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Inventory

The butterflies of Cristalino Lodge, in the Brazilian southern Amazonia: An updated species list with a significant contribution from citizen science

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Abstract: The richest butterfly communities in the world are found in the Amazon rainforest. Despite of this, and the importance of species inventories for the knowledge of diversity patterns, there are few comprehensive lists of butterflies for localities in the Brazilian Amazon. Here, we present an updated list of the butterflies of Cristalino Lodge (Alta Floresta, Mato Grosso, Brazil), in southern Amazonia, based on specimens collected by researchers and photographic records taken by ecotourists, butterfly watchers, and tour guides. With 1010 species recorded, this is currently the largest list of butterflies published for a single locality in Brazil and the first to reach (and surpass) 1000 species, with more than one third of the records coming from citizen science. The region has about 29% of the butterfly species in Brazil and one of the greatest richnesses known in the country, inferior only to areas in the western Amazon. Its fauna is mainly composed of species widely distributed in lowland Amazonia, with the addition of some species typical of the Cerrado. It has a relatively low number of species of the tribe Ithomiini (Nymphalidae: Danainae), generally considered a good indicator of the total butterfly diversity in neotropical forests, which points to the need for caution when using a single taxonomic group as a surrogate of richness of entire communities. The present work highlights the importance of citizen science and ecotourism centers for inventories and data on species distribution in diverse tropical forests.

Keywords: *Amazon Forest; arch of deforestation; butterfly watching; ecotourism; iNaturalist.*

As borboletas do Cristalino Lodge, no sul da Amazônia: Uma lista atualizada de espécies com contribuição significativa da ciência cidadã

Resumo: As comunidades de borboletas mais ricas do mundo são encontradas na Amazônia. Apesar disso, e da importância dos inventários de espécies para o conhecimento dos padrões de diversidade, existem poucas listas abrangentes de borboletas para localidades da Amazônia brasileira. Aqui, apresentamos uma lista atualizada das borboletas do Cristalino Lodge (Alta Floresta, Mato Grosso, Brasil), no sul da Amazônia, baseada em espécimes coletados por pesquisadores e em registros fotográficos feitos por ecoturistas, observadores de borboletas e guias turísticos. Com 1010 espécies registradas, essa é atualmente a maior lista de borboletas publicada para uma localidade no Brasil e a primeira a atingir 1000 espécies, sendo mais de um terço dos registros provenientes da ciência cidadã. A região apresenta cerca de 29% das espécies de borboletas do Brasil e uma das maiores riquezas conhecidas no país, inferior apenas a áreas no oeste da Amazônia. Sua fauna é composta principalmente por espécies amplamente distribuídas na planície amazônica, com adição de algumas típicas do Cerrado. Possui um número relativamente baixo de espécies da tribo Ithomiini (Nymphalidae: Danainae), que é geralmente considerada uma boa indicadora da riqueza total de borboletas em florestas neotropicais, o que aponta para a necessidade de cautela ao se usar um grupo taxonômico como previsor da riqueza de comunidades inteiras. O presente trabalho destaca a importância da ciência cidadã e dos centros de ecoturismo para inventários e dados sobre distribuição de espécies em florestas tropicais diversas.

Palavras-chave: *Floresta Amazônica; arco do desmatamento; observação de borboletas; ecoturismo; iNaturalist.*

Introduction

The world faces a biodiversity crisis, with habitats being lost and species becoming extinct at a rate that is unprecedented in historical times (Hoekstra et al. 2005, Ceballos et al. 2015). In this context, local species inventories are especially important because they help to clarify diversity patterns and species distribution, and to identify efficient conservation strategies (Balmford & Gaston 1999, Meyer et al. 2015). However, even for a relatively well-known group of invertebrates such as the butterflies, there are areas where available occurrence data is scanty, especially in portions of tropical forests, which contain the bulk of the planet's terrestrial biodiversity, such as the Amazon Basin (Girardello et al. 2019). Historically, a great part of our knowledge of the Amazonian fauna has come from expeditions that followed rivers stopping periodically to sample, instead of focusing on single areas, and the specimens gathered by such expeditions, frequently without precise geographic data, are scattered through museum collections and in need of thorough review (Casagrande et al. 2012). As for studies that focus on local faunas, the richest butterfly communities in the world have been found in western Amazonia (Lamas 1985, Emmel & Austin 1990, Robbins et al. 1996, Brown & Freitas 2002). Yet, Santos et al. (2008) showed that there are few species lists for the Brazilian Amazon Forest, compared to most other biomes in the country. Although the number of butterfly inventories in Brazil has increased considerably since then (Shirai et al. 2019), the number of comprehensive inventories for single localities in the more than 4000000 km² of Brazilian Amazonia is still low, considering that most of the studies rely on relatively small sampling efforts (e.g., Ebert 1965, Garcia et al. 1990, Mielke & Casagrande 1991, Mielke et al. 2010, Martins et al. 2017a, Oliveira et al. 2021), do not include actual species lists (e.g., Brown 1984, 2005, Brown & Freitas 2002), or use a small subset of the butterflies, the fruit-feeding nymphalids, to answer ecological questions (e.g., Ramos 2000, Ribeiro & Freitas 2012, Graça et al. 2017a, b, Martins et al. 2017b, Montejo-Kovacevich et al. 2018, Araujo et al. 2020, Rabelo et al. 2021). Contributing reasons for this outcome include low human population densities near these sites, difficult access, and distance to most Brazilian research centers, which makes it difficult and expensive for scientists to produce long-term inventories in most of the Brazilian Amazon Forest.

In recent years, however, the growing interest in citizen science has proven to be increasingly helpful for the documentation and generation of biodiversity data, by taking advantage of new and easier ways to gather, access, produce and share this information (Dickinson et al. 2012, Mazumdar et al. 2018). Such efforts can aid in filling knowledge gaps for butterflies (Girardello et al. 2019, Mesaglio et al. 2021). One interesting case relevant to the Amazon Forest was the publication of the book "Butterflies of Southern Amazonia: A Photographic Checklist of Common Species" (Garwood & Lehman 2007), which compiled images of live butterflies representing some 2000 species, recorded by several butterfly watchers and ecotourists, especially in Amazonian lodges and ecotourism centers across Peru, Bolivia, and Brazil. This publication included several images taken at Cristalino Lodge, in Alta Floresta, Mato Grosso state, Brazil, information that has already been used in studies of the state of knowledge of butterflies in Brazil (Santos et al. 2008, Queiroz-Santos et al. 2016, Shirai et al. 2019). Photographic records have continued to be made in this location ever since; furthermore, the region has been equally attractive to researchers, and the focus of several expeditions by the authors of this paper, which have resulted in the description of a Satyrini genus (Freitas et al. 2019), a new subspecies of ithomiine (Mota et al. 2022), descriptions of immature stages (Freitas & Brown 2002, 2008, Mota et al. 2020), and research on butterfly communities and mimicry (Mota et al., in preparation). Here, we present a butterfly list for the Cristalino Lodge based on all data collected during field expeditions and the records made by butterfly watchers and ecotourists.

Materials and Methods

1. *Study site*

The Cristalino Lodge (centered at 9°35'51''S, 55°55'52''W) is located in northern Mato Grosso State, in the municipality of Alta Floresta, central Brazil (Figure 1). The climate in the region is warm and humid, with average annual temperature of 24°C, annual rainfall above 2400 mm, with a marked dry season lasting from 3 to 5 months (Nimer 1989). Soils are mostly red-yellow latosols and altitudes vary from 100 m to 400 m at the top of small rocky outcrops (locally known as "serras") (Sazaki & Farias 2008, Müller & Farias 2010). The region is in the southern part of the Amazon Forest, and the vegetation is heterogeneous, presenting various phytophysiognomies (Figure 2 A-D) including evergreen (Figure 2 A,B), igapó (floodplain), bamboo, semi-deciduous and deciduous forests (the latter usually associated with patches of rocky outcrops in the "serras") (Figure 2 D). Despite the proximity to the Cerrado savannas, these are not represented in the region; the open vegetation types in this area are of a different origin (Zappi et al. 2011). The region is situated in the so-called "arch

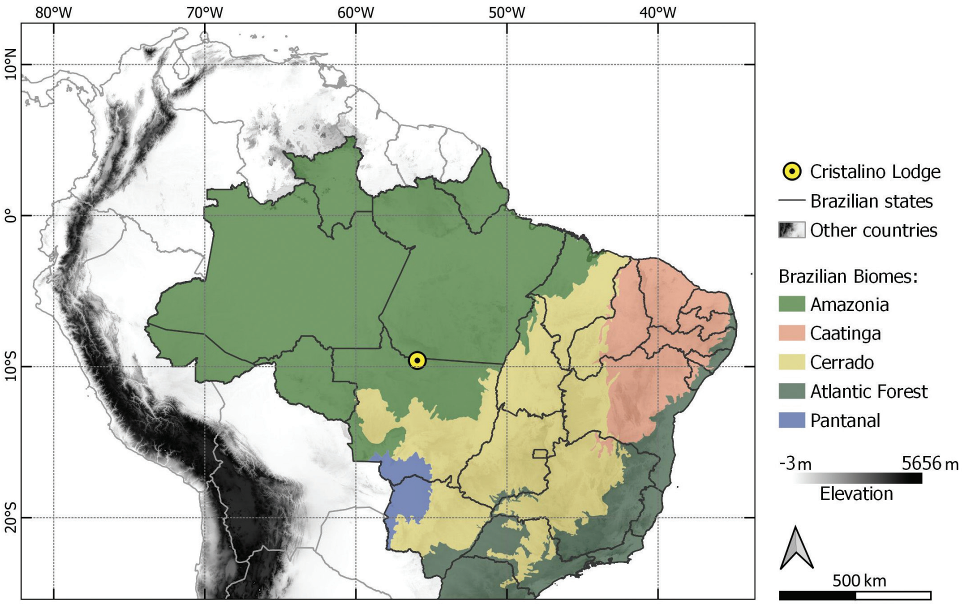

Figure 1. Map showing the location of Cristalino Lodge within the Brazilian Amazon Forest.

of deforestation" and has undergone great land-use change related to goldmining, agriculture, and cattle ranching since the foundation of Alta Floresta in 1976 (Dubreuil et al. 2012).

Cristalino Lodge was created in 1992 and has attracted ecotourists, photographers, and bird and butterfly watchers ever since. It is associated with an ecological foundation (Cristalino Ecological Foundation, CEF) and four contiguous private reserves (Reservas Particulares do Patrimônio Natural) that surround it, located in the municipalities of Alta Floresta and Novo Mundo. The lodge was named after the black waters of the Cristalino river (Figure 2 C), that crosses the area of the private reserves and is a tributary of the larger Teles Pires river, which delimits the reserves to the south. While most of the forest south of Cristalino Lodge is fragmented (Lees & Peres 2006), the 72 km^2 of the Cristalino private reserves are contiguous to the Cristalino State Parks I and II (1849 km^2), which are also contiguous to other large conservation areas in the state of Pará. However, it is important to emphasize that Cristalino State Park II currently has its existence under legal dispute and suffers from deforestation and fires (https://g1.globo.com/mt/mato-grosso/noticia/2022/08/17/incendio-no-parque-do-cristalino-ii-em-mt-pode-ter-sido-causado-por-aeronave-diz-delegado.ghtml). Here, we consider as "Cristalino Lodge" the areas of the lodge itself, the four private reserves, the margins of the Cristalino river adjacent to the RPPNs, the Ariosto Island and the forest area located at the southern margin of the Teles Pires river, adjacent to the reserves, where visitors board the boats to access the lodge. These all form an area of forest that, apart from the rivers, is continuous and have a trail system that is explored by tourists that visit Cristalino Lodge.

2. *Field inventory*

Butterfly sampling was carried out during expeditions of 7–15 days between June and September (during the dry season, when butterflies are apparently more diverse and abundant in the region) in 2000 (twice), 2017 and 2018, and in a longer period between September 2015 and September 2016, with few temporal gaps, as part of a study that was not designed for inventorying species. Most collecting was made through active searching with entomological nets. Additionally, a few Van Someren-Rydon traps baited with banana fermented with beer and installed in the understory were used in the earlier expeditions, in addition to the Ahrenholz technique in 2018, which consists of attaching paper soaked in saliva on leaves in the understory, to attract mostly Hesperiidae (Lamas et al. 1993). Collected butterfly specimens were stored in a freezer, and at least one of each morphospecies was spread and deposited in the entomological collection of the Museu de Diversidade Biológica, Universidade Estadual de Campinas (Unicamp), Campinas, São Paulo, Brazil.

3. *Image searching*

To examine butterfly images for additional species from the region, we intensively searched a number of sources, including websites and books. We focused on the images that could add new records to the list, with a search process in two phases. Firstly, we conducted an initial rapid assessment in which pictures of species that are easy to identify and that had already been recorded were ignored, and separated out other images for further examination. In the second phase, selected images were checked as to their photographer and provenance, to confirm whether they had actually been taken at Cristalino Lodge, and reviewed for potential new taxonomic records. The images selected in the second phase were subsequently sent for identification by specialists and the authors of this paper. Not all pictures could be reliably identified to species level (even if the source suggested an identification), either due to poor image quality or because the specimen belonged to a group which requires dissection or closer inspection for identification. We thus ignored any pictures which the specialists were unable to confirm as a new taxon (e.g., species group, genus or tribe) for Cristalino. We only used photographic records; trip reports and other written records were ignored if not associated with images that could be checked, even if those records were made by knowledgeable people and might be reliable.

The sources and specific searching methods, following the two-phase approach described above, were as follows: We checked every record in the books "Butterflies of Southern Amazonia" (Garwood & Lehman 2007),

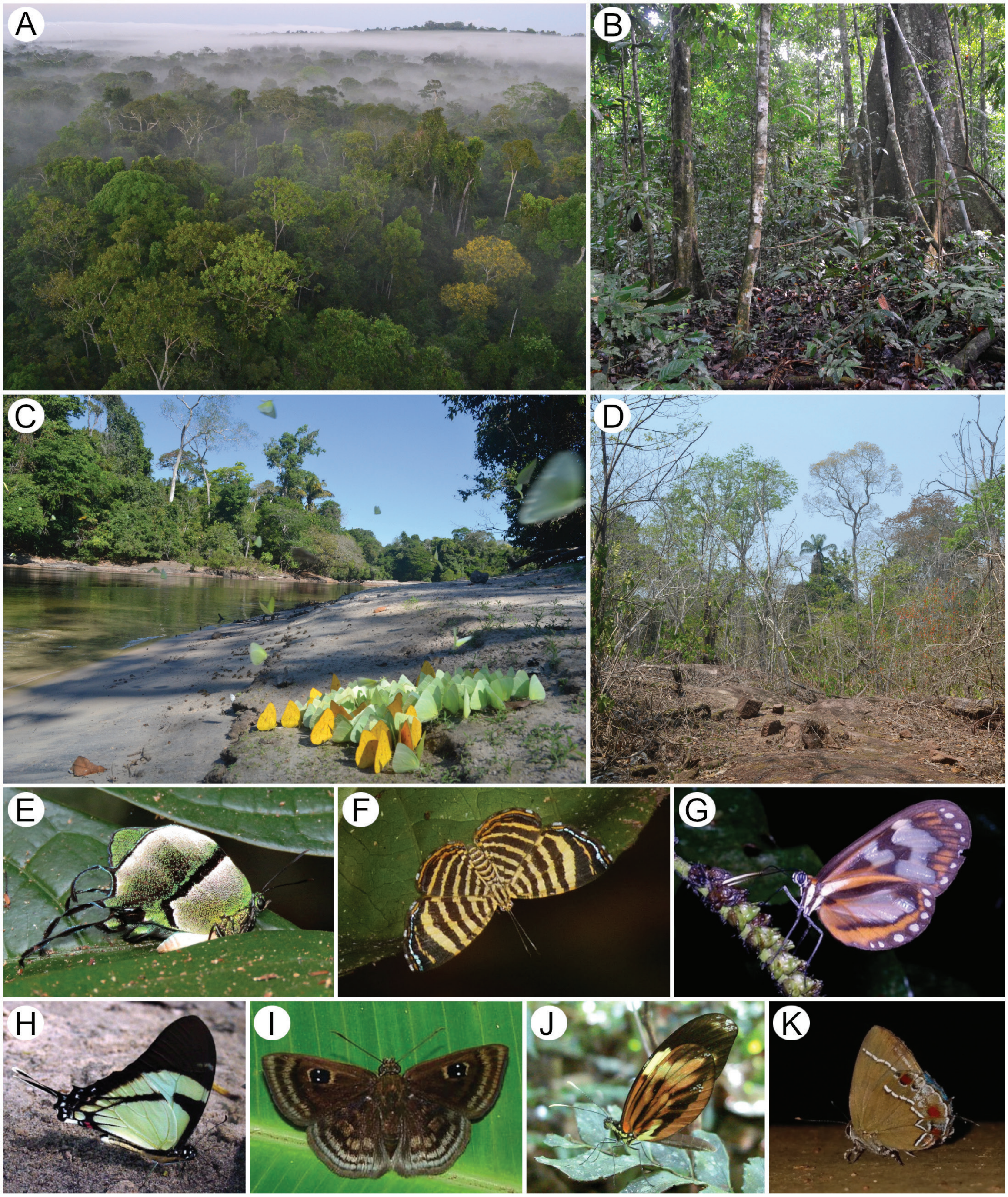

Figure 2. Environments and butterflies of Cristalino Lodge. A) View of evergreen forest from a 50 m. observation tower; B) Interior view of evergreen forest; C) *Phoebis* spp. puddling near the Cristalino River; D) View of deciduous forest during the dry season (~June-September); E-G) Examples of butterfly species that have been recorded in Cristalino Lodge through pictures only. E) *Arcas tuneta* (Lycaenidae), picture by Sidnei M. Dantas; F) *Argyrogrammana glaucopis* (Riodinidae), picture by Stephen J. Boddington; G) *Hypothyris leprieuri ninyas* (Nymphalidae), picture by Richard C. Hoyer; H) *Eurytides callias* (Papilionidae), picture by Kim Garwood; I) *Cyclosemia* sp. (Hesperiidae), picture by Will Carter; J) *Dismorphia amphione* (Pieridae), picture by Gill Carter; K) Undescribed Lycaenidae (tentatively identified as *Arumecla* sp.), picture by Sidnei M. Dantas.

"Borboletas do Brasil (three volumes)" (Palo jr. 2017) and "Lepidoptera: Borboletas e Mariposas do Brasil" (Almeida & Freitas 2012). The first contains several pictures from Cristalino Lodge, identified by the initials "CL". We used the online search platforms Google Search and Google Images, where all combinations of the keywords "butterflies", "butterfly", "borboletas", "borboleta" or "lepidoptera" with "Cristalino", "Cristalino Lodge" or "Alta Floresta" were used. At Google Search, we visited all sites and blogs in the first ten pages of results for each keyword combination; at Google Images, we checked every picture retrieved for every combination.

We also searched in specific websites and social media sites that specialize in pictures and/or butterflies where there was a reasonable likelihood of finding new records. In Flickr's search tool, we used the same combinations of keywords cited above, and checked all results (https://www.flickr.com). At Instagram (https://www.instagram.com), we searched for images of butterflies among every public picture with the hashtag "#cristalinolodge". At Tolweb (http://tolweb.org), we used "Cristalino Lodge" in the search resource, and checked all the pages about butterfly taxa shown in the results. At Borboletas e Mariposas (http://borboletaskmariposas.blogspot.com), we used "Cristalino" in the search resource and checked all the results. At Calydna database (https://calydna.com), we manually found the Cristalino region in the map present in the site, clicked at one of the records from the area, and then clicked in the location name ("Cristalino Jungle Lodge") beyond the taxon name; this led to a page with all records made at Cristalino Lodge, and we checked each one. We searched manually among the live specimen records at Butterflies of America (Warren et al. 2016), and checked every picture at the site Neotropical Butterflies (https://www.neotropicalbutterflies.com), which includes many of the same records of Butterflies of Southern Amazonia, and the "Butterflies of the Amazon and Andes" section of the site Learn about Butterflies (https://www.learnaboutbutterflies.com). The website Butterfly Catalogs (https://www.butterflycatalogs.com) provides a useful guide and checklist of the butterflies of Cristalino Lodge (Garwood & Jaramillo V. 2021), but it was not used here because the locality of each picture is given only as country. However, it includes many pictures that are also available in other sources, with finer locality data, and could therefore be used.

