBRA	Museu de Ciências Naturais, Setor de Zoologia de Vertebrados e Invertebrados, Universidade Luterana do Brasil, ULBRA	Canoas	RS	S	P	NA	NC
UNISC	Universidade de Santa Cruz do Sul, UNISC	Santa Cruz do Sul	RS	S	P	NA	C
UNISINOS	Universidade do Vale do Rio dos Sinos, UNISINOS	São Leopoldo	RS	S	P	NA	C

¹ Correct acronym (L. Bugoni pers. comm.).

were not investigated (collections NA), among them the MLE (Coleção de Mineralogia e Petrologia da UFRGS), which had been cited by Aleixo & Straube (2007) for future investigation of the presence of specimens of birds. Two collections were found only in online database of the CRIA system (*SpeciesLink*) or SiBBR - CRAR and ZEE-AVI. The first is a small reference collection of the avifauna of Rondônia, with 24 records online. The second is a collection of relevance, from the Zoneamento Ecológico-Econômico do Acre – Avifauna, da Secretaria do Meio Ambiente do estado do Acre, in Rio Branco. This collection has 3561 records online, the majority of which are specimens preserved, and several of them collected by Fernando Novaes and Olivério Mário de Oliveira Pinto in the 1950s.

We contacted 24 more collections than Aleixo & Straube (2007) and added 27 collections to their list of Brazilian Ornithological Collections. We considered 13 more collections in the current study (see Table 1).

The 35 collections considered (C) have 335,152 listed specimens (*e.g.*, skins, skeletons, skin-skeletons, tissues, nests and eggs) (Table 2). About 80% of these collections are kept with federal (17) or private (12) funds and 20% are maintained by state (5) and municipal (1) funds. The representativeness of the collections are mainly to the regional or state levels (66%), but 12 collections have some representation of birds from Brazil, South America and the world (34%). Most of the collections are from southeastern and southern Brazil, from sites located in the Atlantic Forest Biome (~60%). Among the new collections or those which grew the most, two are in northern Brazil (MPEG and INPA); one is in northeastern Brazil (CAHZ); one in midwestern Brazil (COMB); and five are located in southeastern (the MZUSP, MN, MHNT and DZUFMG), and in southern Brazil (MCP) (Fig. 1, Table 2). Some collections from the northern, midwestern, southeastern and southern regions also have preserved complementary materials such as gonads, stomachs, syringes, eyes, tongues, ecto and/or endoparasites (Fig. 2). In 10 years, we observed an increase in the number of collections in northeastern and southern Brazil. Northeastern collections are mostly young collections (initiating in the 2000s), such as the collections from Paraíba state, Bahia state (Feira de Santana), Alagoas state, and Rio Grande do Norte state. These are being cited for the first time in this survey and maintain collections in the style of the most traditional ornithological collections, with skins, skeletons, nests and eggs and with little supplementary material (Fig. 2). Although young, these collections are well organized and are important for their representation of the avifauna of the Caatinga Biome, in addition to the Atlantic Forest Biome.

Based on the answers, we could classify the collections into three types:

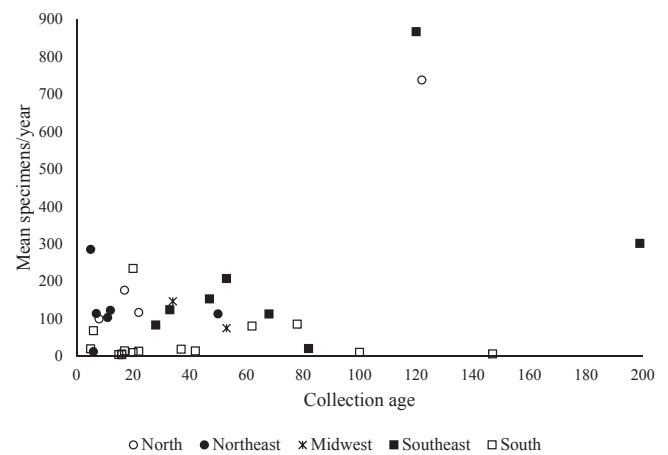


Figure 1. Growth of collections according to the annual rate of specimens accessed since their foundation. Each collection listed in Table 2 is represented with the symbol of its regional localization. Original data is presented in Table 2.