We made a special effort to compile and examine records submitted to iNaturalist (www.inaturalist.org). To more easily find records of interest, we created the project "Butterflies of Cristalino Lodge" in June 2019. In this kind of project, iNaturalist automatically adds all the pictures of the selected taxa (in this case, "butterflies") from a given locality. For this, we created in iNaturalist a locality named "Cristalino Lodge" that consists of a polygon which encompasses and slightly surpasses our area of interest (to account for imprecisions in the record locations given by the users).

The search for pictures was made in June of 2020, and the statistics of iNaturalist are from January 2022, about two years and a half after the creation of the project. Additionally, we checked pictures from the Cristalino Lodge archives and the images made by the first author during fieldwork (which were not added to iNaturalist before the submission of this work, to separate them from the citizen science records).

4. *Identification and taxonomy*

Collected specimens and pictures of live butterflies selected in the second phase of the image search were identified by specialists and the authors of this study. Although the live specimen images are usually identified at their sources, and frequently by knowledgeable people, all the images were sent to specialists and, thus, the identifications provided in the species list might differ from those at the original source. Apart from a few records available upon request to the first author, all the photographic records are published in books or on the internet and therefore can be checked, updated, or disputed. Information on the identification, photographers and photography sources of each taxon is available as supplementary material (Table S1).

We follow Heikkilä et al. (2012) for Papilionoidea, and the taxonomy of butterflies follows mostly Lamas (2004), updated after Wahlberg et al. (2009) for higher classification of Nymphalidae, Tyler et al. (1994) for Papilionidae, the Riodinidae Species Checklist (Seraphim 2019) and Zhang et al. (2021) for Riodinidae, Robbins (2004) and subsequent publications for Lycaenidae, the Euptychiina Species Checklist (Zacca et al. 2018) for Euptychiina, Murillo-Ramos et al. (2018) for *Phoebis*, Penz et al. (2017) for *Bia*, Penz (2021) for *Cithaerias*, Paluch (2006) for *Actinote* and Núñez et al. (2021) for *Agraulis* and *Dryas*. *Eurema furtadoi* Casagrande & Mielke, 1979, synonymized with *Eurema lirina* (H. Bates, 1861) by Lamas (2004), is tentatively used for a specimen different from another that is morphologically similar to the type of *Eurema lirina*. We follow the higher classification of Hesperiidae summarized by Zhang et al. (2019a), and the taxonomy of the group follows Mielke (2005) with recent updates (Cong et al. 2019, Li et al. 2019, Medeiros et al. 2019, 2020, Zhang et al. 2019b, c, 2022, Siewert et al. 2020, 2022).

5. *Species richness estimates*

Beccaloni & Gaston (1995) suggest that the nymphalid tribe Ithomiini is a good surrogate of the total butterfly fauna of neotropical forests, since this group is easy to sample and represent 4.3–4.6% of the butterfly species. Brown & Freitas (2000) indicates that the Nymphalidae fauna of a well sampled site represents 25–29% of the total butterfly community. Therefore, the numbers of recorded species of Nymphalidae and Ithomiini were both used to estimate the total butterfly species richness of Cristalino Lodge.

Results

We collected approximately 2500 specimens and searched for new records among thousands of images, whose number cannot be quantified because of our searching methods and the presence of many images that were repeated in more than one source and frequently cropped, inverted or with different identifications. As an example, the search for "butterfly" plus "Cristalino" at Flickr resulted in 782 images, and there were 157 images of butterflies among 4290 images tagged with "#cristalinolodge" at Instagram. About two years and a half after being created, the project "butterflies of Cristalino Lodge" in iNaturalist reported in its statistics a total of 3398 observations (specimens recorded), 839 species, 168 identifiers, and 59 observers (photographers). These numbers have continued to grow. Although not all images were labeled with correct species names or even could lead to a precise identification, these numbers give a good estimate of the scope of the project.

Combining information from collected specimens and photographic records, a total of 1010 species (1012 taxa, including subspecies), including Hedylidae and all butterfly families, were recorded at Cristalino Lodge (Table 1). The most represented family was Hesperiidae with 314 species, followed by Nymphalidae (301), Riodinidae (221), Lycaenidae (123), Papilionidae (24), Pieridae (23) and Hedylidae (4). The two species that had more than one recorded subspecies were the nymphalids *Heliconius numata* (Cramer, 1780) and *Memphis acidalia* (Hübner, [1819]).

A total of 351 species, representing 34.7% of all species, were recorded only through photographs (examples in Figure 2 E-K). Such records contributed with at least one quarter of each family. They were particularly important to the Lycaenidae, representing more than half of its species (52,8%) and to the Hesperiidae (41,1% of the species). A total of 318 of the species with photographic records only were recorded by 5 photographers (but not necessarily only them), who are either expert butterfly watchers and/or expedition guides: SMD (155), RCH (109), GC (74), SJB (57) and WC (50).

Table 1. List of the butterflies and moth-butterflies (Papilionoidea) of Cristalino Lodge. Total number: 1010 species. The number of species of each major taxa is provided within parenthesis. * Species recorded only through live specimen photographs; ** including or restricted to images made by the 5 photographers with the most records.

Papilionoidea (1010)	
Hedylidae (4)	
	Macrosoma heliconiaria (Guenée, 1858)
	Macrosoma lucivittata Walker, 1863
	Macrosoma rubedinaria Walker, 1862 **
	Macrosoma tipulata Hübner, 1818
Papilionidae (24)	
Papilioninae (24)	
Leptocircini (8)	*Eurytides callias* (Rothschild & Jordan, 1906) **
	Eurytides dolicaon (Cramer, 1775) **
	Mimoides ariarathes arianus (Staudinger, 1884)
	Mimoides pausanias pausanias (Hewitson,1852)
	Neographium agesilaus (Guérin-Méneville & Percheron, 1835)
	Neographium thyastes (Drury, 1782)
	Protesilaus glaucolaus (H. Bates, 1864)
	Protesilaus telesilaus (C. Felder & R. Felder, 1864)
Troidini (10)	*Battus belus* (Cramer, 1777)
	Battus crassus (Cramer, 1777)
	Battus lycidas (Cramer, 1777)
	Battus polydamas (Linnaeus, 1758) **
	Parides aeneas linoides K. Brown & Lamas, 1994
	Parides anchises cf. *humaita* D'Abrera, 1981
	Parides chabrias (Hewitson, 1852) **
	Parides neophilus eurybates (G. Gray, [1853])
	Parides sesostris sesostris (Cramer, 1779)
	Parides vertumnus cutora (G. Gray, [1853])
Papilionini (6)	*Heraclides anchisiades* (Esper, 1788)
	Heraclides androgeus (Cramer, 1775) **
	Heraclides astyalus (Godart, 1819)
	Heraclides hyppason (Cramer, 1775) **
	Heraclides thoas (Linnaeus, 1771) **
	Heraclides torquatus (Cramer, 1777) **
Pieridae (23)	
Dismorphiinae (5)	
	Dismorphia amphione (Cramer, 1779) **
	Enantia lina (Herbst, 1792) **
	Enantia melite vilma Lamas, 2004
	Moschoneura pinthous ssp.
	Pseudopieris nehemia limbalis Röber, 1924 **
Coliadinae (12)	
	Anteos menippe (Hübner, [1818]) **
	Eurema albula (Cramer, 1775)
	Eurema elathea (Cramer, 1777)
	Eurema furtadoi Casagrande & Mielke, 1979
	Eurema lirina (H. Bates, 1861)
	Phoebis cf. argante (Fabricius, 1775)
	Phoebis philea (Linnaeus, 1763)
	Phoebis cf. *sennae* (Linnaeus, 1758) *
	Phoebis statira (Cramer, 1777)
	Phoebis trite (Linnaeus, 1758)
	Pyrisita nise tenella (Boisduval, 1836)
	Pyrisitia leuce (Boisduval, 1836)
Pierinae (6)	
Anthocharidini (2)	*Cunizza hirlanda* (Stoll, 1790)
	Hesperocharis nera (Hewitson, 1852) **
Pierini (4)	*Ganyra phaloe phaloe* (Godart, 1819) **
	Glutophrissa drusilla drusilla (Cramer, 1777)
	Melete lycimnia (Cramer, 1777)
	Perrhybris pamela (Stoll, 1780) **
Lycaenidae (123)	
Polyommatinae (2)	
	Hemiargus hanno (Stoll, 1790)
	Leptotes cassius (Cramer, 1775)
Theclinae (121)	
Eumaeini (121)	*Arawacus separata* (Lathy, 1926)
	Arawacus tarania (Hewitson, 1868) *
	Arcas imperialis (Cramer, 1775)
	Arcas tuneta (Hewitson, 1865) **
	Arumecla sp. **
	Atlides atys (Cramer, 1779) **
	Atlides polybe (Linnaeus, 1763) **
	Aubergina alda (Hewitson, 1868)
	Brangas getus (Fabricius, 1787) **
	Brevianta ematheon (Cramer, 1777) **
	Calycopis anastasia complex
	Calycopis anfracta complex
	Calycopis atnius (Herrich-Schäffer, [1853])
	Calycopis bellera (Hewitson, 1877)
	Calycopis caesaries (H. Druce, 1907) **
	Calycopis centoripa (Hewitson, 1868) **
	Calycopis cerata (Hewitson, 1877)
	Calycopis demonassa (Hewitson, 1868)

Continue...

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Calycopis lerbela W. D. Field, 1967
Calycopis sp.1
Calycopis sp.2
Calycopis sp.3
Camissecla vesper (H. Druce, 1909)
Celmia celmus (Cramer, 1775)
Celmia color (H. Druce, 1907) **
Celmia conoveria (Schaus, 1902) **
Celmia mecrida (Hewitson, 1867) *
Chalybs janias (Cramer, 1779)
Cupathecla cupentus (Stoll, 1781)
Cyanophrys herodotus (Fabricius, 1793) **
Denivia hemon (Cramer, 1775)
Denivia lisus (Stoll, 1790)
Denivia phegeus (Hewitson, 1865)
Enos polka Lamas & Robbins, 2009 *
Erora sp.
Eumaeini sp.
Evenus batesii (Hewitson, 1865) **
Evenus satyroides (Hewitson, 1865)
Evenus sp. **
Hypostrymon asa (Hewitson, 1868)
Iaspis castinotus (K. Johnson & Le Crom, 1997) **
Iaspis sp. **
Iaspis temesa (Hewitson, 1868)
Iaspis verania (Hewitson, 1868) *
Ignata mulsus (H. Druce, 1907) **
Ipidecla crepundia (H. Druce, 1909) **
Janthecla leea Venables & Robbins, 1991
Janthecla malvina (Hewitson, 1867) **
Janthecla rocena (Hewitson, 1867)
Janthecla sista (Hewitson, 1867)
Kisutam syllis (Godman & Salvin, 1887)
Kolana cf. *buccina* (H. Druce, 1907) **
Lamprospilus orcidia (Hewitson, 1874) *
Michaelus jebus (Godart, [1824])
Michaelus joseph Robbins, 2010 **
Michaelus phoenissa (Hewitson, 1867)
Michaelus thordesa (Hewitson, 1867) **
Ministrymon azia (Hewitson, 1873) **
Ministrymon cleon (Fabricius, 1775) **

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Ministrymon cruenta (Gosse, 1880)
Ministrymon megacles (Stoll, 1780)
Ministrymon una (Hewitson, 1873)
Ministrymon zilda (Hewitson, 1873)
Mithras nautes (Cramer, 1779)
Nicolaea fabulla (Hewitson, 1868) **
Nicolaea opalia (Hewitson, 1868) **
Nicolaea petilla (Hewitson, 1868) **
Ocaria ocrisia (Hewitson, 1868)
Ocaria thales (Fabricius, 1793)
Oenomaus cf. *magnus* Faynel & Moser, 2008 **
Oenomaus minyia (Hewitson, 1867) **
Oenomaus ortygnus (Cramer, 1779) **
Oenomaus sp.1 **
Oenomaus sp.2 **
Olynthus essus (Herrich-Schäffer, [1853])
Olynthus cf. *obsoleta* (Lathy, 1926) **
Ostrinotes gentiana (H. Druce, 1907)
Ostrinotes silva (Faynel & Robbins, 2014) **
Ostrinotes sp.
Paiwarria telemus (Cramer, 1775)
Panthiades aeolus (Fabricius, 1775) **
Panthiades bitias (Cramer, 1777)
Panthiades boreas (C. Felder & R. Felder, 1865) **
Panthiades phaleros (Linnaeus, 1767) **
Paraspiculatus cf. *emma* Busby & Robbins, 2017 **
Paraspiculatus elis (Cramer, 1779) **
Parrhasius orgia (Hewitson, 1867)
Parrhasius polibetes (Stoll, 1781) **
Pseudolycaena marsyas (Linnaeus, 1758) **
Rekoa meton (Cramer, 1779) **
Rekoa palegon (Cramer, 1780) **
Rekoa stagira (Hewitson, 1867) **
Rubroserrata ecbatana (Hewitson, 1868) **
Siderus athymbra (Hewitson, 1867) **
Siderus cf. *leucophaeus* (Hübner, [1813]) **
Strephonota ambrax (Westwood, 1852)
Strephonota cyllarissus (Herbst, 1800)
Strephonota dindymus (Cramer, 1775) **
Strephonota cf. *parvipuncta* (Lathy, 1926) **

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	Strephonota cf. *strephon* (Fabricius, 1775) **
	Strephonota sp. **
	Strymon astiocha (Prittwitz, 1865) **
	Strymon megarus (Godart, [1824])
	Strymon mulucha (Hewitson, 1867) **
	Strymon yojoa (Reakirt, [1867])
	Strymon ziba (Hewitson, 1868) **
	Symbiopisis sp.
	Terenthina terentia (Hewitson, 1868)
	Theclopsis gargara (Hewitson, 1868)
	Theclopsis lydus (Hübner, [1819])
	Thereus enenia (Hewitson, 1867) **
	Thereus pedusa (Hewitson, 1867) **
	Theritas mavors Hübner, 1818
	Thestius selina (Hewitson, 1869)
	Tmolus cydrara (Hewitson, 1868) **
	Tmolus echion (Linnaeus, 1767)
	Tmolus mutina (Hewitson, 1867)
	Tmolus ufentina (Hewitson, 1868) **
	Trichonis immaculata Lathy, 1930 **
	Ziegleria ceromia (Hewitson, 1877) **
	Ziegleria hesperitis (A. Butler & H. Druce, 1872) **
Riodinidae (221)	
Nemeobiinae (35)	
Euselasiini (35)	*Erythia labdacus* (Stoll, 1780) **
	Eugelasia brevicauda (Lathy, 1926)
	Eugelasia eugeon (Hewitson, 1856)
	Eurylasia euryone (Hewitson, 1856)
	Euselasia angulata (H. Bates, 1868)
	Euselasia calligramma (H. Bates, 1868) **
	Euselasia cf. *praeclara* (Hewitson, 1869) **
	Euselasia clithra (H. Bates, 1868)
	Euselasia erilis Stichel, 1919
	Euselasia euphaes (Hewitson, [1855]) **
	Euselasia euriteus (Cramer, 1777)
	Euselasia euromus (Hewitson, 1856)
	Euselasia eurypus (Hewitson, 1856)
	Euselasia eutaea (Hewitson, [1853])
	Euselasia eutychus (Hewitson, 1856)
	Euselasia gelanor (Stoll, 1780)
	Euselasia kartopus Stichel, 1919
	Euselasia nr. *attrita*
	Euselasia orba Stichel, 1919
	Euselasia phelina (H. Druce, 1878)
	Euselasia scotinosa Stichel, 1930 **
	Euselasia toppini Sharpe, 1915
	Euselasia uria (Hewitson, [1853])
	Euselasia uzita (Hewitson, [1853]) **
	Euselasiae euoras (Hewitson, [1855])
	Methone cecilia magnarea (Seitz, 1913)
	Methone dolichos (Staudinger, [1887]) **
	Myselasia cafusa (H. Bates, 1868) **
	Myselasia crinon (Stichel, 1919)
	Myselasia eustola (Stichel, 1919)
	Myselasia mys (Herrich-Schäffer, [1853])
	Pelolasia euboea (Hewitson, [1853])
	Pelolasia eumenes (Hewitson, [1853])
	Pelolasia melaphaea (Hübner, 1823)
	Pelolasia pellonia (Stichel, 1919)
Riodininae (186)	
Eurybiini (42)	*Alesa amesis* (Cramer, 1777)
	Alesa lipara H. Bates, 1867
	Alesa prema (Godart, [1824]) **
	Ectosemia eumene (Cramer, 1776)
	Eurybia albiseriata stellifera Stichel, 1910 **
	Eurybia caerulescens H. Druce, 1904 **
	Eurybia dardus (Fabricius, 1787) **
	Eurybia halimede halimede (Hübner, [1807])
	Eurybia molochina hyathincina Stichel, 1910
	Eurybia nicaeus (Fabricius, 1775) **
	Eurybia patrona Weymer, 1875 **
	Hyphilaria parthenis (Westwood, 1851)
	Ithomiola orpheus (Westwood, 1851) **
	Mesosemia cf. *antaerice* Hewitson, 1859 **
	Mesosemia cippus Hewitson, 1859
	Mesosemia croesus trilineata (A. Butler, 1874)
	Mesosemia esperanza Schaus, 1913
	Mesosemia evias Stichel, 1923
	Mesosemia gneris Westwood, 1851 **
	Mesosemia hesperina tenuivittata Stichel, 1910
	Mesosemia hyphea pallida (Lathy, 1932)
	Mesosemia ibycus Hewitson, 1859
	Mesosemia icare (Hübner, [1819])
	Mesosemia idotea (Westwood, 1851)