(1) Exhibition collections - located in institutions that have primarily didactic purposes, although they also have material that is scientifically relevant. Examples are the collection of the Museu Anchieta, Porto Alegre, Rio Grande do Sul state - RS, which has perhaps the last *Harpia harpyja* specimen from the metropolitan region of Porto Alegre (RS) (Bencke *et al.* 2003); and the Museu de Ciências Naturais Carlos Ritter (MCNCR) with an important collection of birds from RS collected by the naturalist Carlos Ritter, who lived from 1851 to 1926 in Pelotas. These collections are curated and continue to carry on the activities they support, although their holdings are not growing (Fig. 1). Other collections such as the Museu Guido Straube (MGS), or the Museu Sete Quedas (MSQ) which did not respond to the questionnaire, would be classified as Exhibition collections.

(2) Inactive or underactive collections - located mostly in public and private university teaching institutions, which do not have associated museums and which therefore depend on the voluntary action of collaborating researchers, students and teachers in order to maintain the collection's adequate structure. This contingent of personnel is ephemeral and/or the researchers fail to meet all the demands of maintaining a collection, which, after being initiated, are stagnated or go through processes of temporary growth and stagnation. Such collections that are not growing in number of specimens, without visitation or research in the last years, or do not even have staff to respond to the demands related to maintenance of the collection, such as answering our questionnaire. Under this category are included didactic and reference collections for undergraduate classes (Tables 1 & 2).

(3) Active collections - collections of museums or/and universities that have curatorship and/or researchers taking care of the collection and minimal infrastructure

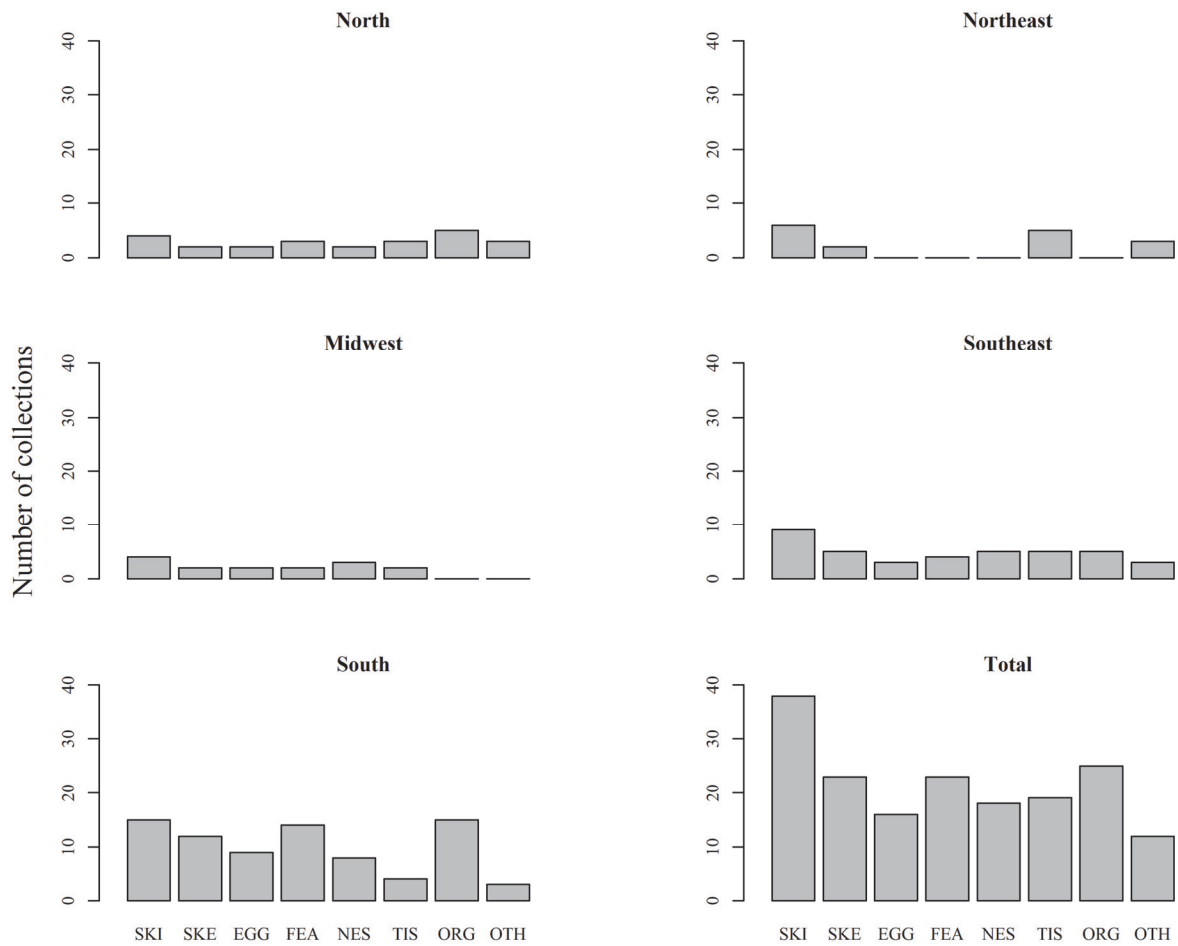


Figure 2. Types of ornithological materials available in collections by Brazilian region. Abbreviations: SKI – skin, SKE – skeleton, EGG – egg, FEA – feathers (feathers and open wing), NES – nest, TIS – tissue, ORG – organs (gonads, eyes, tongue, syrinx and gizzard), OTH – others (specimens in liquid, stomach contents, photo, video, claw, endo- and ectoparasites). Original data is presented in Table 3.

Table 2. Information on the 35 Brazilian ornithological collections that answered the questionnaire in full, and comparisons with the data provided by Aleixo & Straube (2007). Collections are sorted by current number of specimens. Collection acronyms are listed in Table 1. Region: N – north, NE – northeast, CO – midwest, SE – southeast, S – south. Geographic scope: S - State, R – Regional, B - Brazilian, SA – South America, W - Worldwide. Biome: Am – Amazon, Ce – Cerrado, Ca – Caatinga, Af – Atlantic Forest, Pt – Pantanal, P – Pampas, C - Coastal. The data in parentheses are from Aleixo & Straube (2007), different from the current data received.

Collection	Region	Foundation year	Number of specimens		Growth (%)	Number of type specimens		Geographic scope	Biome
			Aleixo & Straube (2007) ¹	This study		Aleixo & Straube (2007) ¹	This study		
MZUSP	SE	1897 (1898)	83,400	104,000	20	140	150	SA, W	Af, Ce
MPEG	N	1895	58,874	90,000	35	80	111	W	Am
MN	SE	1818 (1915)	58,100	60,000	3	n.i.	114	B	Af, Ce
MHNT	SE	1964	5650	11,000	50	-	-	W	Af
MBML	SE	1949	7508	7678	5	22	45	W	Af
DZUFMG	SE	1970	4550	7201#	38	1	-	B	Af, Ce
MHNCI	S	1939 (1930)	6100	6700	10	-	n.i.	R	Af
UFPE	NE	1967	NC	5659	-	NC	2	R	Ca, Af