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	Mesosemia jucunda Stichel, 1923
	Mesosemia lacernata Stichel, 1909
	Mesosemia lagora (Herrich-Schäffer, [1853])
	Mesosemia marisa marisa (Hewitson, 1858)
	Mesosemia melaene Hewitson, 1859
	Mesosemia melpia Hewitson, 1859
	Mesosemia metope Hewitson, 1859
	Mesosemia minos modica Stichel, 1910
	Mesosemia nesti (Hewitson, 1858) **
	Mesosemia nr. *sirenia* **
	Mesosemia nyctea (Hoffmannsegg, 1818)
	Mesosemia philocles laetifica H. Bates, 1868
	Mesosemia tenella (Stichel, 1910)
	Mesosemia thetys Godman & Salvin, 1885
	Mesosemia thymetus (Cramer, 1777)
	Mesosemia tullius (Fabricius, 1787)
	Napaea eucharila (H. Bates, 1867) **
	Napaea heteroea (H. Bates, 1867)
Nymphidiini (61)	*Adelotypa* sp.
	Archaeonympha drepana (H. Bates, 1868)
	Argyraspila gyges (Stichel, 1911)
	Argyraspila pirene (Godman 1903)
	Argyraspila rhesa (Hewitson, 1858) **
	Aricoris propitia (Stichel, 1910)
	Calospila parthaon (Dalman, 1823)
	Dysmathia portia H. Bates, 1868
	Hallonympha maculosa (H. Bates, 1868)
	Juditha azan (Westwood, 1851) **
	Juditha molpe (Hübner, [1808])
	Juditha odites (Cramer, 1775)
	Lemonias zygia (Hübner, [1807])
	Livendula aristus (Stoll, 1790)
	Livendula huebneri (Butler, 1867)
	Livendula jasonhalli (Brévignon & Gallard, 1999)
	Livendula pauxilla (Stichel, 1911)
	Livendula violacea (A. Butler, 1867)
	Nymphidium acherois (Boisduval, 1836)
	Nymphidium aurum Callaghan, 1985
	Nymphidium azanoides A. Butler, 1867
	Nymphidium baeotia Hewitson, [1853]
	Nymphidium callaghani Brévignon, 1999 **
	Nymphidium caricae (Linnaeus, 1758)
	Nymphidium carmentis Stichel, 1910
	Nymphidium chione H. Bates, 1867
	Nymphidium leucosia (Hübner, [1806])
	Nymphidium manicorensis Callaghan, 1985
	Nymphidium mantus (Cramer, 1775)
	Nymphidium minuta H. Druce, 1904
	Nymphidium robiginosum Stichel, 1929
	Nymphidium velatum Stichel, 1914
	Pachythone cf. *conspersa* Stichel, 1926 *
	Pachythone xanthe H. Bates, 1868
	Pandemos pasiphae (Cramer, 1775)
	Parvospila emylius (Cramer, 1775)
	Periplacis menander (Stoll, 1780) **
	Protonymphidia senta (Hewitson, 1853)
	Rodinia calphurnia (Saunders, 1850)
	Setabis epitus (Cramer, 1780) **
	Setabis flammula (H. Bates, 1868)
	Setabis lagus (Cramer, 1777)
	Setabis serica serica (Westwood, 1851) **
	Stalachtis calliope (Linnaeus, 1758)
	Stalachtis phaedusa (Hübner, [1813])
	Stalachtis phlegia (Cramer, 1779) *
	Synargis abaris (Cramer, 1776)
	Synargis gela (Hewitson, [1853])
	Synargis ochra (H. Bates, 1868)
	Synargis orestessa Hübner, [1819]
	Synargis regulus Hübner, [1819]
	Theope cf. *archimedes* (Fabricius, 1793) **
	Theope discus H. Bates, 1868
	Theope eurygonina H. Bates, 1868
	Theope leucanthe H. Bates, 1868
	Theope lycaenina H. Bates, 1868
	Theope nycteis (Westwood, 1851)
	Theope pedias Herrich-Schäffer, [1853]
	Theope philotes (Westwood, 1851)
	Theope thootes Hewitson, 1860
	Zelotaea phasma H. Bates, 1868
Calydnini (8)	*Calydna caieta* Hewitson, 1854
	Calydna carneia Hewitson, 1859
	Calydna catana Hewitson, 1859

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	Calydna charila Hewitson, 1854
	Calydna jeannea J. Hall, 2002 **
	Calydna nicolayi J. Hall, 2002
	Echenais thelephus (Cramer, 1775) **
	Echydna punctata (C. Felder & R. Felder, 1861)
Symmachiini (15)	*Argyrogrammana glaucopis* (H. W. Bates, 1868) **
	Argyrogrammana nr. *venilia* **
	Argyrogrammana talboti Brévignon & Gallard, 1998 *
	Argyrogrammana trochilia (Westwood, 1851)
	Mesene cf. *bigemmis* Stichel, 1925 **
	Mesene cf. *silaris* Godman & Salvin, 1878 **
	Mesene epaphus pyrrha (H. Bates, 1868)
	Mesene leucophrys (H. Bates, 1868)
	Mesene nola Herrich-Schäffer, [1853]
	Mesene phareus (Cramer, 1777)
	Phaenochitonia pyrsodes (H. Bates, 1868)
	Pterographium thyatira (Hewitson, [1853]) **
	Symmachia accusatrix Westwood, 1851
	Symmachia estellina Gallard, 2008
	Symmachia tricolor Hewitson, 1867
Helicopini (11)	*Anteros acheus* (Stoll, 1781) **
	Anteros bracteata Hewitson, 1867 **
	Anteros formosus (Cramer, 1777)
	Ourocnemis aerosus (Stichel, 1924) **
	Ourocnemis renaldus (Stoll, 1790) **
	Sarota acanthoides (Herrich-Schäffer, [1853])
	Sarota acantus (Stoll, 1781)
	Sarota chrysus (Stoll, 1781)
	Sarota gyas (Cramer, 1775)
	Sarota lasciva (Stichel, 1911) **
	Sarota miranda Brévignon, 1998
Emesidini (8)	*Emesis angularis* Hewitson, 1870 *
	Emesis cerea (Linnaeus, 1767) **
	Emesis condigna Stichel, 1925
	Emesis diogenia Prittwitz, 1865 **
	Emesis fatimella Westwood, 1851
	Emesis mandana (Cramer, 1780)
	Emesis spreta H. Bates, 1868
	Emesis temesa (Hewitson, 1870)
Riodinini (41)	*Amarynthis meneria* (Cramer, 1776)
	Ancyluris aulestes (Cramer, 1777)
	Ancyluris colubra (Saunders, 1859) **
	Ancyluris etias (Saunders, 1859) **
	Ancyluris meliboeus (Fabricius, 1776)
	Caria mantinea (C. Felder & R. Felder, 1861)
	Caria sponsa (Staudinger, [1887]) *
	Caria trochilus arete (C. Felder & R. Felder, 1861)
	Cariomothis erythromelas (Sepp, [1841]) **
	Chalodeta chitinosa J. Hall, 2002
	Chalodeta theodora (C. Felder & R. Felder, 1862)
	Chamaelimnas tircis C. Felder & R. Felder, 1865
	Chorinea octauius (Fabricius, 1787) **
	Crocozona coecias (Hewitson, 1866) **
	Detritivora cuiaba (Harvey & J. Hall, 2002)
	Detritivora zama (H. Bates, 1868)
	Isapis agyrtus sestus (Stichel, 1909)
	Ithomeis aurantiaca H. Bates, 1862
	Lasaia agesilas (Latreille, [1809])
	Lasaia arsis Staudinger, [1887]
	Lyropteryx apollonia Westwood, 1851 **
	Melanis aegates (Hewitson, 1874)
	Melanis electron (Fabricius, 1793)
	Melanis marathon (C. Felder & R. Felder, 1865)
	Melanis smithiae (Westwood, 1851) **
	Metacharis lucius (Fabricius, 1793)
	Metacharis regalis A. Butler, 1867
	Monethe albertus C. Felder & R. Felder, 1862
	Notheme erota (Cramer, 1780)
	Panara phereclus (Linnaeus, 1758) **
	Parcella amarynthina (C. Felder & R. Felder, 1865) **
	Pheles heliconides heliconides Herrich-Schäffer, [1853]
	Pheles incerta Staudinger, [1887] **
	Rhetus arcius (Linnaeus, 1763) **
	Rhetus periander (Cramer, 1777)
	Riodina lysippus (Linnaeus, 1758)
	Riodinini sp.
	Syrmatia lamia H. Bates, 1868
	Themone pais (Hübner, [1820])

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	Themone poecila H. Bates, 1868
	Themone pulcherrima (Herrich-Schäffer, [1853])
Nymphalidae (301)	
Libytheinae (1)	
	Libytheana carinenta (Cramer, 1777)
Danainae (32)	
Danaini (2)	*Lycorea halia pales* C. Felder & R. Felder, 1862
	Lycorea pasinuntia (Stoll, 1780)
Ithomiini (30)	*Aeria eurimedia eurimedia* (Cramer, 1777)
	Brevioleria aelia jamariensis (R.F. d'Almeida, 1951) **
	Callithomia alexirrhoe zeuxippe H. Bates, 1862
	Callithomia lenea epidero (H. Bates, 1862)
	Ceratinia cayana giparanaensis R.F. d'Almeida, 1964
	Dircenna loreta acreana R.F. d'Almeida, 1950
	Hypoleria alema consimilis Talbot, 1928 **
	Hyposcada anchiala cynara R.F. d'Almeida, 1945 **
	Hypothyris euclea barii (H. Bates, 1862)
	Hypothyris leprieuri ninyas R.F. d'Almeida, 1945 **
	Hypothyris maenas ssp.
	Hypothyris ninonia ssp.
	Ithomia agnosia pellucida Weymer, 1875
	Mechanitis lysimnia tapajona Freitas & Mota, 2022
	Mechanitis polymnia cf. *mauensis* W. Forbes, 1948
	Melinaea marsaeus pothete R.F. d'Almeida, 1945
	Melinaea mneme cf. *mauensis* Weymer, 1891
	Melinaea ludovica ludovica (Cramer, 1780)
	Methona confusa confusa A.G. Butler, 1873 **
	Methona grandior grandior (W.T.M. Forbes, 1944)
	Napeogenes inachia pyrois H. Bates, 1862
	Napeogenes rhezia adelphe H. Bates, 1862
	Napeogenes sylphis ithra (Hewitson, 1855)
	Oleria aegle ssp.**
	Oleria antaxis ssp.
	Oleria astrea ssp.
	Sais rosalia rosalinde Weymer, 1890
	Scada reckia labyrintha Lamas, 1985
	Thyridia psidii psidii (Linnaeus, 1758)

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	Tithorea harmonia pseudonyma Staudinger, 1894
Heliconiinae (22)	
Acreini (1)	*Actinote pyrrha crucis* Jordan, 1913
Heliconiini (20)	*Agraulis maculosa* (H.F.E.J. Stichel, [1908]) **
	Dione juno (Cramer, 1779) **
	Dryas alcionea (Cramer, 1779)
	Eueides aliphera (Godart, 1819)
	Eueides isabella dissoluta Stichel, 1903
	Eueides lybia (Fabricius, 1775)
	Eueides vibilia unifasciatus A. Butler, 1873
	Heliconius antiochus antiochus (Linnaeus, 1767)
	Heliconius aoede aoede (Hübner, [1813])
	Heliconius burneyi (Hübner, [1831])
	Heliconius doris doris (Linnaeus, 1771)
	Heliconius erato amazona Staudinger, 1897
	Heliconius eratosignis (Joicey & Talbot, 1925)
	Heliconius ethilla cf. *penthesilea* Neukirchen, 1994
	Heliconius cf. *hecale* (Fabricius, 1776)
	Heliconius numata silvana (Stoll, 1781)
	Heliconius numata superioris A. Butler, 1875
	Heliconius ricini ricini (Linnaeus, 1758)
	Heliconius sara sara (Fabricius, 1793)
	Heliconius wallacei flavescens Weymer, 1891
	Philaethria dido dido (Linnaeus, 1763)
Argynnini (1)	*Euptoieta hegesia* (Cramer, 1779) *
Limenitidinae (15)	
Limenitidini (15)	*Adelpha barnesia* Schaus, 1902 **
	Adelpha boeotia (C. Felder & R. Felder, 1867) **
	Adelpha capucinus capucinus (Walch, 1775)
	Adelpha cocala cocala (Walch, 1775)
	Adelpha cytherea cytherea (Linnaeus, 1758)
	Adelpha epione agilla Fruhstorfer, 1907
	Adelpha erotia (Hewitson, 1847) **
	Adelpha iphiclus iphiclus (Linnaeus, 1758)
	Adelpha melona (Hewitson, 1847) **
	Adelpha mesentina (Cramer, 1777)
	Adelpha paraena (H. Bates, 1865) **
	Adelpha plesaure phliassa (Godart, [1824])
	Adelpha pollina Fruhstorfer, 1915 *

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	Adelpha thesprotia (C. Felder & R. Felder, 1867) **
	Adelpha thoasa (Hewitson, 1850) **
Apaturinae (5)	
	Doxocopa agathina (Cramer, 1777)
	Doxocopa laure (Drury, 1773) **
	Doxocopa lavinia (A. Butler, 1866)
	Doxocopa linda linda (C. Felder & R. Felder, 1862)
	Doxocopa zunilda (Godart, [1824])
Biblidinae (53)	
Biblidini (1)	*Vila emilia* (Cramer, 1779)
Catonephelini (20)	*Catonephele acontius* (Linnaeus, 1771)
	Catonephele antinoe (Godart, [1824])
	Catonephele numilia (Cramer, 1775) **
	Eunica alpais alpais (Godart, [1824])
	Eunica amelia (Cramer, 1777)
	Eunica anna (Cramer, 1780)
	Eunica bechina bechina (Hewitson, 1852)
	Eunica caelina (Godart, [1824]) **
	Eunica concordia (Hewitson, 1852) **
	Eunica eurota eurota (Cramer, 1775)
	Eunica ingens Seitz, 1915
	Eunica malvina H. Bates, 1864 **
	Eunica mygdonia (Godart, [1824]) **
	Eunica orphise (Cramer, 1775)
	Eunica phasis C. Felder & R. Felder, 1862 **
	Eunica pusilla H. Bates, 1864
	Eunica sydonia (Godart, [1824]) **
	Eunica tatila bellaria Fruhstorfer, 1908
	Eunica volumna (Godart, [1824]) **
	Nessaea obrinus (Linnaeus, 1758)
Ageroniini (9)	*Ectima iona* E. Doubleday, [1848]
	Ectima thecla (Fabricius, 1796)
	Hamadryas amphinome (Linnaeus, 1767)
	Hamadryas belladonna (H. Bates, 1865) **
	Hamadryas chloe (Stoll, 1787)
	Hamadryas februa (Hübner, [1823]) *
	Hamadryas feronia (Linnaeus, 1758)
	Hamadryas laodamia (Cramer, 1777)
	Hamadryas velutina (H. Bates, 1865) **
Epiphelini (6)	*Nica flavilla* cf. *flavilla* (Godart, [1824])

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	Peria lamis (Cramer, 1779)
	Pyrrhogyra amphiro H. Bates, 1865
	Pyrrhogyra crameri Aurivillius, 1882
	Temenis laothoe (Cramer, 1777)
	Temenis pulchra (Hewitson, 1861) **
Eubagini (8)	*Dynamine agacles* (Dalman, 1823)
	Dynamine arene Hübner, [1823]
	Dynamine artemisia (Fabricius, 1793)
	Dynamine athemon (Linnaeus, 1758)
	Dynamine myrson (E. Doubleday, 1849)
	Dynamine pebana Staudinger, [1885]
	Dynamine postverta (Cramer, 1779) **
	Dynamine racidula (Hewitson, 1852) **
Callicorini (9)	*Callicore astarte* (Cramer, 1779)
	Callicore cynosura (E. Doubleday, [1847])
	Callicore hesperis (Guérin-Méneville, [1844]) **
	Callicore texa (Hewitson, [1855])
	Catagramma hystaspes hystaspes (Fabricius, 1781)
	Diaethria clymena (Cramer, 1775)
	Diaethria kolyma pasithea (Hewitson, 1864)
	Paulogramma pygas (Godart, [1824])
	Paulogramma pyracmon (Godart, [1824]) **
Cyrestinae (10)	
Cyrestini (10)	*Marpesia berania* (Hewitson, 1852)
	Marpesia chiron (Fabricius, 1775)
	Marpesia crethon (Fabricius, 1776) **
	Marpesia egina (H. Bates, 1865) **
	Marpesia furcula (Fabricius, 1793)
	Marpesia livius (W. F. Kirby, 1871) *
	Marpesia orsilochus (Fabricius, 1776)
	Marpesia petreus (Cramer, 1776) **
	Marpesia themistocles (Fabricius, 1793)
	Marpesia tutelina (Hewitson, 1852)
Nymphalinae (26)	
Coeini (5)	*Baeotus aeilus* (Stoll, 1780) **
	Baeotus deucalion (C. Felder & R. Felder, 1860) **
	Baeotus japetus (Staudinger, [1885])
	Historis acheronta (Fabricius, 1775) **
	Historis odius (Fabricius, 1775)

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Nymphalini (5)	*Colobura annulata* Willmott, Constantino & J. Hall, 2001
	Colobura dirce (Linnaeus, 1758)
	Hypanartia lethe (Fabricius, 1793) **
	Smyrna blomfildia (Fabricius, 1781) **
	Tigridia acesta (Linnaeus, 1758)
Victorinini (3)	*Anartia amathea* (Linnaeus, 1758) **
	Napeocles jucunda (Hübner, [1808]) **
	Siproeta stelenes (Linnaeus, 1758)
Junoniini (1)	*Junonia* sp. **
Melitaeini (12)	*Anthanassa drusilla* (C. Felder & R. Felder, 1861)
	Anthanassa hermas hermas (Hewitson, 1864) *
	Chlosyne lacinia (Geyer, 1837) **
	Eresia clio (Linnaeus, 1758) **
	Eresia eunice (Hübner, [1807])
	Eresia nauplius (Linnaeus, 1758)
	*Eresia perna averyona*H. Bates, 1864
	Mazia amazonica (H. Bates, 1864)
	Ortilia gentina Higgins, 1981
	Ortilia ithra (W. F. Kirby, 1900) **
	Tegosa cf. *fragilis* (H. Bates, 1864)
	Telenassa teletusa burchelli (Moulton, 1909)
Charaxinae (20)	
Anaeini (11)	*Consul fabius* ssp.
	Fountainea ryphea (Cramer, 1775) **
	Hypna clytemnestra (Cramer, 1777)
	Memphis acidalia acidalia (Hübner, [1819])
	Memphis acidalia memphis (C. Felder & R. Felder, 1867) **
	Memphis leonida (Stoll, 1782)
	Memphis moruus moruus (Fabricius, 1775) **
	Memphis philumena philumena (E. Doubleday, [1849]) **
	Polygrapha xenocrates (Westwood, 1850)
	Siderone galanthis (Cramer, 1775) **
	Zaretis isidora (Cramer, 1779)
	Zaretis strigosus (Gmelin, [1790])
Preponini (9)	*Archaeoprepona amphimachus* (Fabricius, 1775) **
	Archaeoprepona demophon (Linnaeus, 1758) **
	Archaeoprepona demophoon (Hübner, [1814])
	Archaeoprepona licomedes (Cramer, 1777)

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	Archaeoprepona meander (Cramer, 1775) **
	Mesoprepona pheridamas (Cramer, 1777)
	Prepona claudina (Godart, [1824]) **
	Prepona eugenes H. Bates, 1865 **
	Prepona laertes (Hübner, [1811])
Satyrinae (117)	
Morphini (12)	*Antirrhea philoctetes* (Linnaeus, 1758) **
	Antirrhea taygetina (A. Butler, 1868)
	Antirrhea watkinsi Rosenberg & Talbot, 1914 **
	Caerois chorinaeus (Fabricius, 1775) **
	Morpho achilles phokylides Fruhstorfer, 1912
	Morpho cisseis C. Felder & R. Felder, 1860
	Morpho deidamia (Hübner, [1819])
	Morpho helenor helenor (Cramer, 1776)
	Morpho menelaus (Linnaeus, 1758)
	Morpho rhetenor (Cramer, 1775) **
	Morpho telemachus (Linnaeus, 1758) **
	Morpho zephirytis A. Butler, 1873 *
Brassolini (18)	*Bia rebeli* Bryk, 1953
	Brassolis sophorae (Linnaeus, 1758) **
	Caligo eurilochus (Cramer, 1775) **
	Caligo idomeneus idomeneus (Linnaeus, 1758)
	Caligo illioneus (Cramer, 1775)
	Caligo teucer (Linnaeus, 1758) **
	Caligopsis seleucida (Hewitson, 1877) **
	Catoblepia berecynthia unditaenia Fruhstorfer, 1907
	Catoblepia soranus (Westwood, 1851)
	Catoblepia xanthicles (Godman & Salvin, 1881) **
	Dynastor darius (Fabricius, 1775) *
	Eryphanis automedon (Cramer, 1775)
	Narope denticulatus Talbot, 1928
	Narope panniculus Stichel, 1904
	Opoptera hilaris Stichel, 1901
	Opsiphanes invirae (Hübner, [1808])
	Opsiphanes quiteria (Stoll, 1780)
	Selenophanes cassiope (Cramer, 1775) **
Haeterini (7)	*Cithaerias bandusia* Staudinger, 1887
	Haetera piera (Linnaeus, 1758)
	Pierella astyoche stollei Ribeiro, 1931
	Pierella chalybaea Godman, 1905
	Pierella hortona (Hewitson, 1854) **