Collection	Region	Foundation year	Number of specimens		Growth (%)	Number of type specimens		Geographic scope	Biome
			Aleixo & Straube (2007) ¹	This study		Aleixo & Straube (2007) ¹	This study		
COUFMT	CO	1983	NC	5000	-	NC	-	R	Ce, Pt
MCN	S	1955 (1950)	3635	5000	30	-	-	R	Af, P
MCP	S	1997	2365	4689	53	5	25	B	Af, P
MCNA	SE	1984	NC	4100	-	NC	-	B	Af, Ce
COMB	CO	1964 (1965)	2803	4000	31	-	-	R	Ce
INPA	N	2000 (1984)	633	3000	79	-	4	R	Am
NZT	N	1995 (1993)	2315	2577	10	-	-	W	Am, Ce
ZUEC	SE	1989 (1970)	1840	2340	30	-	-	B	Af, Ce
MZUFV	SE	1935 (1932)	1450	1700	16	-	-	R	Af
MZFS	NE	2005	NC	1473	-	NC	-	R	Af
CAHZ	NE	2012 (1976)	155	1428	89	-	-	R	Ca, Af
MMOL	NE	2006	NC	1140	-	NC	-	R	Ca, Af
ANCHIETA	S	1917	NC	1058	-	NC	-	R	Af, P
UNISINOS	S	1870	NC	933	-	NC	-	B, Antarctica	P, C
UFAC	N	2009	NC	800	-	NC	-	R	Am
MHN	NE	2010	NC	800	-	NC	-	R	Ca, Af
CAFURG	S	1980	NC	700	-	NC	-	B	Af, P, C
MUCPEL	S	1997	NC	600	-	NC	-	R	Af, P
MUCIN	S	2011	NC	411	-	NC	-	R	Af, P, C
MCNCS	S	1995	NC	300	-	NC	-	R	Af
MZPUCPR	S	2000 (1978)	378	250	-29*	-	-	S	Af
MuRAU	S	1975	NC	200	-	NC	-	R	P
MCNCR	S	2012	NC	100	-	NC	-	R	Af, P
UNISC	S	2001	NC	100	-	NC	-	R	Af
CHNUFPI	NE	2011	NC	75	-	NC	-	R	Am, Ce
MUZAR	S	2002	NC	70	-	NC	-	R	Af, P
MZUEL	S	2001	NC	70	-	NC	-	R	Af

¹ Sum of number of skins, anatomical collections and exhibition collection.

NC – not considered.

n.i. – not informed.

* negative value, we believe the curator informed us only of skins which did not change since Aleixo & Straube (2007).

pers. commun. by Marcelo Ferreira de Vasconcelos in 13 November 2017.

for the collection. These collections are generally well-established and can grow constantly because they are independent of the voluntary work. They have researchers and technicians and institutionally guaranteed infrastructure. Most of the collections compared in this work and in the previous study are of this type, as well as the largest and best-rated collections, such as MPEG, MZUSP, MCP, MN, INPA, MCN, MHNCI, MNHT, UFPE and MBML (Tables 2 & 3, Fig. 1).

The largest Brazilian collection (MZUSP) and the oldest (MN), in addition to other collections over 50 years old, are from the southeastern region. This region concentrates almost 60% of the ornithological collections of Brazil, with the youngest collection (MCNA) having more than 30 years. In contrast, the collections from northeastern Brazil are the youngest ones on average (Fig. 1). The collections of MZUSP and MN together have more than 250 type specimens of birds, exemplifying

their importance, although they are restricted to researchers until the present and their database is only partially computerized (see ranking, Table 3). Until 2015, 15 (40%) of the 38 collections analyzed were fully digitalized (CAFURG, CAHZ, CHNUFPI, DZUFMG, MBML, MCN, MCNA, MHN, MHNCI, MOVI, MPEG, MZFS, NZT, UNISINOS, ZUEC), 17 (45%) were partially digitalized, and only six (16%) were not digitized. In addition, four (11%) are available for general public consultation, 14 (37%) are restricted to researchers, and half (19) are available for internal use only. Approximately 50% of the 37 collections (35 collections considered, plus MCDB and MOVI) do not make any type of loan, while 35% (13) lend annually few materials (one to six loan proforma invoices). The percentage of collections with more than six documented loans is 15% (Table 3). We found the same pattern regarding visitors, with half of the collections (19) receiving on average one to six researchers annually, and 19% (7) receiving more than 19 researchers per year (Table 3). Finally, as for the published articles using the collection, 54% of them have one to four articles citing them, and about 22% of the collections have 13 or more published articles (Table 3). The MOG collection did not provide information regarding the issues: number of loans, number of visitors

and number of published articles. Only one collection (DZUFMG) informed that it does not have a curator.