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	Pierella hyalinus hyalinus (Gmelin, [1790])
	Pierella lena lena (Linnaeus, 1767)
Melanitini (1)	*Manataria hercyna* (Hübner, [1821])
Satyrini (79)	*Amiga arnaca* (Fabricius, 1776)
	Amphidecta calliomma (C. Felder & R. Felder, 1862)
	Amphidecta pignerator A. Butler, 1867
	Amphidecta reynoldsi Sharpe, 1890 **
	Caeruleuptychia aegrota (A. Butler, 1867)
	Caeruleuptychia cf. *coelestis* (A. Butler, 1867) **
	Caeruleuptychia glauca (Weymer, 1911)
	Caeruleuptychia cf. *penicillata* (Godman, 1905)
	Caeruleuptychia cf. *scopulata* (Godman, 1905)
	Caeruleuptychia twalela Brévignon, 2005
	Caeruleuptychia umbrosa (Butler, 1870) **
	Cepheuptychia cephus (Fabricius, 1775)
	Chloreuptychia agatha (A. Butler, 1867) *
	Chloreuptychia chlorimene (Hübner, [1819])
	Chloreuptychia herseis (Godart, [1824])
	Chloreuptychia hewitsonii (A. Butler, 1867)
	Chloreuptychia marica (Weymer, 1911) **
	Chloreuptychia rectilinea Brévignon, Rosant, Lamas & Willmott, 2019
	Chloreuptychia tolumnia (Cramer, 1777)
	Cisandina lea (Cramer, 1777)
	Cissia maripa (Brévignon, 2005)
	Cissia myncea (Cramer, 1780)
	Cissia penelope (Fabricius, 1775)
	Cissia proba (Weymer, 1911)
	Cristalinaia vitoria Mota, Zacca & Freitas, 2019
	Erichthodes antonina (C. Felder & R. Felder, 1867)
	Euptychia mollina (Hübner, [1813])
	Euptychia cf. *picea* A. Butler, 1867
	Euptychia sp.
	Euptychia westwoodi A. Butler, 1867
	Harjesia blanda (Möschler, 1877) **
	Harjesia cf. *obscura* (A. Butler, 1867)
	Hermeuptychia sp.1
	Hermeuptychia sp.2
	Macrocissia iris (C. Felder & R. Felder, 1867)
	Magneuptychia ca. *analis*
	Magneuptychia harpyia batesii (A. Butler, 1867)
	Magneuptychia lethra (H.B. Möschler, 1883)
	Magneuptychia ocypete (Fabricius, 1776)
	Magneuptychia tricolor(Hewitson, 1850)
	Malaveria affinis (A. Butler, 1867)
	Megeuptychia antonoe (Cramer, 1775)
	Modestia cf. *modesta* (A. Butler, 1867) **
	Nubila moderata (Weymer, 1911)
	Pareuptychia binocula (A. Butler, 1869)
	Pareuptychia lydia (Cramer, 1777)
	Pareuptychia ocirrhoe (Fabricius, 1776)
	Paryphthimoides brixius (Godart, [1824])
	Paryphthimoides poltys(Prittwitz, 1865)
	Paryphthimoides sylvina (C. Felder & R. Felder, 1867)
	Paryphthimoides terrestris muyrakytan Zacca, Casagrande & Mielke, 2020
	Posttaygetis penelea (Cramer, 1777)
	Pseudodebis celia (Cramer, 1779)
	Pseudodebis valentina (Cramer, 1779)
	Sepona punctata (Weymer, 1911)
	Splendeuptychia clorimena (Stoll, 1790) **
	Splendeuptychia itonis (Hewitson, 1862)
	Splendeuptychia salvini (A. Butler, 1867) *
	Splendeuptychia sp.1
	Splendeuptychia sp.3
	Splendeuptychia sp.4
	Splendeuptychia sp.2
	Splendeuptychia tupinamba Freitas, Huertas & Rosa, 2021
	Splendeuptychia zischkai Forster, 1964
	Taygetina gulnare (A. Butler, 1870)
	Taygetina sp.
	Taygetis angulosa Weymer, 1907
	Taygetis echo (Cramer, 1775)
	Taygetis laches (Fabricius, 1793)
	Taygetis larua C. Felder & R. Felder, 1867
	Taygetis mermeria (Cramer, 1776)
	Taygetis sosis Hopffer, 1874
	Taygetis sylvia H. Bates, 1866
	*Taygetis tripunctata*Weymer, 1907
	Taygetis cf. *virgilia* (Cramer, 1776)
	Taygetis sp.
	Yphthimoides eriphule (A. Butler, 1867)

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	Yphthimoides renata (Stoll, 1780)
	Zischkaia baku Zacca, Dolibaina & Dias, 2019
Hesperiidae (314)	
Eudaminae (89)	
Entheini (15)	*Augiades crinisus* (Cramer, 1780)
	Augiades vespasius bicolor (Mabille & Boullet, 1919)
	Drephalys alcmon (Cramer, 1780) **
	Drephalys dumeril (Latreille, [1824])
	Drephalys eous (Hewitson, 1867)
	Drephalys oriander (Hewitson, 1867)
	Entheus priassus priassus (Linnaeus, 1758) **
	Hyalothyrus infernalis (Möschler, 1877) *
	Hyalothyrus leucomelas (Geyer, 1832)
	Hyalothyrus neleus neleus (Linnaeus, 1758)
	Phanus marshalli (W. F. Kirby, 1880)
	Phanus vitreus (Stoll, 1781)
	Tarsoctenus corytus corba Evans, 1952 **
	Tarsoctenus praecia plutia (Hewitson, 1857) **
	Udranomia kikkawai (Weeks, 1906) **
Eudamini (51)	*Astraptes enotrus* (Stoll, 1781) **
	Autochton bipunctatus (Gmelin, [1790]) **
	Autochton neis (Geyer, 1832) **
	Aguna asander asander (Hewitson, 1867)
	Aguna squamalba Austin & O. Mielke, 1998
	Cephise maculatus Austin & Mielke, 2000 **
	Cecropterus sp. **
	Cecropterus zarex (Hübner, 1818)
	Cecropterus albimargo (Mabille, 1875) *
	Cecropterus doryssus doryssus (Swainson, 1831)
	Cecropterus reductus (Riley, 1919) **
	Cecropterus dorantes dorantes (Stoll, 1790) **
	Cecropterus virescens (Mabille, 1877)
	Ectomis auginus (Hewitson, 1867)
	Ectomis caunus (Herrich-Schäffer, 1869)
	Ectomis labriaris (Butler, 1877) **
	Ectomis metallescens (Mabille, 1888) **
	Ectomis octomaculata (Sepp, [1844]) **
	Ectomis orpheus (Plötz, 1881)
	Ectomis otriades (Hewitson, 1867)
	Ectomis perniciosus (Herrich-Schäffer, 1869) **

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	Ectomis pervivax (Hübner, [1819]) **
	Ectomis teutas (Hewitson, 1876) *
	Epargyreus clavicornis clavicornis (Herrich-Schäffer, 1869)
	Epargyreus exadeus (Cramer, 1779)
	Narcosius narcosius (Stoll, 1790)
	Polygonus leo pallida Röber, 1925 **
	Proteides mercurius mercurius (Fabricius, 1787) **
	Spicauda cindra (Evans, 1952)
	Spicauda simplicius (Stoll, 1790)
	Spicauda tanna (Evans, 1952) **
	Spicauda teleus (Hübner, 1821)
	Spicauda sp.
	Telegonus alector hopfferi (Plötz, 1881)
	Telegonus anaphus anaphus (Cramer, 1777)
	Telegonus cretatus cretatus Hayward, 1939
	Telegonus apastus apaustus (Cramer, 1777) **
	Telegonus chalco (Hübner, 1823) *
	Telegonus fulgerator (Walch, 1775)
	Telegonus talus (Cramer, 1777)
	Telemiades amphion (Geyer, 1832)
	Telemiades antiope (Plötz, 1882) **
	Telemiades avitus (Stoll, 1781)
	Telemiades delalande (Latreille, [1824])
	Telemiades epicalus Hübner, [1819]
	Telemiades penidas (Hewitson, 1867)
	Urbanus esma Evans, 1952 **
	Urbanus esmeraldus (Butler, 1877)
	Urbanus pronta Evans, 1952
	Urbanus proteus proteus (Linnaeus, 1758)
	Urbanus velinus (Plötz, 1880)
Oileidini (6)	*Cogia calchas* (Herrich-Schäffer, 1869) **
	Cogia crameri (McHenry, 1960) **
	Cogia galbula (Plötz, 1880) **
	Cogia undulatus (Hewitson, 1867) **
	Marela tamyris Mabille, 1903 **
	Marela tamyroides (C. Felder & R. Felder, 1867) *
Phocidini (17)	*Aurina azines* (Hewitson, 1867)
	Bungalotis astylos (Cramer, 1780) **
	Bungalotis midas (Cramer, 1775)
	Dyscophellus porcius porcius (C. Felder & R. Felder, 1862) **

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	Dyscophellus ramusis ramusis (Stoll, 1781)
	Dyscophellus sebaldus (Stoll, 1781) **
	Euriphellus euribates (Stoll, 1782)
	Nascus broteas (Cramer, 1780)
	Nascus paulliniae (Sepp, [1842]) **
	Nascus phocus (Cramer, 1777)
	Nascus solon solon (Plötz, 1882) *
	Nicephellus nicephorus (Hewitson, 1876)
	Phareas coeleste Westwood, 1852
	Phocides pigmalion pigmalion (Cramer, 1779)
	Porphyrogenes sororcula (Mabille & Boullet, 1912)
	Salatis salatis (Stoll, 1872) **
	Sarmientoia sp. **
Pyrginae (65)	
Achlyodini (21)	*Achlyodes busirus busirus* (Cramer, 1779)
	Aethilla echina echina Hewitson, 1870
	Cabirus procas procas (Cramer, 1777)
	Charidia lucaria ssp. **
	Eantis thraso (Hübner, [1807])
	Grais stigmaticus stigmaticus (Mabille, 1883)
	Livida assecla (Mabille, 1883) **
	Milanion sp.
	Morvina morvus cyclopa Evans, 1953
	Myrinia catua O. Mielke, 1968 **
	Ouleus friderichus friderichus (Geyer, 1832) **
	Ouleus juxta dampa Evans, 1953 **
	Pseudodrephalys sohni Burns, 1999 **
	Pythonides homer Evans, 1953
	Pythonides jovianus crameri (Mabille & Boullet, 1917)
	Pythonides lerina (Hewitson, 1868)
	Quadrus cerialis (Stoll, 1782)
	Quadrus contubernalis contubernalis (Mabille, 1883) **
	Quadrus fanda Evans, 1953
	Quadrus sp.
	Spioniades artemides (Stoll, 1782) *
Carcharodini (10)	*Conognathus platon*C. Felder & R. Felder, 1862 **
	Cornuphallus onoribo (Möschler, 1883)
	Cyclosemia sp. **
	Nisoniades brunneata (Williams & Bell, 1939) **
	Nisoniades macarius (Herrich-Schäffer, 1870) **
	Nisoniades mimas (Cramer, 1775)
	Pachyneuria sp. **
	Pellicia sp.
	Polyctor polyctor polyctor (Prittwitz, 1868)
	Sophista aristoteles (Westwood, 1852) **
Erynnini (24)	*Anastrus neaeris narva* Evans, 1953
	Anastrus virens virens Austin, 1999 *
	Anaxas petius petius (Möschler, 1877)
	Camptopleura auxo (Möschler, 1879)
	Camptopleura impressus (Mabille, 1889) *
	Chiomara mithrax (Möschler, 1879) **
	Cycloglypha sp. **
	Cycloglypha thrasibulus thrasibulus (Fabricius, 1793)
	Cycloglypha tisias (Godman & Salvin, 1896)
	Ebrietas anacreon anacreon (Staudinger, 1876)
	Ebrietas elaudia livius Mabille, 1898
	Ebrietas infanda (Butler, 1877)
	Echelatus sempiternus simplicior (Möschler, 1877) **
	Festivia festiva (Erichson, [1849])
	Gorgythion begga pyralina (Möschler, 1877)
	Gorgythion plautia (Möschler, 1877)
	Helias phalaenoides palpalis (Latreille, [1824])
	Hoodus exstincta (Mabille & Boullet, 1917) **
	Hoodus pelopidas (Fabricius, 1793)
	Hoodus simplex (Austin, 2000) **
	Mylon maimon (Fabricius, 1775)
	Sostrata bifasciata bifasciata (Ménétriés, 1829) **
	Sostrata pusilla pusilla Godman & Salvin, 1895
	Tolius tolimus robigus(Plötz, 1884)
Pyrgini (10)	*Burnsius orcus* (Stoll, 1780)
	Carrhenes chaeremon (Mabille, 1891)
	Heliopetes arsalte (Linnaeus, 1758)
	Heliopetes orbigera (Mabille, 1888) **
	Heliopetes petrus (Hübner, [1819])
	Paches exosa (Butler, 1877) **
	Paches liborius liborius Plötz, 1884 **
	Plumbago plumbago (Plötz, 1884) *
	Santa santes (Bell, 1940) **
	Xenophanes tryxus (Stoll, 1780)

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Pyrrhopyginae (22)	
Passovini (5)	*Agara assaricus assaricus* (Cramer, 1779)
	Aspitha agenoria agenoria (Hewitson, 1876) **
	Myscelus nobilis (Cramer, 1777) **
	Passova glacia Evans, 1951 **
	Passova passova passova (Hewitson, 1866)
Pyrrhopygini (17)	*Croniades pieria pieria* (Hewitson, 1857)
	Gunayan rubricollis (Sepp, [1841]) *
	Jemadia hospita hospita (Butler, 1877) **
	Jemadia hewitsonii hewitsonii (Mabille, 1878)
	Jemadia gnetus gnetus (Fabricius, 1781) **
	Jemadia sp. **
	Microceris azeta azeta (Hewitson, 1866) **
	Microceris blanda (Evans, 1951) **
	Microceris rondonia (Mielke, 1995)
	Microceris intersecta intersecta (Herrich-Schäffer, 1869)
	Mimoniades fallax fida (Evans, 1951) **
	Mysoria sejanus stolli O. Mielke, 2002
	Parelbella sp. **
	Pyrrhopyge sergius semana Evans, 1951
	Pyrrhopyge sp.1 **
	Pyrrhopyge sp.2 **
	Yanguna thelersa (Hewitson, 1866) **
Tagiadinae (3)	
Celaenorrhinini (3)	*Celaenorrhinus astrigera* (Butler, 1877)
	Celaenorrhinus autochton Steinhauser & Austin, 1996
	Celaenorrhinus jao (Mabille, 1889)
Hesperiinae (135)	
Hesperiini (130)	*Adlerodea mineira* O. Mielke, 1968
	Adlerodea sp.
	Aides aegita (Hewitson, 1866)
	Aides brino (Stoll, 1781) **
	Aides duma duma Evans, 1955
	Anthoptus epictetus (Fabricius, 1793)
	Anthoptus insignis (Plötz, 1882)
	Artines bamba Medeiros & O. Mielke, 2019
	Callimormus alsimo (Möschler, 1883)
	Callimormus corades (C. Felder, [1863]) **
	Callimormus saturnus (Herrich-Schäffer, 1869) **
	Calpodes antoninus (Latreille, [1824])
	Calpodes esperi esperi (Evans, 1955)
	Calpodes ethlius (Stoll, 1782) **
	Calpodes longirostris (Sepp, [1840])
	Calpodes nigel (Evans, 1955) **
	Calpodes salius (Cramer, 1775)
	Calvetta calvina (Hewitson, 1866)
	Cantha calva Evans, 1955
	Carystoides basoches (Latreille, [1824]) **
	Carystoides cathaea (Hewitson, 1866)
	Carystoides noseda (Hewitson, 1866) **
	Carystoides yenna Evans, 1955 **
	Carystus hocus Evans, 1955
	Carystus lota (Hewitson, 1877) **
	Carystus moeros (Möschler, 1877) **
	Chloeria psittacina (C. Felder & R. Felder, 1867) **
	Cobalopsis nero (Herrich-Schäffer, 1869) **
	Cobalopsis valerius (Möschler, 1879)
	Cobalus virbius virbius (Cramer, 1777)
	Conga chydaea (Butler, 1877)
	Cyclosma altama (Schaus, 1902) **
	Cymaenes alumna (Butler, 1877)
	Cynea popla Evans, 1955
	Damas clavus (Herrich-Schäffer, 1869)
	Decinea sp. **
	Dion uza (Hewitson, 1877) **
	Dubia dubia (Bell, 1932)
	Dubiella dubius (Stoll, 1781)
	Ebusus ebusus ebusus (Cramer, 1780) *
	Eprius veleda veleda (Godman, 1901) **
	Eutocus vetulus vinda Evans, 1955
	Eutus mubevensis (Bell, 1932)
	Evansiella cordela (Plötz, 1882) **
	Flaccilla aecas (Stoll, 1781)
	Gallio seriatus (Mabille, 1891)
	Justinia justinianus justinianus (Latreille, [1824]) **
	Justinia maculata (Bell, 1930)
	Lento apta Evans, 1955
	Lento lento (Mabille, 1878)
	Lento lora Evans, 1955

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Lento ludo Evans, 1955 **
Lerema geisa geisa (Möschler, 1879)
Lindra sp.
Lychnuchus demon (Evans, 1955)
Methionopsis ina (Plötz, 1882)
Metrocles cotundo (Nicolay, 1980)
Metrocles sp. **
Metron chrysogastra chrysogastra (Butler, 1870)
Misius misius (Mabille, 1891) **
Mnasicles hicetaon Godman, 1901
Mnasicles sp.
Mnasitheus forma Evans, 1955
Mnasitheus sp.
Naevolus orius (Mabille, 1883) **
Neoxeniades cincia (Hewitson, 1867) **
Niconiades peri (Evans, 1955) **
Niconiades yoka Evans, 1955
Nyctelius nyctelius nyctelius (Latreille, [1824]) **
Onophas columbaria columbaria (Herrich-Schäffer, 1870) **
Orthos orthos minka Evans, 1955
Oxynthes corusca (Herrich-Schäffer, 1869) **
Panca trogon (Evans, 1955)
Panoquina fusina viola Evans, 1955
Panoquina hecebolus (Scudder, 1872)
Panoquina lucas lucas (Fabricius, 1793)
Panoquina pauper grapte (H. Druce, 1908) **
Paracarystus menestries rona (Hewitson, 1866)
Pares pares (Bell, 1959)
Parphorus decora (Herrich-Schäffer, 1869)
Parphorus sp.
Peba verames (Schaus, 1902)
Phanes almoda (Hewitson, 1866)
Phemiades pohli pohli (Bell, 1932) **
Pheraeus honta Evans, 1955
Pheraeus maria Steinhauser, 1991
Pheraeus sp.
Phlebodes buriti O. Mielke, 1968
Phlebodes fuldai (Bell, 1930) **
Pompeius pompeius (Latreille, [1824])

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Propapias sipariana (Kaye, 1925)
Psoralis arva (Evans, 1955)
Psoralis visendus (Bell, 1942) **
Pyrrhopygopsis socrates crates Mabille & Boullet, 1912 **
Quasimellana angra (Evans, 1955)
Quasimellana eulogius (Plötz, 1882) **
Saturnus reticulata meton (Mabille, 1891)
Saturnus saturnus saturnus (Fabricius, 1787)
Sodalia sodalis (Butler, 1877)
Synapte malitiosa pericles (Möschler, 1879)
Synapte silius (Latreille, [1824])
Talides sp. **
Thargella caura caura (Plötz, 1882)
Thargella volasus (Godman, 1901)
Thespieus dalman (Latreille, [1824])
Thoon modius (Mabille, 1889)
Thracides cleanthes telmela (Hewitson, 1866)
Thracides phidon (Cramer, 1779) **
Thracides thrasea (Hewitson, 1866)
Tirynthoides lotana (Butler, 1870) **
Tirynthoides virilis (Riley, 1929) **
Tisias sp. 1 **
Tisias sp. 2
Tricrista taxes (Godman, 1900)
Troyus marcus (Fabricius, 1787)
Turesis basta Evans, 1955
Turesis complanula (Herrich-Schäffer, 1869)
Vacerra evansi Hayward, 1938
Vehilius inca (Scudder, 1872)
Vehilius stictomenes stictomenes (Butler, 1877)
Vehilius vetula (Mabille, 1878)
Venas caerulans (Mabille, 1878) **
Vertica verticalis grandipuncta (Mabille, 1883)
Vettius lafrenaye pica (Herrich-Schäffer, 1869) **
Vettius phylus phylus (Cramer, 1777)
Vettius triangularis (Hübner, [1831])
Vinius exilis phellus (Mabille, 1883)
Xeniades orchamus (Cramer, 1777) **
Xeniades putumayo (Constantino & Salazar, 2013) **

Continue...