DISCUSSION

The percentage of questionnaires returned was similar to that of Aleixo & Straube (2007), about 63% in both cases. This aspect suggests that the data compiled portrays most of the bird collections in Brazil and certainly the most important ones. The percentage of responses are higher than the results of the research conducted in 2013 by SiBBR to know the Brazilian scientific collections, whose questionnaire was answered by only 35% of the institutions (SiBBR 2017) and no collections were found in Amapá, Rondônia, Maranhão, Piauí and Goiás states. We verified using forms, internet and bibliographic sources that there are at least 23 Brazilian states and the Federal District with ornithological specimens in their collections; that is, seven more states than in the Aleixo & Straube study (2007). We did not find collections of birds in the states of Roraima, Maranhão and Sergipe only. We found some minor inconsistencies between the data of Aleixo & Straube (2007) and the present data (*e.g.*, acronyms, year of foundation, number of specimens; see

Table 3. Ranking of the most valuable Brazilian ornithological collections according to the criteria considered in this paper. Collection acronyms are listed in Table 1. Region: N – north, NE – northeast, CO – midwest, SE – southeast, S – south.

Collection	A	B	C	D	E	F	G	H	I	J	Total	Ranking	Region
MPEG	1	1	1	1	1	1	0.75	1	1	1	9.75	1	N
MZUSP	1	1	1	1	1	1	0.25	1	1	1	9.25	2	SE
MCP	0.5	1	1	1	1	1	0.75	0.75	0.5	1	8.5	3	S
MN	1	1	1	1	1	1	0.5	0.25	0.5	1	8.25	4	SE
INPA	0.5	0.75	1	1	0.5	1	0.25	1	0.5	1	7.5	5	N
MCN	0.75	0.25	1	0	1	0	0.75	0.75	0.5	1	6	6	S
MHNCI	0.75	0.25	0.5	1	0.5	0	1	0.75	0.5	0.5	5.75	7	S
MHNT	1	1	1	0	0.5	0	0	0.25	1	1	5.75	7	SE
UFPE	0.75	0.5	1	1	0	1	0.25	0.25	0.5	0.5	5.75	7	NE
MBML	0.75	0.5	0.5	0	0	1	1	0.25	1	0.5	5.5	8	SE
COMB	0.5	0.25	1	1	0.5	0	0.5	0.5	0.5	0.5	5.25	9	CO
COUFMT	0.75	0.5	1	0	1	0	0.5	0.5	0.5	0.5	5.25	9	CO
CAHZ	0.5	1	1	0	0	0	0.75	0.5	0.5	0.5	4.75	10	NE
MZFS	0.5	0.5	1	0	0.5	0	0.75	0.5	0.5	0.5	4.75	10	NE
CAFURG	0.25	0	1	0	1	0	0.75	0.25	0.5	0.5	4.25	11	S
MUCPEL	0.25	0	0.5	1	1	0	0	0.5	0.5	0.5	4.25	11	S
MUZAR	0	0	1	1	0.5	0	0.25	0.5	0.5	0.5	4.25	11	S
MZUFV	0.5	0	1	0	1	0	0.25	0.5	0.5	0.5	4.25	11	SE
UFAC	0.25	0.5	1	0	1	0	0	0.5	0.5	0.5	4.25	11	N