...Continuation

	Zenis minos (Latreille, [1824])
Pericharini (5)	*Orphe gerasa* (Hewitson, 1867) *
	Orphe vatinius Godman, 1901 **
	Orses cynisca (Swainson, 1821) **
	Perichares adela (Hewitson, 1867)
	Perichares butus (Möschler, 1877) **

The total richness of butterflies in the region was estimated to be from 1038 to 1204 species when the number of recorded Nymphalidae was used as a predictor, and from 652 to 698 species when the group used was Ithomiini.

Discussion

This study is one of the few to provide an extensive list of the butterflies of a Brazilian Amazon Forest locality, and the first in Brazil to surpass 1000 species. This results from the combined efforts of many researchers and citizen scientists, over more than two decades, to document the butterfly fauna of a diverse region. The 1010 recorded species and the estimates for the total number of species present in the area (see below) represent between one quarter and one third of the 3522 butterfly species (including 23 Hedylidae) known to occur in Brazil (Casagrande 2022), a proportion similar to that of the well-known avifauna of the region (Lees et al. 2013). The species recorded also surpass the total diversity of butterflies of the State of Mato Grosso in the thorough assessment by Queiroz-Santos et al. (2016), which found a total of 901 species recorded in the State, and confirms their suggestion of the need for intensive inventories of its northernmost, Amazonian portion. For two families, Hesperiidae and Lycaenidae, we recorded more species than were represented in the previous list from the whole of Mato Grosso, with a remarkable 314 species at Cristalino compared with 148 species from Mato Grosso for Hesperiidae, and 123 versus 77 for Lycaenidae. These two families were precisely the ones that Queiroz-Santos et al. (2016) expected to be the most underrepresented in their study. A quick and conservative look through their database, considering unknown subspecies or other ambiguities in both lists as representing the same taxa, reveals that the Cristalino Lodge list adds more than 360 species to the previously reported State total. As expected, the present list is responsible for an important extension in the known distribution of several species (examples in Figure 3).

Amazonian butterfly communities are known to have high turnover rates and a high proportion of species that are rare and hard to detect; therefore, high sampling effort and long-term sampling, spanning several years, are required to produce representative inventories (Brown & Hutchings 1997, Mielke et al. 2010, Lamas et al. 2021). Considering that the sampling effort at Cristalino Lodge has been relatively high and includes not only collected specimens but also images made through more than fifteen years by several citizen scientists, covering different trails, vegetation types and in both dry and wet seasons, this list can be regarded as relatively complete for an Amazonian butterfly fauna. However, for the reasons already mentioned, we still expect many future additions to the list, especially among the Hesperiidae, Riodinidae and Lycaenidae, and that is supported by the fact that several new photographic species records have been made after the first assessment through the iNaturalist project, mostly of rare, small riodinids and lycaenids. Also, in Neotropical forests, the family Hesperiidae is typically found to be the richest at every site with nearly complete lists, while the Nymphalidae is usually the richest in sites with less complete lists because the latter are easier to collect and identify (Brown & Freitas 2002, Francini et al. 2011). In our study, these two families have a rather equivalent richness, which indicates that there are still likely a number of Hesperiidae species in the region that have gone undetected, probably mostly among the fast-flying canopy species. Future collecting in the region should therefore focus on Hesperiidae and the use of the Ahrenholz method.

The total species richness estimates were substantially different according to the taxonomic group used as a predictor. The number of recorded Nymphalidae suggested that there are from 1038 to 1204 butterfly species at Cristalino Lodge, and that we should still expect something between 30 to 200 additional species. However, using the number of Ithomiini, the total species richness would be from 652 to 698 species, which is considerably lower than the actual number of species already recorded. This result does not seem to be linked to undersampling of this group, which is well-known for being locally abundant and easy to detect, collect and photograph. As an example, with a lower sampling effort, Mielke et al. (2010) found 35 Ithomiini species at Chandless State Park, Acre, Brazil and KSB and AVLF recorded more than 70 species of Ithomiini in a two day census in a locality in the upper Juruá river, Acre, Brazil (unpublished data). Instead, the Cristalino fauna seems to be particularly poor in its proportion of ithomiines, with only 30 species known, a mere 3% of the total recorded butterfly richness. This is in accordance with Brown & Freitas (2000), who indicated that the proportion of Ithomiini presents a great variance, ranging from 2% to 6% of the total butterfly species richness in the Atlantic Forest, and reaching a maximum of 8% in the east Andean slopes. This result suggests that the tribe Ithomiini is not necessarily a good surrogate of butterfly species richness in neotropical forests, and calls attention to the importance of considering the characteristics of each region's fauna in terms of using a taxon or guild for this kind of estimate. Since the Ithomiini is a tribe of Nymphalidae it is possible that other nymphalid groups are under-represented in comparison with other regions, but it seems clear that using Nymphalidae to estimate overall diversity is likely to be more precise. It may thus be assumed that we have recorded at least 80% of the butterfly species of Cristalino. Although this estimate should be used carefully, we believe it is safe to consider this list as a good illustration of the diversity and distribution patterns of this region (the small representation of Ithomiini being an example), and to compare it to other areas.

Relative to the other tropical forest biome in Brazil, the Atlantic Forest, Cristalino Lodge presents a higher number of species than the richest localities (Brown & Freitas 2000, Dolibaina et al. 2010, Francini et al. 2011). As for the Amazon Forest, it is not as rich as areas in western Amazonia, such as Tambopata and Pakitza in Peru or Cacaulândia and Marechal Thaumaturgo in the Brazilian states of Rondônia and Acre (Lamas 1985, Robbins et al. 1996, Brown & Freitas 2002, respectively, see also Brown 2005 for other equally rich localities in western Amazonia). Therefore, although the present butterfly inventory is currently the richest for a locality in Brazil, it is expected that it will be surpassed when lists of sufficiently sampled

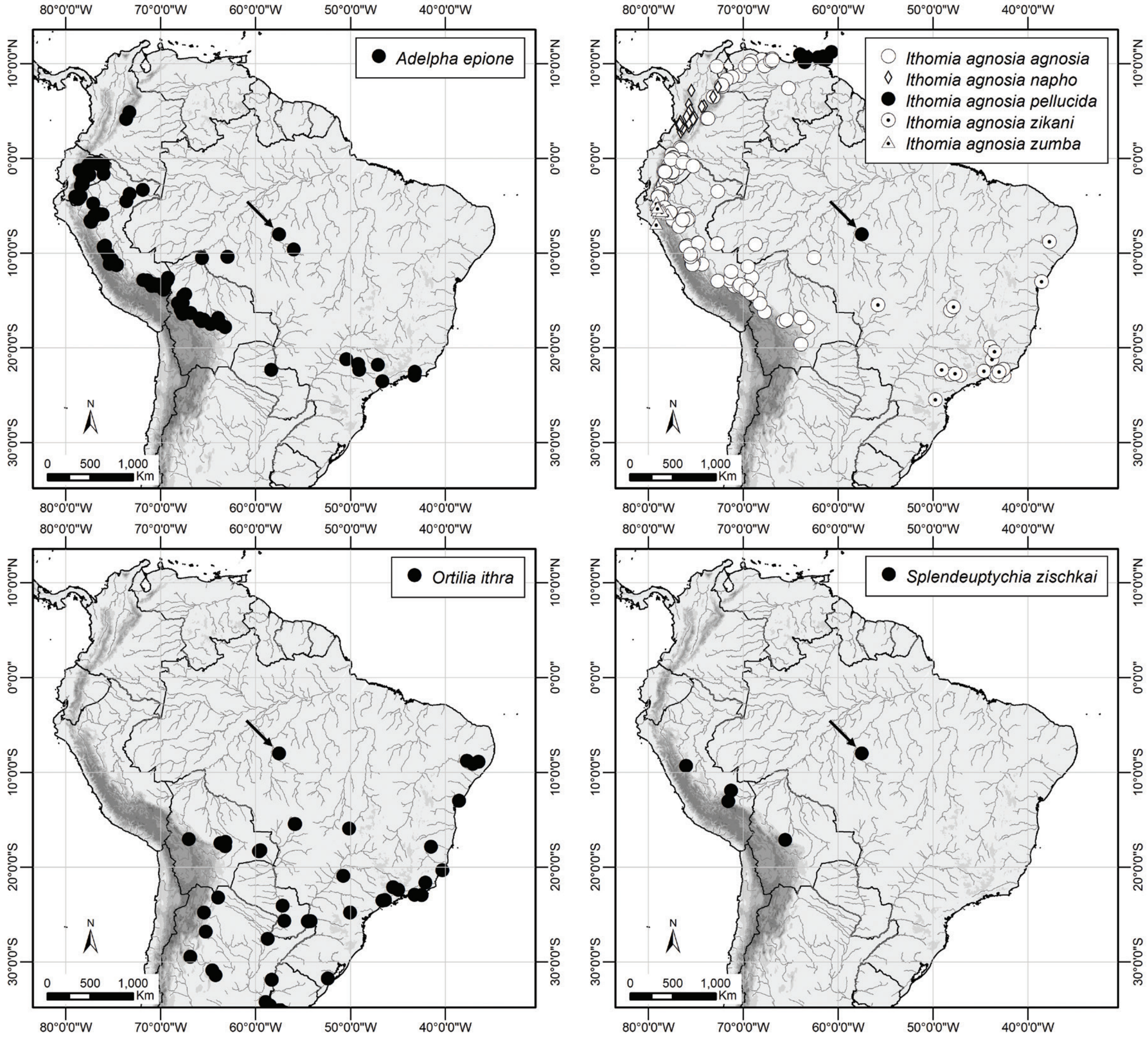

Figure 3. Distribution map for some butterfly species with notable range extensions documented at Cristalino Lodge (arrows).

regions in the Brazilian western Amazonia are published. At the same time, the region of Manaus, in central Amazonia, is known to be less rich, with about 800 estimated species (Brown 1984). Factors such as soil richness, proximity to the Andes and environmental heterogeneity have been proposed as important to determine the butterfly richness of Amazonian localities (Brown 1984). The Cristalino region has poorer soils than rich areas in Acre and Rondônia, and is much more distant to the Andes than Tambopata and even the aforementioned Brazilian states, thus being less under the influence of the diverse Andean fauna. The latter factor could be especially important for the Ithomiini, since the Andes is the area where this tribe is the richest and many of its groups originated and diversified (Chazot et al. 2016, 2018). Such an influence, however, is not completely absent: interestingly, the Andean *Morpho zephyritis* A. Butler, 1873, cited by Brown (1984) as an occasional visitor in Jaru, Rondônia, has also been recorded at Cristalino. At the same time, the great environmental heterogeneity and different vegetation types found in Cristalino could explain in part why it is a richer site than Manaus for butterflies.

The butterfly fauna found in Cristalino is mostly composed of species widely distributed in the lowland Amazon Forest, with some notable absences: for example, the widespread Amazonian genera *Asterope* Hübner, [1819], *Panacea* Godman & Salvin, 1883 and *Batesia* C. Felder & R. Felder, 1862 (Nymphalidae) have never been observed in the region. Conversely, the Cristalino region also harbors several species that are typical of southern biomes such as the Cerrado and the Atlantic Forest. That is the case with *Arawacus tarania* (Hewitson, 1868) (Lycaenidae), a species of open Cerrado vegetation, and of the newly described *Splendeuptychia tupinamba* Freitas, Huertas & Rosa, 2021 (Nymphalidae), found primarily in the Cerrado but also in the Atlantic Forest and some localities in southwest Amazonia (Rosa et al. 2021). Another good example is the presence of *Ortilia ithra* (W. F. Kirby, 1900) (Nymphalidae); this species is widespread through the Atlantic Forest and in riparian forest in the Cerrado domain and the present record is the northernmost and the first in the Amazon Forest (Figure 3). In addition, the Hesperiidae *Pythonides homer* Evans, 1953 and *Lento apta* Evans, 1955 were both considered endemics of the Cerrado, usually found in riparian forests (Mielke et al. 2008). However, it is unknown if these elements from the southern biomes are part of an original mixed fauna or recent invaders following the open areas created with the advance of agriculture and cattle ranching. It is likely that the presence of these species is due to the region being relatively close to the southern border of Amazonia and having patches of deciduous and semi-deciduous vegetation with influence from the Cerrado flora (Zappi et al. 2011). Several other butterflies from open vegetation are widely distributed species, such as *Junonia* sp. and *Euptoieta hegesia* (Cramer, 1779), both found in the deciduous forest fragments, while many common Neotropical pierids follow the river margins, where they puddle (figure 1c). The bamboo forests have an important community of Euptychiina associated with them, probably due the use of bamboo as hostplants by many species (See et al. 2018, Freitas et al. 2019). The Ithomiini and their mimics reveal that the region is heavily influenced by the Tapajós center of endemism and a little by the Rondônia center, with some undescribed subspecies (Brown 1979, 1982). The list presents two cases of species with more than one recorded subspecies, the nymphalids *Heliconius numata* and *Memphis acidalia*. The first is a polymorphic species that participates in several mimicry rings and is known to have as many as seven forms in a single locality (Brown & Benson 1974). Therefore, even though the forms found at Cristalino Lodge are currently treated as subspecies, they represent the expected polymorphism found in *H. numata.* In contrast, the reason why two subspecies of *M. acidalia* have been recorded is not known, but it is possible, for instance, that the region is close to the distribution limits between them.

None of the butterflies recorded at the site is listed as endangered, which is unsurprising since the only butterfly species in the Brazilian Amazon Forest considered to be threatened is *Parides klagesi* (Ehrmann, 1904), which is found in a small area very distant to Cristalino (Freitas et al. 2018). However, it is important to emphasize that, as noted by Freitas & Marini-Filho (2011), the low numbers of Amazonian butterfly species regarded as threatened could partly result from poor knowledge about the distribution of Amazonian species. In particular, the degree to which rarer species, such as *Splendeuptychia tupinamba*, occupy sites within their extent of occurrence, is critical for estimating global range and population size and threat status. In addition, Silva et al. (2005) showed that habitat loss is not homogeneous among terrestrial vertebrate centers of endemism, which somewhat correspond to those of butterflies (Brown 1979, Tyler et al. 1994, Hall & Harvey 2002). This fact, combined with the large total area of long-term degraded forests (Matricardi et al. 2020), the recent increase in deforestation of the Amazon Forest in Brazil (INPE, 2020), and the perspective of future savannization of forest areas if certain temperature and deforestation "tipping-points" are achieved (Nobre et al. 2016, Sales et al. 2020), means that Amazonian butterfly species and subspecies could already be or become endangered in the future. This is especially true if there are any butterflies endemic to the region of the arch of deforestation, which encompasses the southern Amazon border. It is clear that more inventories and distribution data on the Amazonian butterfly fauna are needed not only to better understand its diversity patterns and the factors that determine them, but also how it is responding and will respond to anthropogenic changes in the region.

Images of live butterflies available on the internet contributed an impressive proportion of the present species list (virtually one third), and were especially important for a representative inventory of Hesperiidae and Lycaenidae. Photographic records include rare and undescribed taxa, which reinforces the value of photographic data for tropical butterflies (Mesaglio et al. 2021). It is important to note that the use of photographic records for butterfly species lists has limitations, since not all species can be identified based on images only, and, even for those that can, a precise identification depends also on the image quality and aspects such as the butterfly's position. Such limitations and the necessities for the identification of each taxon are often unknown to the general public, which is probably the reason behind the presence of a great number of images labeled with wrong or uncertain identifications on the internet. It also seems possible that the identification of some key pictures (i.e., shared in many sources or in a few relevant ones) is frequently copied for records of similar looking specimens, leading to a cascade of misidentified images that could be confusing for citizen scientists. However, as noticed by Mesaglio et al. (2021), the iNaturalist platform is used by many knowledgeable, professional and amateur taxonomists, who contribute with hundreds or even thousands of identifications on their groups of interest. Therefore, identifications of images available on this platform are often corrected, justified, discussed, or have comments regarding their uncertainty. For these reasons, it is extremely important that the use of photographic records for butterfly inventories, as well as other areas of research, is made with caution and the aid of specialists (which might include the ones that use iNaturalist), and that the identification methods are made clear to readers. The source of the images used should also be explicit, so identifications can be disputed or corrected in the future, in the same way as with collected specimens deposited in collections. Overall, our study shows that images can be invaluable for butterfly species lists, and, even if many of them are not identified to species-level, they at least give an idea of the characteristics of the fauna found in a certain region, and even serve as a guideline for what researchers should look for in further visits to the location. Future studies should help clarify the extent to which live-specimen images are informative for different taxonomic groups and localities.

Although ecotourists not focusing on butterfly watching generated hundreds of pictures of butterflies at Cristalino, providing important data that can be used in future studies in fields such as ecology and behavior, this huge amount of information contributed few new records (not present among the collected specimens) of butterfly species for the region. One possible reason is that tourists typically focus on big, colorful, and easy-to-photograph specimens, thus tending to record the same common or flashy species. We found that the majority of new records come from expert butterfly watchers and tour guides, who together contributed more than 300 species for the total list. This is similar to what was found by Mesaglio et al. (2021), and many of the iNaturalist users (including both photographers and identifiers) cited there also participated in the project "Butterflies of Cristalino Lodge" in this platform. Butterfly watchers and tour guides: a) are interested in high numbers of records, with an emphasis on the new and rare species; b) are familiar with specific scientific knowledge, searching for information about behavior and taxonomy in the literature, and often (but not necessarily) having a degree in environment-related areas; c) are enthusiastic about sharing their records and knowledge, including in online platforms, and communicating with researchers and other interested people; and d) accumulate thousands of hours of field experience in either one or several localities. We believe that there is huge potential for greater communication between scientists and taxon-oriented ecotourists (such as butterfly watchers) and tour guides, with their knowledge and experience being both backed up by and supporting research in creative ways. In particular, photographers are able to visit and document butterflies in many areas that are not open to researchers wishing to collect specimens because of the time or complexities in obtaining the necessary research permits, and potentially the expense to access field sites. Fortunately, butterfly taxonomy is sufficiently advanced in most groups for many images to be identified, and photographic contributions have extended even to the discovery of new species (e.g., Willmott et al. 2020).

Finally, this study lists the butterflies known from the private reserves associated with an ecolodge and an environmental foundation. Without the existence of these institutions, it is unlikely that the butterfly fauna of this region would have been the subject of so many photographers and visiting researchers. Ecotourism facilities thus can provide access to and infrastructure in areas that would be otherwise remote, giving support for citizen scientists (and, in cases such as that presented here, formal scientific researchers) to reach these areas. Responsible ecotourism initiatives therefore can link themes such as environmental education, conservation, and science, and become a basis for unusually complete and long-term occurrence data, especially for charismatic groups such as butterflies.