Collection	A	B	C	D	E	F	G	H	I	J	Total	Ranking	Region
MCNA	0.5	0.5	1	0	0	0	0.75	0.25	0.5	0.5	4	12	SE
MCNCS	0	0	1	1	0.5	0	0.25	0.25	0.5	0.5	4	12	S
MMOL	0.5	0.5	1	0	0.5	0	0.5	0.5	0.5	0	4	12	NE
MUCIN	0	0.25	1	0	1	0	0.25	0.5	0.5	0.5	4	12	S
NZT	0.5	0.5	0.5	0	0	0	0.75	0.25	1	0.5	4	12	N
UNISINOS	0.25	0	0.5	0	1	0	0.5	0.5	0.5	0.5	3.75	13	S
ZUEC	0.5	0.25	1	0	0	0	0.5	0.5	0.5	0.5	3.75	13	SE
DZUFMG	0.75	0.75	0	0	0	0	0.75	0.25	0.5	0.5	3.5	14	SE
ANCHIETA	0.5	0	0.5	0	0.5	0	0.5	0.25	0.5	0.5	3.25	15	S
MHN	0.25	0.5	1	0	0.5	0	0.5	0	0.5	0	3.25	15	NE
MOVI	n.i.	n.i.	0	0	0.5	0	0.75	0.5	0.5	1	3.25	15	S
MZUEL	0	0	0.5	1	0.5	0	0.75	0	0.5	0	3.25	15	S
MCNCR	0.5	0	1	0	0.5	0	0	0.5	0.5	0	3	16	S
MuRAU	0	0	0.5	0	0.5	0	0.25	0.75	0.5	0.5	3	16	S
CHNUFPI	0	0	0.5	0	0.5	0	0.5	0.25	0.5	0	2.25	17	NE
MCDB	n.i.	n.i.	0	0	0	0	0.25	0.5	1	0.5	2.25	17	CO
MZPUCPR	0	0	1	0	0	0	0.25	0.25	0	0.5	2	18	S
UNISC	0	0	0.5	0	0	0	0	0	0.5	0.5	1.5	19	S
MOG	n.i.	n.i.	0	0	0.5	0	0	n.i.	0.5	n.i.	1	20	CO

Avaliation Criteria:

(A) Total size of the collection - 1, greater than 10,000 specimens; 0.75, from 5,000 to 10,000 specimens; 0.5, from 1000 to 5000 specimens; 0.25, from 500 to 1000 specimens; 0, less than 500 specimens;

(B) Relationship between the total number of specimens/total years of existence (*i.e.*, annual growth rate) - 1, more than 200 specimens, 0.75, between 200 and 150 specimens; 0.5, between 150 and 100 specimens; 0.25, between 100 and 50 specimens; 0, less than 50 specimens;

(C) Curator - 1, presence of a curator and/or professional ornithologist in the collection (based on *Lattes CV*; www.lattes.cnpq.br); 0.5, without a curator but with a head researcher with a degree in any area of Zoology, based on the *Lattes CV*; 0, Museum general manager, even with an academic degree in a different area or who answered "no curator" in the questionnaire;

(D) Taxidermist - 1, presence of a taxidermist; 0, absence of a taxidermist;

(E) Diversification of the Collection - 1, six or more preparation forms (*e.g.*, skins, skeletons, tissues, nests, eggs, carcasses, syringes, stomachs, etc.); 0.5, between three and five types of preparation; 0, only one or two types of forms;

(F) Presence of type specimens reported (*e.g.*, Holotypes, Paratypes, Syntypes) - 1, presence; 0, absence;

(G) Average proportion of digitalization of the collection, such as: total digitalization (1), partial digitization (0.5) and non-digitalization (0), and the availability of the database to the public (1), to researchers (0.5), or only to the internal public (0);

(H) Average between the number of visits/year (1, more than 13 visits; 0.5, 1 to 12 visits; 0, no visit) and the number of loans per year (1, more than 12 loans; 0.5, 12 loans; 0, no loans);

(I) Geographical representativeness of the collection - 1 (Global); 0.5, regional (Brazil, regions); 0, state where the collection is located;

(J) Known citations of the collection in scientific articles - 1, 13 or more articles; 0.5, 1 to 12 articles; 0, no articles.

n.i. = not informed.