Supplementary Material

The following online material is available for this article:

Table S1 - Butterflies and moth-butterflies (Papilionoidea) of Cristalino Lodge recorded only through pictures. Indicates the photographers, picture sources (including links, when available), and species identifiers.

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Author Contributions

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Keith S. Brown Jr.: Contribution to data collection, contribution to data analysis and interpretation.

Curtis J. Callaghan: Contribution to data analysis and interpretation.

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Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

A MS Excel file containing information on the species recorded only through pictures including each species' photographers, picture sources and links is available at: https://doi.org/10.48331/scielodata.SDBURK.

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Short Communication

Non-invasive genetic sampling reveals a habitat use extension of *Chrysocyon brachyurus* and *Leopardus guttulus* inside a protected area of Southeastern Brazil

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Abstract: Anthropogenic activities have modified landscapes leading to environmental damages and to a threatened biodiversity. As a result, protected areas have become the last refuge for many species. Protected areas surrounded by a highly modified landscape may accumulate species, especially large mammals, which may alter their habitual habitat use. Here we used non-invasive DNA analysis, molecular species identification, and landscape analyses to assess the habitat use of carnivore species in an isolated protected area, Itatiaia National Park (PNI). Two species were by far the most sampled within PNI, *Chrysocyon brachyurus* and *Leopardus guttulus*. The spatial distribution of each species was assessed to the following landscape variables: altitude; land use/land cover; slope and Euclidean distances from water and from urban buildings. The habitat use of *C. brachyurus* and *L. guttulus* was related to altitude and land use/land cover. We tested whether there were differences in the environmental indicators considering both species, which showed that higher altitudes, forest and/or grassland formation were indeed associated with them. We highlighted the unprecedented presence of both species at altitudes up to 2,631 meters. Our results suggest a habitat use extension for both species inside the PNI that could be a consequence of the highly modified landscape where PNI is inserted. Therefore, the results can be helpful for better understanding the species dynamics and their conservation in the face of landscape changes. Further, this study may be of help for management and conservation policies of this emblematic protected area.

Keywords: *Conservation; non-invasive DNA; landscape; land use/land cover; carnivores.*

Amostragem genética não-invasiva revela uma extensão do uso de habitat por *Chrysocyon brachyurus* e *Leopardus guttulus* em uma área protegida do Sudeste do Brasil

Resumo: As atividades antropogênicas modificaram as paisagens levando a danos ambientais e a uma biodiversidade ameaçada. Como resultado, as áreas protegidas se tornaram o último refúgio para muitas espécies. Áreas protegidas cercadas por uma paisagem altamente modificada podem acumular espécies, especialmente grandes mamíferos, o que pode alterar o uso de seu habitat habitual. Neste trabalho, usamos análise de DNA não-invasivo, identificação molecular de espécies e análises de paisagem para avaliar o uso de habitat de carnívoros em uma área protegida isolada, o Parque Nacional de Itatiaia (PNI). Duas espécies foram de longe as mais amostradas dentro do PNI, *Chrysocyon brachyurus* e *Leopardus guttulus*. A distribuição espacial de cada espécie foi avaliada com as seguintes variáveis paisagísticas: altitude; uso e cobertura do solo; declividade e distâncias euclidianas da água e de construções urbanas. O uso de *C. brachyurus* e *L. guttulus* no habitat estava relacionado à altitude e ao uso e cobertura do solo. Testamos se existiam diferenças nos indicadores ambientais considerando ambas as espécies, o que mostrou que altitudes mais elevadas, formação de florestas e/ou campestres estavam de fato associadas a elas. Destacamos a presença incomum de ambas as espécies em altitudes de até 2.631 metros. Nossos resultados sugerem uma extensão do uso do habitat conhecido para ambas as espécies como possível consequência da paisagem altamente modificada onde o PNI está inserido. Portanto, os resultados podem ser úteis para entender melhor a dinâmica das espécies e sua conservação diante das mudanças na paisagem. Além disso, este estudo pode ser útil para as políticas de manejo e conservação desta emblemática área protegida.

Palavras-chave: *Conservação; DNA não-invasivo; paisagem; uso e cobertura do solo; carnívoros.*

Introduction

Anthropogenic activities are the main source of environmental changes once they have intensified the process of landscape fragmentation and enhanced ecological damage (Cerqueira et al. 2003). These land use modifications represent the greatest immediate threat to biodiversity, and it can lead to variations in the ecosystem functioning, including biodiversity loss (Cardinale et al. 2006).

In this scenario, protected natural areas are one of the most important mechanisms to slow down biodiversity loss. (Godet and Devictor 2018; Wintle et al. 2019). They are also essential to watershed protection and carbon storage, as well as to cultural services that are more challenging to quantify (DeFries et al. 2007). Nevertheless, even protected areas may face several threats such as deforestation and fragmentation, invasion of alien species, wildfires, logging, and hunting (Ervin 2003; Carey et al. 2000). Protected areas surrounded by a highly modified landscape may suffer with the potential negative consequences associated with neighbor land use changes (Hansen and DeFries 2007). A most common consequence of these landscape modifications to animals, mainly large mammals, is altering their range distribution and habitat use (Ripple et al. 2017).

Nonetheless, understanding the habitat use and its conservation becomes a challenge when focusing on large mammals, due to recurring problems in observing or capturing most of these species. The use of non-invasive samples left in the environment by animals as scats, hair, urine, saliva, nails, and feathers, may decrease the expenditure of capturing these animals and the time spent in the field (Duque et al. 2018). Furthermore, the increased interest in molecular techniques among ecologists has been improving our knowledge of the biology and ecology of these large mammals. As an example, the use of non-invasive samples as DNA sources (Deyoung and Honeycutt 2005; Ruell and Crooks 2007) for species identification or for assessing social organization system, demographic history, and population dynamics (Marker et al. 2007; Miotto et al. 2014; Riley et al. 2006; Saranholi et al. 2017; Souza et al. 2017).

Among mammals, the carnivores have been increasingly suffering from habitat loss and landscape modifications (Noss et al. 1996; Ripple et al. 2014). However, because of their important ecological function of regulating other populations through predation (Santos et al. 2004; Ripple et al. 2014), their persistence in the ecosystem is critical.

In this study, we employed non-invasive-derived DNA from carnivores' scats to understand how these species use available habitats inside an important protected mountain area inserted in a highly modified landscape in Southeastern Brazil. We focused in *Chrysocyon brachyurus* and *Leopardus guttulus,* which are by far the two carnivore species most sampled in the studied area. Regarding habitat use, we expected that *C. brachyurus* would be associated with grassland and *L. guttulus* with forest formations. In addition, *C. brachyurus* inhabits the Brazilian savannas in altitudes up to 2000 m (Queirolo et al. 2011; Paula & DeMatteo, 2015; Bereta et al. 2017) and *L. guttulus* appears in areas of dense vegetation, such as Atlantic Forest from the coastal plain to fields with altitudes no higher than 1300 m (Oliveira and Cassaro 1999; Goulart et al. 2009), although it can reach up to 2000 m of altitude (Oliveira et al. 2016; Sartor et al. 2021). Hence, we also expected to find both species up to a maximum altitude of 2000 meters.

Material and Methods

The sample collection was made in previously existing trails in the emblematic Itatiaia National Park (PNI), the first national park created in Brazil in 1937. The area is classified by the Brazilian legislation as an integral protection conservation unit (IPCU), where only indirect use of natural resources is allowed. PNI has a total area of 28,084 hectares (ICMBio 2012), ranging altitude from 549 to 2791 meters and is located between the states of Rio de Janeiro and Minas Gerais ((Fig. 1a) - boundaries from the Brazilian Institute of Geography and Statistics), Southeastern Brazil. The conservation area is integrally inserted in the Atlantic Forest biome, and is considered a priority area for the conservation of biodiversity of extreme relevance due to the high concentration of endemic and endangered species (Bencke et al. 2006). Also, it is a priority area for future mammal censuses considering the absence of data, especially about medium and large mammals (Galetti et al. 2009).

Despite being a protected area, the PNI is circumvented by municipalities historically recognized for agricultural activities, which present a series of conflicts concerning PNI (Aximoff and Rodrigues 2011; Richter 2004). Between the alarming activities, we can highlight the use of fire for cleaning and maintenance of pastures, disorderly tourism, hunting, and illegal extraction (de Medeiros 2002; Aximoff and Rodrigues 2011; Dib et al. 2020). The unregulated land tenure also causes irregular parceling of the soil and may even allow people living in the PNI, culminating in the generation of waste, effluents, and others (ICMBio 2012).

The traveled trails totaling 352.20 km covered the entire extension of the PNI (Fig. 1a), varying between 773 m and 2766 m in altitude, with 46% in Forest Formation, 49% in Grassland Formation, 4% in Mosaic of Agriculture and pasture, and 1% in Rocky outcrops.

The trails were covered once by foot in non-periodic visits and the sample collection was carried out between July 2017 and April 2018. This was done preferably in the dry season when finding fresh scats is easier (Miotto et al. 2012) and considering that the presence of carnivores is not strongly affected by seasonality (Nagy-Reis et al. 2019; Trolle et al. 2006; de Almeida Jácomo et al. 2004).

Scats morphologically identified in the field as belonging to medium and large carnivores were collected along the trails in rocks and open places up to 3 m maximum around the trails since carnivores can use these places to mark their territory (Kleiman 2011; Lyra-Jorge et al. 2008). All scat samples collected were stored in 95% alcohol at –20 °C for molecular species identification, and the sampling geographic coordinates were recorded using a GPS device (Table S1).

Total DNA was extracted from fecal using QIAamp Fast DNA Stool Mini Kit (Qiagen) following the manufacturer's recommendations. We used the scat surface to minimize contamination from non-target DNA (Ball et al. 2007); additionally, two carnivore-specific fragments of mitochondrial DNA from the 12S (148 bp, Rodríguez-Castro et al. 2018), and ATP6 (179 bp, Haag et al. 2009; Chaves et al. 2012) genes were amplified by PCR for molecular identification. The use of taxon-specific primers avoided amplification of non-target species, such as the prey on which carnivores feed, facilitating the DNA amplification of the species of interest. PCRs were performed on the Applied Biosystems ProFlex PCR System thermocycler (Life Technologies) following the conditions proposed for suitable amplification of mitochondrial regions of carnivore scats using the Car12Ss2 rRNA primers (Rodríguez-Castro et al. 2018), and ATP6-DF3 (Haag et al. 2009), and ATP6-DR1 (Chaves et al. 2012).

PCR products were verified in electrophoresis using 1.5% agarose gel with GelRed (Biotium), purified using ExoSAP-IT enzyme (Affymetrix), and sequenced in ABI3730XL automatic sequencer (Applied Biosystem). Sequences obtained were manually edited and aligned using the CLUSTAL method (Thompson et al. 1994) with the Geneious software (Kearse et al. 2012). We compared each obtained sequence with the deposited sequences in the National Center for Biotechnology Information (NCBI), using the Basic Local Alignment Search Tool (BLAST) (Altschul et al. 1990). Likewise, the sequence was contrasted with sequences previously obtained by the Laboratory of Molecular Biodiversity and Conservation (Department of Genetics and Evolution/Federal University of São Carlos), using the neighbor-joining distance-based method (Saitou and Nei 1987). Only sequences that showed the identity similarity value above 98% with the reference sequences were considered.

The landscape variables land use/land cover, Euclidean distance (ED) from water bodies, ED from the nearest urban buildings and altitude which have already been identified in other studies as influencing the occurrence of carnivores (Queirolo et al. 2011; Bereta et al. 2017; Cruz et al. 2019) were analyzed. The fine-scaled measure of climate variables was not available and was not included in the analyses. We extracted the variables from each fecal sample point and added random points obtained through the Create Random Points tool in QGis. All points were used to test whether each species occurrence had a specific pattern, given the possible habitats within PNI. Land use/land cover were obtained from the MAPBIOMAS PROJECT 3.0 platform (http://mapbiomas.org). The annual series used (2017) was obtained with LandSat images using Google Earth Engine with 30 m resolution and accuracy validated by the platform owner (Fig. 1b). Based on information from the drainage network, the distance between the samples and the nearest water body was calculated (Fig. 1f), aiming to establish the geographical range of water bodies by Euclidean distance using QGis. The urban infrastructure locations were obtained from the PNI's Management Plan, Map 2.1, booklet 2, where they were named as Villages, Hamlets and Neighborhoods. These locations were completed using Google Earth Pro. The ED calculated between urban buildings and the species location is shown in Fig. 1e.

The geographical relief was obtained from a Digital Elevation Model (DEM), which reproduces the spatial representation of a terrain's surface from points that describe its three-dimensional elevation (Montgomery 2003). Planialtimetric data were acquired using ALOS Palsar satellite images with 30 m resolution. The primary attributes of relief features (Klingebiel et al. 1987) obtained from the DEM and considered in this study were the altitude and slope (Figures 1c, d). Those values were taken from the pixel of each sampling point using QGis (pixel resolution 30 m).

We tested whether species occurrence was related to environmental variables (land use/land cover, altitude, slope, ED from water bodies and urban buildings), comparing the sample fecal points to a null random sampling points for each species, using R (R Development Core Team 2020). For the land use/land cover, the unique categorical variable, we also compared species across vegetation types using the "*lsmeans*" package (Lenth et al. 2016). Since *C. brachyurus* and *L. guttulus* shown similar presence with regard to the environmental variables, we compared species occurrence in a single generalized mixed model, one species relative to the other. We used sets of generalized mixed models with binomial distribution, and the PCA-axis-built with ecological variables as fixed-factors, in all possible arrangements for PCA following Lindstrom and Bates (1990).

Generalized mixed models were fitted using the '*lme4*' package (Bates et al. 2015). In all cases, we selected the best model relating species occurrence to these variables, using the lowest Akaike Information Criterion (AIC; Akaike 1974) values and significant differences. The significance of each explanatory variable was tested using the '*Anova*' function in the '*car*' package (Fox and Weisberg 2019).

Results

From a total of 244 scats, we were able to identify 175 (71.7%) using non-invasive-derived DNA for molecular species identification. The remaining 81 samples were removed from the analyses because they presented degradation in the genetic material likely due to prolonged exposure to environmental conditions or they did not belong to carnivores.

The scat samples were identified as following: 94 (57.6%) as belonging to *C. brachyurus* (maned wolf), 52 (31.9%) *L. guttulus* (southern tiger cat), three (1.84%) *Cerdocyon thous* (crab-eating fox) and 14 (8.58%) of *Canis familiaris* (domestic dog). Only the two most sampled species (n > 50), *C. brachyurus* and *L. guttulus*, were analyzed hereafter. *C. brachyurus* scats were mainly found in grassland formation (69 scats, 73%), following by forest formation (25 scats, 27%). Otherwise *L. guttulus* scats were mostly found in forest formation (35 scats, 67%), following by grassland formation (16 scats, 31%) and mosaic of agriculture and pasture (1, 2%), Table S1.

Seven different types of land use and land cover were determined within the PNI, mostly natural elements of the landscape, such as Forest formation (79.3%), Grassland formation (15.55%), Rock Outcrop (0.79%). Nevertheless, other types, such as the Mosaic of Agriculture and pasture (3.3%), Pasture (0.83%), Non-vegetated areas (0.04%) and Forest plantation (0.01%), were generated by the human presence (Fig. 1b).

Using DEM analysis, we found altitudes ranging from 549 to 2790 m (Pico das Agulhas Negras – Fig. 1c). According to the classification proposed by Lepsch (1983), the relief of the PNI can be characterized as strongly wavy to steep, with slope above 15% on most of its land (Fig. 1d). The ED results for each sample to water bodies ranged from 1 to 750 m (Fig. 1f), while for urban buildings ranged from 1 to 6650 m (Fig. 1e).

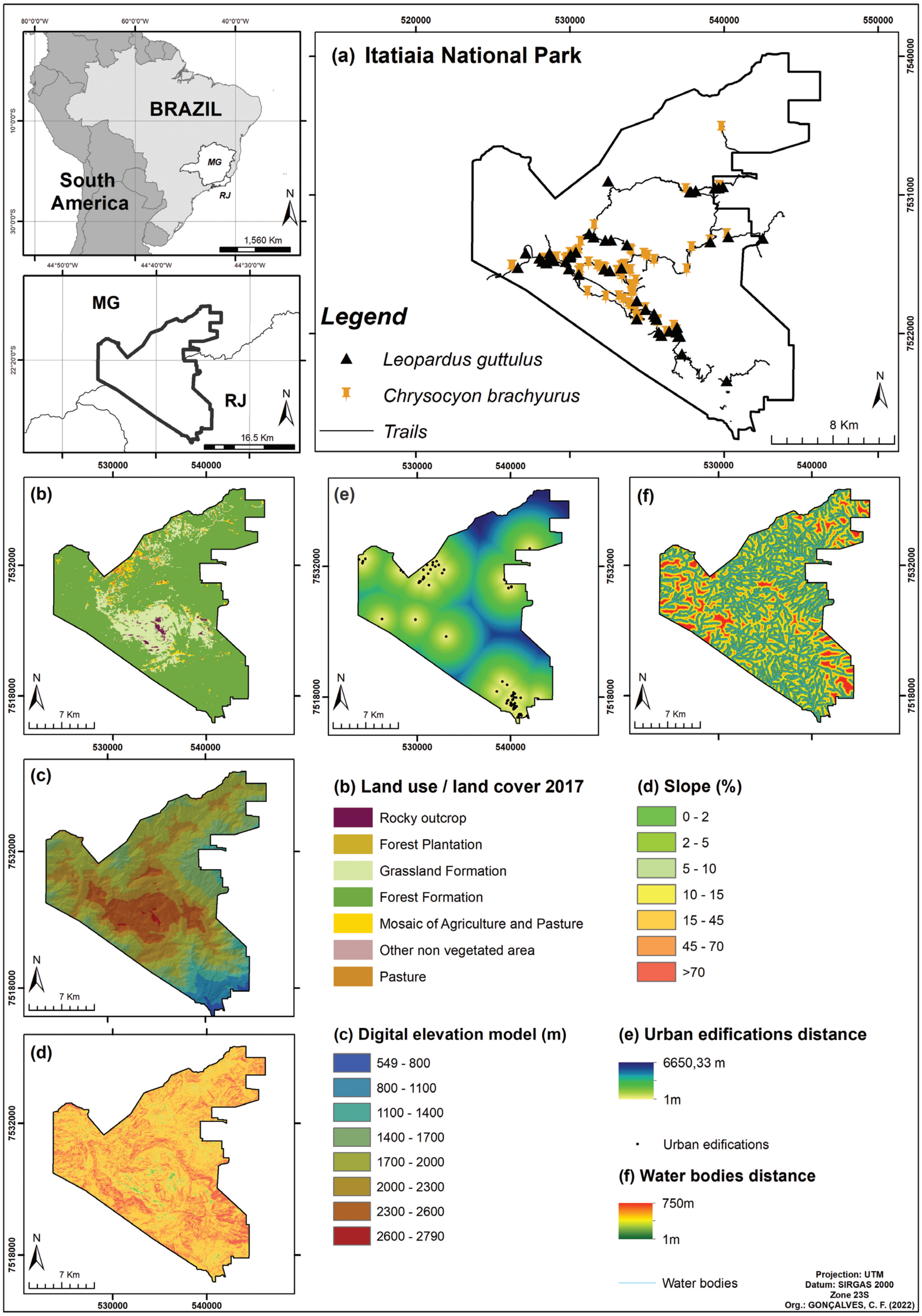

Figure 1. (a) Location of Itatiaia National Park (PNI), trails and samples location; (b) Land use/land cover; (c) digital elevation model; (d) slope; (e) Distance from urban buildings and their locations (f) Distance from water bodies.