Tables 1 & 2); these must follow from the broad character and the simplified format of the general questions of our questionnaire, to minimize the time spent by the interviewee.

Corroborating the previous study, the southeastern and southern regions continue to be those with the highest number of ornithological collections, 39 of the 59 collections (approximately 66%). This result was expected due to the oldest and most traditional research in ornithology being located in southeastern Brazil, being the home of great ornithologists and bird collectors since the late nineteenth century, such as Herman von Ihering (MZUSP), Olivério Mário de Oliveira Pinto (MZUSP),

Helmut Sick (MN), Emilie Sneath (MN, besides MPEG), and Augusto Ruschi (MBML), among others. Another aspect to consider is the bias arising from the authors of this paper being from southern Brazil, which have more detailed knowledge of the collections of that region. Larger collections (MPEG, MN and MZUSP) also have the largest number of type specimens, around 375, approximately 83% of those in Brazil. Two other collections are worth mentioning in terms of the number of registered specimens - INPA and MCP - since they are relatively recent collections (up to 20 years since their foundation), with about 8000 specimens in total and 30 type specimens until 2015. There are some young

collections in the midwestern and northeastern regions of the country, which is desirable to improve the knowledge from such parts of the country and especially from the Pantanal, Cerrado and Caatinga Biomes.

As already reported in Aleixo & Straube (2007), few ornithological collections have projects aimed at scientific collections of specimens, and for this reason, the growth of these collections fluctuates. Several collections obtain specimens through donations, road kills, and studies using capture/release of birds, or specific taxonomic projects. In the previous diagnosis (data from 2005; Aleixo & Straube 2007), the Brazilian ornithological collections had problems of administration, infrastructure, maintenance and organization. They suggested at least five measures to overcome the obstacles faced by Brazilian ornithological collections, which made difficult for them to expand, diversify and modernize them: (1) development of institutional programs that can fund basic improvements and infrastructure; (2) professional training of people in curation, taxidermy and data digitalization; (3) create specific funding to finance publishing periodicals (*e.g.*, about collecting and taxidermy manuals), staff and student training, digitalizing data and other tasks related to curate of specimens and other aspects of ornithological collections; (4) funding proposals that guide the inventory and collection of ornithological specimens; and (5) regulation of the use of firearms by zoologists in scientific collections of specimens. In this regard we observed the follow issues. Only 12 (32%) of the 38 collections have a hired or resident taxidermist, which is not a higher value than that reported by Aleixo & Straube (2007), who mention that taxidermists exist in 45% of the 22 collections considered. The percentage of total digital data, however, increased from 18% to 40% and there was a decrease from 60% to 45% in the number of collections with only partially digital data, but the number of collections studied here is higher. These data are quite favorable when compared to 10 years ago, where there was no collection available online. The data digitalization is the first step in making data available to use, which means a great step forward in the advancement of knowledge. Such a task is easier for younger collections than for those that are older and larger. Perhaps for this reason, most digitalized collections are small or medium sized and bigger collections, with exception of MPEG, are still in the process to digitalizing. Two of the four collections with complete data digitalization in Aleixo & Straube (2007) are now available on the Internet (MPEG and MBML), which we considered a limited advance. Only a few collections are partially available to the public (CRAR, COUFMT, IAL, MCP, MHNCI, MZUEL, ZEE-AVI, ZUEC) despite availability of data being a requirement of support by government development agencies (CNPq, Agency of the Ministry of Science and Technology of Information and Communication

[MCTIC]), and in spite of initiatives involving the digitalization of the collections. This involves a paradigm shift in the use of collections and of initiatives of global knowledge of biodiversity such as the Systematic Agenda, whose mission was to understand the role of systematics in biology, education and politics (Claridge 1995, Lane 1996, Systematics Agenda 2000). An example of this is the CRIA (*SpeciesLink*) project, created in 2001, which integrates programs for managing collections around the world, such as the Specify Program, which has existed for 30 years.

Approximately 76% of the collections have up to eight publications citing specimens in their holdings, which may be a consequence of the expansion of the postgraduate courses in Zoology, improvement of Zoology courses according to the evaluation criteria used by "CAPES" (Coordination of Improvement of Higher Education Personnel), as well as an increase in the impact factors of journals in this area. Such aspects are among the main accomplishments made by collections since the publication of Aleixo & Straube (2007). Advances were also found in licenses to collect specimens with the use of digital systems of Sisbio (Information System of Brazilian Biodiversity) that allowed curators to handle quickly a permanent collecting license in the whole national territory. An amendment to the Brazilian national firearms control statute (PL 3722/12) is under analysis in Congress, and, if approved, will give every citizen the right to carry firearms, and in the case of biologists using guns for scientific purposed, registration will be with the Brazilian Army and will be valid for 5 years, being renewed in succession.

Regarding the new classification ranking of the collections we propose, large national collections also face problems related to the maintenance of the collection and there is little difference of quality among Brazilian collections. Twelve collections have reached a grade higher than 5 (from a 0 to 10 scale) and most of the collections have intermediate marks (between 4 to 5) (Table 3). Although most of the better-ranked collections are in the southeast and southern Brazil, it is in the northern Brazil that we find the best classified Brazilian collection (MPEG) according to our ranking system. This is due to the criteria used, which are not based solely on the number of species and representativeness of the collection, but also on their use and availability to the scientific community and the public.

Finally, we conclude that the Brazilian ornithological collections expanded the number of specimens recorded in the last 10 years by about 28% and the general use and issues related to maintenance and access had limited improvements in comparison with Aleixo & Straube (2007). We consider that the number of collections in Brazil is adequate, since it covers most states in the country. We recommend the improvement of the current

active collections instead of creating more collections. An exception to that would be the states where collections do not exist. There is still a shortage of projects and funding for collections in Brazil, and this requires a better understanding of the importance of scientific collections and where resources should be applied. Therefore, we suggest that improvement in personal, financial and logistical issues and the proper recognition of the active collections as a means of biodiversity conservation is still necessary in Brazil. Among the many benefits of collections cited here, we also highlight their relevance in supporting studies on bird ecology, understanding climate change and population declines, as well as habitat loss. Even field guide illustrators are dependent on the specimens of the collections (Joseph 2011, Cavarzere *et al.* 2017).

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APPENDIX I

Questionnaire sent to curators/managers of 59 Brazilian bird collections, in October 2014 and from January to March 2015.

Name of curator or manager

Name of Institution

Collection acronym

1. Year of collection's foundation

2. Approximate number of listed specimens

3. Presence of taxidermist (if there is a taxidermist hired)

a. Yes b. No

4. Nature of deposited material

a. Egg b. Feathers c. Skeleton d. Skin (taxidermy specimens)

e. Nest f. Tissue (muscle of the chest, heart, kidneys and liver)

g. Gonads h. Eyes i. Tongue j. Syrinx

k. Gizzard l. Open wing m. Other:

5. Presence of type specimen

a. Yes b. No

6. If yes, how many type specimens

7. Geographic scope of collection

a. Regional b. Brazilian c. Other:

8. Digitalization of the collection

a. No b. Partial c. Total

9. Digitalization is available

a. General public b. Restricted to researches c. Intern use

10. Number of annual loan documents

a. None b. 1 to 6 c. 7 to 12 d. 13 to 18

e. 19 or more f. We do not make a loan

11. Average annual visits to the collection

a. None b. 1 to 6 c. 7 to 12 d. 13 to 18 e. 19 or more

12. Number of published articles citing collection

a. None b. 1 to 4 c. 5 to 8 d. 9 to 12 e. 13 or more