Table 1. Coefficients of generalized mixed models using a random sampling showing correlation between presence of species (*C. brachyurus* and *L. guttulus*) and environmental variables (altitude, forest formation, grassland formation and mosaic of agriculture and pasture).

Variable	Estimate	Std. error	t-value	P (>|t|)
C. brachyurus				
Intercept	-1.775^{+00}	2.893^{-01}	–6.134	<0.001
Altitude	6.959^{-04}	8.797^{-05}	7.911	<0.001
Grassland Formation	7.295^{-01}	1.873^{-01}	3.895	<0.001
Forest Formation	1.025^{+00}	2.076^{-01}	4.936	<0.001
Mosaic agriculture and pasture	1.959^{-01}	2.994^{-01}	0.654	0.5136
L. guttulus				
Intercept	-1.734^{+00}	2.964^{-01}	–5.849	<0.001
Altitude	6.798^{-04}	9.126^{-05}	7.450	<0.001
Grassland Formation	7.229^{-01}	1.882^{-01}	3.841	<0.001
Forest Formation	9.995^{-01}	2.111^{-01}	4.735	<0.001
Mosaic agriculture and pasture	1.914^{-01}	3.008^{-01}	0.636	0.5254

The top-ranked models of generalized mixed models performed to evaluate the relationship between presence of species (*C. brachyurus* and *L. guttulus*) and environmental variables are shown in Table S2, and the model selected included altitude and land use/land cover, considering the lowest AIC with significant P values. Because we did not obtain fecal samples in rocky outcrop, forest plantation, other non-vegetated area and pasture, these variables were not included in the GLMM analyses. The generalized mixed models using random sample ($P < 0.001$, Table 1) and both species (Table S3), performed to assess the association of species occurrence to environmental variables according to availability within the PNI, showed that altitude, forest and grassland formation were relevant for their habitat use.

Altitude, forest and grassland positively affected the presence of both *C. brachyurus* and *L. guttulus* ($P < 0.001$, Table 1). Since the habitat use was similar between the two species, we have included both in a single model only with observational data to test whether there were any differences between them, and the results were similar (Table S3). Of note, among the numerical variables analyzed, altitude was the only variable that differed between species (Figure S1).

Discussion

Our findings suggest a habitat use extension of *C. brachyurus* inhabiting grassland and forest in the studied area. In contrast, *L. guttulus* was mostly found in the forest formation (67%) as expected, corroborating its habitat use already reported (Oliveira and Cassaro, 1999; Gourlart et al. 2009; Sartor et al. 2021), although scats of this species were also obtained in grassland formation (31%), suggesting an important association with this habitat in PNI. It is well known that *C. brachyurus* is affected throughout its original range by habitat loss and modification due to urbanization, agricultural and livestock raising (Paula et al. 2013; Queirolo et al. 2011, 2014; Vynne, 2014). These human-promoted habitat modifications can be leading to habitat use expansion in this species (Queirolo et al. 2011). Thus, even though the original range of *C. brachyurus* did not include Atlantic Forest, it has been already reported inside this domain (Rodrigues and Oliveira 2006; Lourenzutti and Almeida 2006) and had its first record for PNI in 1954 (Ávila-Pires & Gouvea, 1977).

In the present study, *C. brachyurus* was observed in the grassland formation, as frequently reported across its distribution area (Dietz 1984; Rodden et al. 2004; Lyra-Jorge et al. 2010; Coelho et al. 2018), but an expressive amount of scats (27%) was sampled in the forest, contrasting with other studies which showed that this animal avoids these areas (e.g. Coelho et al. 2008). It is important to notice that the proportion of grassland formation in PNI is low (16%), but it concentrates 73% of all records obtained for *C. brachyurus*, demonstrating a strong association of this canid with this vegetation. However, it is suggested that PNI represents an important refuge for the local population of *C. brachyurus* that once was putatively expelled from the highly modified areas nearby. Limited by the geographical and vegetational characteristics of PNI, *C. brachyurus* seems to be expanding its habitat use to the forest.

Our findings of differential occurrence in relation to altitude also have some novelties. Although *L. guttulus* occurred preferably in lower altitudes, our data revealed its presence at altitudes ranging from 1436 to 2544 m, representing the highest altitudinal limit observed for the species (Oliveira et al. 2016; Goulart et al. 2009). In a recent modelling study, the presence of *L. guttulus* reached altitudes of about 1000 m, declining to a minimum value at 2000 m (Sartor et al. 2021). It is suggested that our findings enlarge the altitudinal range for the species and the presence of forested areas at these altitudes could be facilitating *L. guttulus* to expand its height scope in PNI. However, further studies to evaluate the occurrence of this species in different altitudes are still needed. Similarly, our results on the *C. brachyurus* occurrence also showed higher altitudes than it has ever been reported. While this species preferably appears to inhabit altitudes up to 2000 m (Queirolo et al. 2011; Paula & DeMatteo, 2015; Bereta et al. 2017), we found this species in higher altitudes ranging from 1574 to 2631 m. Together, these results represent the highest altitude reported for both species this far.

In sum, our findings suggest a potential habitat use extension in *C. brachyurus* and *L. guttulus* inhabiting an emblematic protected area in southeastern Brazil. Similar results were already reported for both species living in different studied areas (Rodrigues and Oliveira 2006; Lourenzutti and Almeida 2006; Queirolo et al. 2011; Sartor et al. 2021). We also point out that PNI represents an important refuge for the species that suffer the consequences of the increasingly landscape modifications in this geographical region. The use of molecular species identification through non-invasive sampling was critical for assessing presence and ecological information of both carnivores studied. The integration of molecular species identification and landscape analyses allowed to infer how these species may be responding to anthropic disturbances. Even further, it is gathering useful information for a better understanding of the species dynamics, conservation plans of studied species in a changing scenario, and management and conservation policies of this important protected area.

Supplementary Material

The following online material is available for this article:

Table S1 – Geographic coordinates and landscape variables for each data.

Table S2 – Top-ranked models of generalized mixed models between presence of species (*C. brachyurus* and *L. guttulus*) and environmental variables (ED from water bodies, ED from urban buildings, altitude, slope, land use/land cover).

Table S3 – Coefficients of generalized mixed models showing correlation between presence of species (*C. brachyurus* and *L. guttulus*) and environmental variables (altitude, land use/land cover).

Figure S1 – Boxplot showing the environmental variables describing the occurrence of the studied species. Grey boxplot indicates significant difference after the GLMM tests (P < 0.001).

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Author contributions

Camila F. Gonçalves: substantial contribution in the concept and design of the study; data collection; analysis and interpretation; manuscript preparation and critical revision, adding intellectual content.

Karen Giselle Rodriguez-Castro: substantial contribution to data analysis and interpretation; manuscript preparation and critical revision, adding intellectual content.

Lais Verdan Dib and Alynne da Silva Barbosa: substantial contribution to data collection.

Luiz Eduardo Moschini: substantial contribution in the analysis and interpretation.

Pedro M. Galetti Jr: substantial contribution in the concept and design of the study; analysis and interpretation; manuscript preparation and critical revision, adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

All research was conducted based on the protocols approved by Ethics Committee on Animal Experimentation (CEUA, Instituto Biomédico, Universidade Federal Fluminense), and SISBIO-ICMBio (Authorization System and Biodiversity Information-Chico Mendes Institute for Biodiversity Conservation, Ministry of Environment, Federal Government, Brazil, number 57635-1), and through the National Management System for Genetic Heritage, and Associated Traditional Knowledge (SisGen), under registration code AFB4EA3.

Data Availability

The dataset generated in this study from AT6 region are available in the Dryad repository under DOI number https://doi.org/10.5061/dryad.djh9w0vvx, for 12S and COI in GenBank-NCBI under accession numbers MN509185-MN509198, MN608174-MN608176 (Dib et al. 2020). And all the dataset are available in the Supplementary Information in the Figshare under DOI number https://doi.org/10.6084/m9.figshare.20217044.

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Novelties from the herbaceous stratum in a key region for the conservation of the Southern Amazon

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Abstract: The contribution of the herbaceous stratum to tropical plant diversity is considerable, however this component remains undersampled. We investigated floristic, structural, ecological and conservation issues concerning the herbaceous component of a seasonal deciduous forest associated with granitic rock outcrops in the Cristalino Region, a key area for biodiversity conservation in the Brazilian Amazon. We installed a permanent plot of 1 ha, allocating 10 transect-lines of 20 m each. We identified the sampled individuals, measured height and projection, and verified cover and frequency per species, genera and family. We recorded 86 species, 62 genera and 25 families, with Orchidaceae being the family with the highest species richness. Among the 26 new species added to Cristalino Flora, we included *Philodendron deflexum* Poepp. ex Schott and *Griffinia nocturna* Ravenna, the latter 'Critically Endangered'. Furthermore, the occurrence of *G. nocturna* in an Amazonian forest matrix is a novelty in this study. The estimate of species diversity according to Shannon-Wiener (H') was 2.43 nats.ind.$^{-1}$ (equivalent to 11.37 ± 0.90 $IC_{95\%}$ equally common species), and according to Simpson (1/D), 6.82 (± 0.648 $IC_{95\%}$). The rarefaction and extrapolation curves for the diversity estimates tended to stabilize. Although the vegetation on rock outcrops usually presents a high number of endemic species, this pattern was not found in our study area, which can be explained by its continuous occurrence in the forest matrix. The understory of our study area consists in a mixture of floras, being composed mainly of species from the Amazon and/or Cerrado biomes. In view of the current anthropic pressure faced by the southern Amazon, we reinforce the importance of carrying out inventories of its herbaceous communities, since the risk of species loss is even more alarming when considering present undersampling of this component.

Keywords: *Floristic Survey; Forest Understory; Line Intercept Method; Southern Amazon; Plant Diversity; Species Diversity.*

Novidades do estrato herbáceo em uma região chave para a conservação da Amazônia Meridional

Resumo: A contribuição do estrato herbáceo para a diversidade de plantas tropicais é considerável, mas esse componente permanece subamostrado. Investigamos questões florísticas, estruturais, ecológicas e de conservação relacionadas ao componente herbáceo de uma floresta estacional decidual associada a afloramentos rochosos graníticos na região do Cristalino, que é uma área chave para a conservação da biodiversidade na Amazônia brasileira. Instalamos um plot permanente de 1 ha, alocando 10 linhas de 20 m cada. Identificamos os indivíduos amostrados, medimos altura e projeção e verificamos cobertura e frequência por espécie, gênero e família. Registramos 86 espécies, 62 gêneros e 25 famílias, sendo Orchidaceae a família com maior riqueza de espécies. Entre as 26 novas espécies adicionadas à Flora do Cristalino, incluímos *Philodendron deflexum* Poepp ex Schott e *Griffinia nocturna* Ravenna, esta última 'Criticamente Ameaçada'. Além disso, a ocorrência de *G. nocturna* em uma matriz florestal amazônica é uma novidade neste estudo. A estimativa da diversidade de espécies de acordo com Shannon-Wiener (H ') foi 2,43 nats / ind.-1 (equivalente a 11,37 ± 0,90 $IC_{95\%}$ espécies igualmente comuns), e de acordo com Simpson (1/D), 6,82 (± 0,648 $IC_{95\%)}$. As curvas de rarefação e extrapolação para as estimativas de diversidade tenderam à estabilização.

Embora a vegetação associada a afloramentos rochosos em geral apresente um elevado número de espécies endêmicas, esse padrão não foi encontrado para a nossa área de estudo, o que pode ser explicado pela sua ocorrência contínua à matriz florestal. O sub-bosque da nossa área de estudo apresenta mistura de floras, sendo composto principalmente por espécies dos biomas Amazônia e/ou Cerrado. Diante das pressões antrópicas existentes no sul da Amazônia, reforçamos a importância da realização de inventários das comunidades herbáceas desse bioma, já que o risco de perda de espécies é ainda mais alarmante quando consideramos a subamostragem desse componente.

Palavras-chave: *Região do Cristalino; Levantamento Florístico; Método de Intersecção de Linha; Sul da Amazônia; Diversidade de Espécies; Sub-bosque Florestal.*

Introduction

Floristic and structural studies in tropical forests contemplating the woody component are common, being markedly different from the sampling effort for the herbaceous component (Linares-Palomino et al. 2009). The contribution of the herbaceous stratum to plant diversity is considerable (Gentry & Dodson 1987, Linares-Palomino et al. 2009, Pasion et al. 2018), as well as its ecological importance in the composition of vegetation strata, representing an important ecological filter as it alters environmental conditions, such as temperature and humidity, acting as a potential barrier to the emergence and establishment of tree species (Gilliam 1994; Royo & Carson 2006, George & Bazzaz 1999). Additionally, the assembly mechanisms of herbaceous and woody communities seem to be contrasting, with herbaceous showing a stronger niche-derived structure (Murphy et al. 2019). Thus, the expansion of studies of the herbaceous stratum has direct implications for the different management and conservation strategies that may be necessary for different forms of plant growth within the same community (Murphy et al. 2019).

Rock outcrops are usually surrounded by a vegetation matrix on more developed soils, contributing to the formation of vegetation mosaics, with different soil types, vegetation and microclimate (Sarthou & Villiers 1998). In addition, rock outcrops can constitute vegetation refuges, sheltering remnants of a relict flora more widely distributed in the past, presenting ecological peculiarities from their surroundings, and persisting in very particular environmental conditions (e.g. Colinvaux et al. 2000, Speziale & Ezcurra 2014). Leaves capable of desiccating and rehydrating, water reserve organs and structures capable of absorbing atmospheric moisture represent some of the characteristics that allow herbaceous plant species to thrive in rock outcrops (Lüttge et al. 2007). Thus, considering the environmental conditions in rock outcrops, such as water scarcity, nutrient deficiency, intense solar radiation, and high temperatures (Kluge & Brulfert 2000), the occurrence of species in these environments is not random, but conditioned by environmental factors, such as greater or lesser depth of soil (e.g. de Paula et al. 2015; Porembski et al. 2000). Thus, at a local scale, environmental filtering favors the presence of plant communities phylogenetically clustered in rock outcrops (Villa et al. 2018; Parmentier & Hardy 2009).

The southern Amazon border presents peculiar characteristics, arising from the mixture of rain forest, seasonal forest, and savannas, as well as the influence of well-defined precipitation seasonality (Kunz et al. 2009). The Southern Amazon encompasses the “arc of deforestation”, a region with intense anthropic pressure resulting from changes in land use for mining, logging, and agriculture (Fearnside et al. 2017). In this sense, studies have highlighted the importance of expanding the sampling of vegetation in rock habitats in the south of the Amazon (Sasaki et al. 2010, Zappi et al. 2011, 2016). Based on this, samples of the woody component in Seasonal Deciduous Forest associated with rock outcrops in the Cristalino Region – focus of our study – have brought important contributions, such as the addition of species to the regional flora, expansion of species distribution areas, as well as discussions related to conservation status and endemism (Silva et al. 2020). The Cristalino Region shelters different types of vegetation and varied physiognomies that reflect its geological and geomorphological complexity, and constitutes a key area for biodiversity conservation in the Brazilian Amazon (Zappi et al. 2011, Maury et al. 2004).

We investigated the floristic, structure, ecology and conservation of the herbaceous component in a seasonal deciduous forest associated with rock outcrops in the Cristalino region, addressing the following questions: 1) What is the species composition of the herbaceous component? 2) What is the contribution of our survey to expanding the floristic list of the Cristalino Region? 3) Which and how many endemic and threatened herbaceous species occur there? 4) Which species, genera and families have the greatest frequency and cover? 5) How species-diverse is this stratum/vegetation? While answering these questions, we also addressed their implications for biodiversity conservation.

Material and Methods

1. *Study area*

The study area is located in the Cristalino region, more precisely in the Mirante da Serra Private Natural Heritage Reserve (*in portuguese*, *Reserva Particular do Patrimônio Natural*, RPPN) (Sasaki et al. 2010, Zappi et al. 2011) (Figure 1). In addition to the RPPN Mirante da Serra, the Cristalino region comprises the Cristalino, Castanheira and Gavião Real RPPNs, and the Cristalino State Park (Sasaki et al. 2010; Zappi et al. 2011). The Cristalino region is located in the far north of the state of Mato Grosso and includes part of the Rio Cristalino basin, which rises in the Serra do Cachimbo, and also part of the Nhandu river basin, both tributaries of the Teles Pires river (Zappi et al. 2011). Eight vegetation types can be found in this region: Submontane Dense Ombrophilous Forest, Submontane Open Ombrophilous Forest, Alluvial Dense Ombrophilous Forest, Semideciduous Seasonal Forest, Deciduous Seasonal Forest, *Campinarana*, Amazon *campo rupestre* and Riverine Vegetation (Sasaki et al. 2010, Zappi et al. 2011). The relief has slightly convex tops on ancient rocks of the Beneficent Group (Middle Proterozoic) and is inserted in four geomorphological units I. *Planalto do Cachimbo*; II. *Depressão do Norte de Mato Grosso*; III. *Depressão Interplanáltica dos Rios Juruena/Teles Pires* e IV. *Planaltos Residuais do Sul da Amazônia* (IBGE 2006). The main soil types of the Cristalino Region are Quartz Sands, Red-Yellow Argisols, Rock Outcrops, Litholic and Glazed Hydromorphic Neosols.

The soils are generally sandy, acidic, of medium to low fertility and susceptible to erosion (SEMA 2010). The climate is warm and humid, with a dry period of approximately four months – June to September (SEMA 2010). Average annual rainfall can range between 2,000 mm and 2,500 mm, while average annual temperatures are around 26°C (SEMA 2010). In the Cristalino region there are outcrops of arenitic and granitic rock that are scattered over sloping terrain or on top of the mountains. Granitic outcrops occur in the form of small areas associated with Seasonal Deciduous Forest, while arenitic outcrops are found in larger areas and have a distinct floristic composition (Sasaki et al.

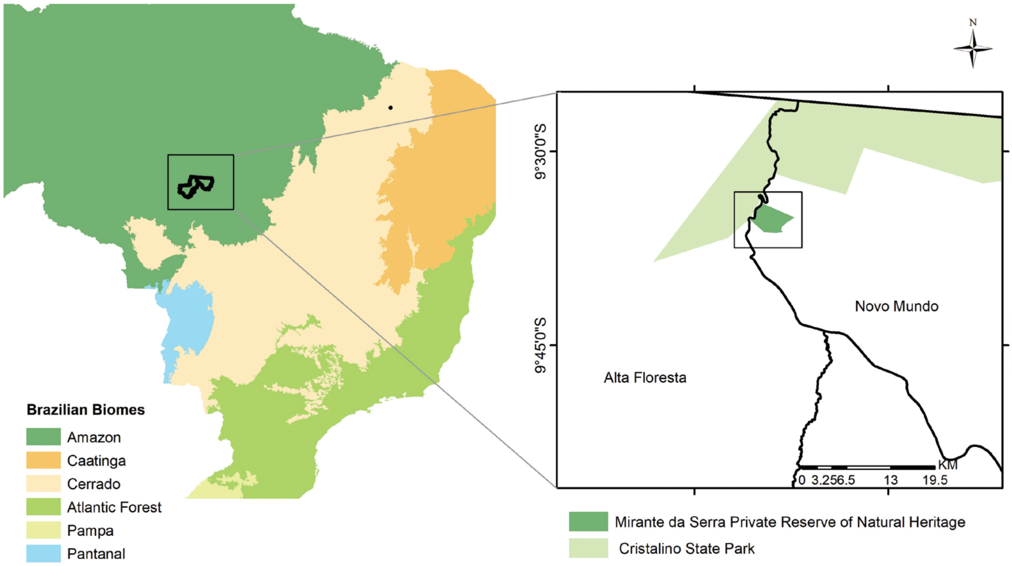

Figure 1. Mirante da Serra Private Natural Heritage Reserve (*in portuguese*, *Reserva Particular do Patrimônio Natural*, RPPN) located in the Cristalino Region, Southern Amazon.

Figure 2. Study area located in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (*in portuguese*, *Reserva Particular do Patrimônio Natural*, RPPN) in the Southern Amazon. A and B = Study area during rainy season; C and D = Study area during dry season.

2010). The vegetation type sampled in this study comprises Seasonal Deciduous Forest associated with granitic rock outcrops (Figure 2). The sample area is located between the coordinates 9°35'12" S and 55°54'59" W, in the municipality of Novo Mundo, MT, with an altitude varying between 280 and 350 m a.s.l..

2. *Installation of sampling units*

To install the permanent plot, we followed the recommendations of the RAINFOR Network (Amazon Network of Forest Inventories; Phillips et al. 2016), which develops a set of standardized actions to monitor forests in the Amazon, promoting an understanding of the dynamics of Amazon ecosystems (Phillips et al. 2016). As the RAINFOR Network method is described for the woody component, we performed adaptations for the herbaceous component, associating the line intercept method (Canfield 1941; Figure 3) with the RAINFOR Network plot delineation method. As guided by the RAINFOR Network, we delineated a 100 x 100 m (= 1 ha) plot, divided into 25 contiguous subplots (S), each measuring 20 x 20 m. We affixed iron rebars 5 mm in diameter and 1 m in length at the four ends of the permanent plot, and carried out the same procedure for the subplots.

3. *Vegetation sampling and botanical material processing*

To carry out the phytosociological survey, we used the line intercept method (Canfield 1941; Figure 3). This method consists of drawing lines over the vegetation to determine the composition of herbaceous species in the area (Munhoz & Felfili 2006; Figure 3). We traced 100 lines 100 m long perpendicular to the permanent plot, with 1 m intervals between them. We held a draw to define 10 subplots, and within each subplot we held another draw to mark a line (Sampling Unit – SU), totaling 10 sampled lines. Each SU was 20 m long. We then affixed iron bars, identified the lines with aluminum plates indicating the line number and subplot and georeferenced the center point of each line. We measured height, aerial part diameter and the horizontal projection of each individual that touched or came within 1 cm of the line.

We carried out 12 monthly incursions into the study area, between July 2016 and July 2017, covering all seasons. The botanical material was collected and herborized according to the methodology of Fidalgo & Bononi (1989). During the expeditions, we collected individuals in the reproductive stage within the subplots, as well as in the 10 m surrounding the plot and on the access trails to it. The surrounding matrix is composed of forest vegetation; in addition, it presents differences in soils, relief and incident light when compared to the rock outcrop area on which the permanent plot was installed.

The species were identified through consultations to the specific literature, online databases, comparisons with the collection of the Herbarium of the Southern Amazon (HERBAM) and consultations with specialists. We followed APG IV (2016) family classification. We checked the life forms and the spellings of the species names in the Flora do Brasil species list database (Flora do Brasil 2020). We verified materials deposited at HERBAM from surveys carried out during the Cristalino Flora Program (Sasaki et al. 2010, Zappi et al. 2011), as well as online searches on Reflora platforms (http://reflora.jbrj.gov.br/reflora/herbarioVirtual/) and speciesLink (https://specieslink.net/search/) to update possible new records for the area. We also verified the threatened status of the species according to the Brazilian National Center for the Conservation of Flora (CNCFlora – *Centro Nacional de Conservação da Flora*, http://cncflora.jbrj.gov.br/portal/). The material collected was incorporated into the HERBAM collection.

4. *Community structure*

We characterized the community structure of the herbaceous stratum through the projection on the line of intercepted individuals. To obtain the absolute cover (AC), we calculated the projection occupied by each individual in the SU and made a sum for all the SUs (Munhoz & Araújo

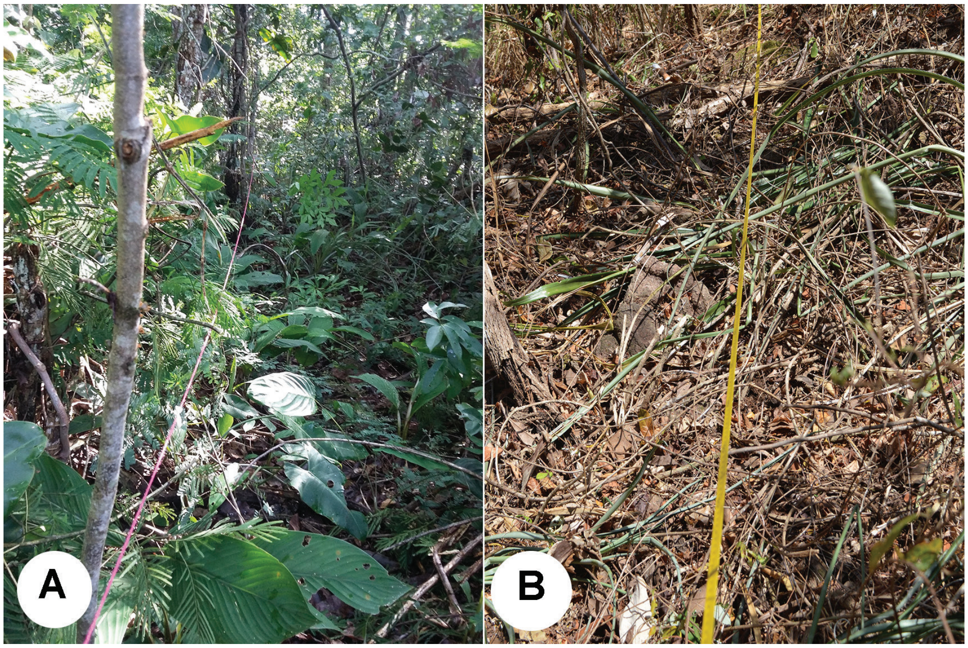

Figure 3. Phytosociological survey according to line intersection method (Canfield 1941) in a Seasonal Deciduous Forest associated with a granitic rock outcrop in the Southern Amazon. A = vegetation survey during rainy season; B = vegetation survey during dry season.

2011). We obtained the relative cover (CR) by dividing the absolute coverage (CA) of each species by the sum of the absolute coverage (CA) of all species, multiplying by 100. We also obtained the values of absolute and relative frequency (Munhoz & Araújo 2011).

CA_i = Absolute cover of the species "i"

$$CA_i = \sum_{i=1}^{n} P_i A$$

$\sum_{I=1}^{n} P_i A$ = sum of the species (i) projection in all SUs.

CR_i = Relative cover of the species "i"

$$CR_i = \left(\frac{CA_i}{\sum_{i=1}^{n} CA_i} \right) \cdot 100$$

$\sum_{I=1}^{n} CA_i$ = sum of all species (i) projection in all SUs.

FA_i = Absolute frequency of the species "i"

$$FA_I = \left(\frac{n_i}{n} \right) \cdot 100$$

n_i = number of SUs where species "i" occurred

n = total number of SUs sampled

FR_i = Relative frequency of the species "i"

$$FR_I = \left(\frac{FA_i}{\sum_{i=1}^{n} FA_i} \right) \cdot 100$$

$\sum_{I=1}^{n} FA_i$ = sum of the absolute frequency of all species.

5. *Species diversity*

We estimated species diversity through rarefaction and extrapolation curves (Chao et al. 2014) with the "iNEXT" package (Hsieh et al. 2016). The confidence interval used was 95%, obtained from 1,000 *bootstrap* randomizations (Chao et al. 2014). The species diversity indices we obtained were numeric richness, Shannon index (H'), Shannon Exponential (H' exp) – also known as effective number of species or number of equally common species (Peet 1974, Jost et al. 2006) – and Simpson index (1/D) (see, for example, Magurran 2013).

Results

We recorded 86 species, 62 genera and 25 families for the herbaceous component of the Mirante da Serra Private Natural Heritage Reserve – RPPN Mirante da Serra (Table 1; Figure 4). The families with the highest number of genera were Orchidaceae (16 spp.), Poaceae (11 spp.), Marantaceae (10 spp.) and Cyperaceae (seven spp.) (Table 1). The genera with the highest number of species were *Paspalum* (five spp.), *Cyperus* and *Goeppertia*, with four species each, and *Maranta*, with three species (Table 1).

There was an increase of 26 new records of species for Flora in the Cristalino region, which comprises the Cristalino State Park and 4 RPPN (Table 1). Among the species added to the Cristalino Flora, we included *Philodendron deflexum* Poepp. ex Schott. This species had already been previously collected and listed in the Cristalino Region inventories (Henicka, G.S. 125), but it was not yet fully named. We also provided the complete identification for *Griffinia nocturna* Ravenna, and this was the first report of occurrence for this species in a forest matrix in the Amazon biome.

Table 1. Herbaceous species from the Seasonal Deciduous Forest associated with a rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (*in portuguese, Reserva Particular do Patrimônio Natural*, RPPN) in the Amazon region of Mato Grosso. RPPN-MS: Mirante da Serra Private Natural Heritage Reserve; CRIST: Cristalino Region; SU: occurrence recorded from our sampling units; Random: occurrence recorded from random walk around RPPN-MS; Voucher: collector number; Occurrences in Brazilian biomes according to Flora do Brazil 2020: amz = Amazon, atl = Atlantic Forest; caa = Caatinga, cer = Cerrado, pam = Pampa, pan = Pantanal; * = new floristic occurrences for the Cristalino Region.

Family/Species	Life form	RPPN-MS	CRIST	SU or Random	Occurrence in Brazilian biomes	Voucher
ACANTHACEAE						
Acanthaceae sp.	Herb	X	–	Random	–	Gallo, S.C. 157
AMARYLLIDACEAE						
Griffinia nocturna Ravenna*	Herb	X	X	Random	cer	Gallo, S.C. 17
ARACEAE						
Anthurium affine Schott	Herb	X	X	Random	atl, caa, cer,	Gallo, S.C. 156
Anthurium bonplandii Bunting	Herb	X	X	SU	amz	Gallo, S.C. 53
Philodendron acutatum Schott	Herb	X	X	SU	atl, amz, caa, cer	Gallo, S.C. 124
Philodendron deflexum Poepp. ex Schott*	Herb	X	X	Random	amz	Henicka, G.S. 125

Continue...

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Family/Species	Life form	RPPN-MS	CRIST	SU or Random	Occurrence in Brazilian biomes	Voucher
ASTERACEAE						
Ichthyothere rufa Gardner	Herb	X	X	SU	cer	Gallo, S.C. 91
Lepidaploa remotiflora (Rich.) H. Rob.	Herb	X	X	SU	cer	Gallo, S.C. 162
Lepidaploa sp.	Herb	X	–	Random	–	Gallo, S.C. 154a
Riencourtia pedunculosa (Rich.) Pruski	Herb	X		SU	amz, cer	Gallo, S.C. 62
BROMELIACEAE						
Aechmea bromeliifolia (Rudge) Baker	Herb	X	X	Random	amz, atl, caa, cer	Gallo, S.C.13
Aechmea castelnavii Baker	Herb	X	X	Random	amz, atl, cer	Gallo, S.C. 14
Ananas ananassoides (Baker) L.B.Sm.	Herb	X	X	SU	amz, atl, caa, cer	Gallo, S.C. 02
Bromelia balansae Mez	Herb	X	X	SU	amz, atl, cer, pan	Gallo, S.C. 37
Pitcairnia burchellii Mez	Herb	X	X	SU	amz, atl, caa, cer	Gallo, S.C. 81
CACTACEAE						
Epiphyllum phyllanthus (L.) Haw.	Herb	X	X	Random	amz, atl, caa, cer, pan	Gallo, S.C. 59
COMMELINACEAE						
Commelina obliqua Vah l*	Herb	X		Random	amz, atl, caa, cer, pam, pan	Gallo, S.C. 128a
Commelina sp.	Herb	X	–	Random	–	Gallo, S.C. 131
Dichorisandra hexandra (Aubl.) C.B.Clarke	Herb	X	X	SU	amz, atl, caa, cer, pam, pan	Gallo, S.C. 121
Dichorisandra villosula Mart. ex Schult.f.	Herb	X	X	Random	amz	Gallo, S.C. 60
CONVOLVULACEAE						
Ipomoea megapotamica Choisi*	Herb	X		Random	atl, caa, cer,	Da Silva, D.R. 164
COSTACEAE						
Chamaecostus lanceolatus (Petersen) C.D.Specht & D.W. Stev.	Herb	X	X	SU	amz	Gallo, S.C. 41
Chamaecostus acaulis (S.Moore) T.André & C.D.Specht	Herb	X	X	Random	amz, cer	Gallo, S.C. 44
Costus arabicus L.	Herb	X	X	Random	amz, atl, cer, pan	Gallo, S.C. 83
CYPERACEAE						
Cyperus brevifolius (Rottb.) Endl. ex Hassk*	Herb	X		Random	amz, atl, caa, cer, pam, pan	Gallo, S.C. 05
Cyperus meyenianus Kunth*	Herb	X		Random	amz, atl, caa, cer, pam, pan	Gallo, S.C. 140
Cyperus sp.3	Herb	X		Random	atl, pam	Gallo, S.C. 129
Cyperus sp.4	Herb	X		Random	amz, atl, cer,	Gallo, S.C. 160

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Eleocharis minima Kunth	Herb	X	X	SU	amz, atl, caa, cer, pam, pan	Gallo, S.C. 134
Rhynchospora pubera (Vahl) Boekeler	Herb	X	X	Random	amz, atl, cer	Gallo, S.C. 98
Cyperaceae sp.	Herb	X	–	Random	–	Gallo, S.C. 118
DIOSCOREACEAE						
Dioscorea piperifolia Humb. & Bonpl. ex Willd.	Liana	X	X	SU	amz, atl, caa, cer	Gallo, S.C. 40/43
EUPHORBIACEAE						
Microstachys corniculata (Vahl) Griseb.*	Herb	X		SU	amz, atl, caa, cer	Gallo, S.C. 04
FABACEAE						
Ancistrotropis peduncularis (Kunth) A. Delgado	Herb	X	X	Random	amz, atl, caa, cer, pam, pan	Da Silva, D.R. 174
Chamaecrista trichopoda (Benth.) Britton & Rose ex Britton & Killip*	Herb	X		Random	amz, atl, caa, cer	Gallo, S.C. 137
Mimosa skinneri Benth.	Herb	X	X	SU	amz, cer	Gallo, S.C. 66b
GESNERIACEAE						
Nautilocalyx forgetii (Sprague) Sprague	Herb	X	X	SU	amz	Gallo, S.C. 55
HAEMODORACEAE						
Xiphidium caeruleum Aubl.*	Herb	X		Random	amz, atl, cer	Gallo, S.C. 78
HELICONIACEAE						
Heliconia psittacorum L.f.	Herb	X	X	Random	amz, atl, caa, cer, pan	Gallo, S.C. 82b
HYPOXIDACEAE						
Curculigo scorzonerifolia (Lam.) Baker*	Herb	X		Random	amz, atl, cer	Gallo, S.C. 22
LENTIBULARIACEAE						
Utricularia nervosa G.Weber ex Benj.	Herb	X	X	Random	amz, atl, cer	Gallo, S.C. 74
MALVACEAE						
Sida linifolia Cav.*	Herb	X		Random	amz, atl, caa, cer, pan	Gallo, S.C. 152
MARANTACEAE						
Goeppertia allouia (Aubl.) Borchs. & S. Suárez	Herb	X		SU	amz, cer	Gallo, S.C. 58
Goeppertia gardneri (Baker) Borchs. & S.Suárez	Herb	X	X	Random	caa, cer	Gallo, S.C. 73

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Family/Species	Life form	RPPN-MS	CRIST	SU or Random	Occurrence in Brazilian biomes	Voucher
Goeppertia mansonis (Körn.) Borchs. & S. Suárez	Herb	X	X	SU	amz, cer, pan	Gallo, S.C. 38
Goeppertia ovata (Nees & Mart.) Borchs. & S.Suárez	Herb	X	X	SU	amz, cer	Gallo, S.C. 49
Ischnosiphon sp.1	Herb	X	–	Random	–	Gallo, S.C. 174
Ischnosiphon sp.2	Herb	X	–	Random	–	Gallo, S.C. 47
Maranta bracteosa Petersen*	Herb	X		SU	amz, cer	Gallo, S.C. 39
Maranta cyclophylla K.Schum.	Herb	X	X	SU	amz, cer	Gallo, S.C. 20
Maranta phrynioides Körn.	Herb	X	X	SU	amz, atl, pan	Gallo, S.C. 23
Myrosma cannifolia L.f.*	Herb	X		Random	amz, atl, caa, cer, pan	Gallo, S.C. 72
MELASTOMATACEAE						
Pseudoernestia cordifolia (O.Berg. ex Triana) Krasser	Herb	X		Random	amz	Gallo, S.C. 111
Pterolepis buraeavii Cogn.*	Herb	X		Random	amz, cer	Gallo, S.C. 114
Pterolepis perpusilla (Naudin) Cogn.*	Herb	X		Random	amz, caa, cer	Gallo, S.C. 161
ORCHIDACEAE						
Aspasia variegata Lindl.*	Herb	X		Random	amz, cer	Gallo, S.C. 16
Campylocentrum mattogrossense Hoehne*	Herb	X		Random	amz, cer	Gallo, S.C. 172
Catasetum telespirense Benelli & Soares-Lopes*	Herb	X		Random	amz	Gallo, S.C. 182
Cyrtopodium andersonii (Lamb. ex Andrews) R.Br.*	Herb	X		SU	amz	Gallo, S.C.08
Encyclia randii (Barb. Rodr.) Porto & Brade*	Herb	X		Random	amz	Gallo, S.C.15
Epidendrum stiliferum Dressler*	Herb	X		Random	amz, cer	Gallo, S.C. 143
Epidendrum strobiliferum Rchb.f.	Herb	X	X	Random	amz, cer	Gallo, S.C. 21
Laelia marginata (Lindl.) L.O. Williams	Herb	X	X	Random	amz	Gallo, S.C. 186
Orchidaceae sp.	Herb	X	–	Random	–	Gallo, S.C. 170
Polystachya concreta (Jacq.) Garay & Sweet	Herb	X	X	Random	amz, atl, caa, cer, pam, pan	Gallo, S.C. 146
Polystachya foliosa (Hook.) Rchb.f.	Herb	X	X	Random	amz, cer	Gallo, S.C. 28

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Prosthechea aemula (Lindl.) W.E.Higgins	Herb	X	X	Random	amz, atl, caa, cer	Gallo, S.C. 54
Scaphyglottis stellata Lodd. ex Lindl.	Herb	X	X	Random	amz, cer	Gallo, S.C. 165
Sobralia augusta Hoehne*	Herb	X		Random	amz	Gallo, S.C. 75
Solenidium lunatum (Lindl.) Schltr.	Herb	X	X	Random	amz	Gallo, S.C. 82a
Trichocentrum sprucei (Lindl.) M.W.Chase & N.H.Williams*	Herb	X		Random	amz	Gallo, S.C. 191
PIPERACEAE						
Peperomia pellucida (L.) Kunth	Herb	X	X	Random	amz, atl, caa, cer	Gallo, S.C. 88
POACEAE						
Hildaea cf *pallens* (Sw.) C. Silva & R.P. Oliveira	Herb	X	X	SU	amz, atl, caa, cer, pam, pan	Gallo, S.C. 115/153b
Hildaea tenuis (J. Presl & C. Presl) C. Silva & R.P. Oliveira*	Herb	X		SU	amz, cer	Gallo, S.C. 145
Ichnanthus calvescens (Nees ex Trin.) Döll	Herb	X		SU	amz, atl, caa, cer, pan	Gallo, S.C. 167/153a
Lasiacis ligulata Hitchc. & Chase	Herb	X	X	Random	amz, atl, caa, cer	Gallo, S.C. 155
Olyra latifolia L.	Herb	X	X	Random	amz, atl, caa, cer	Gallo, S.C. 105
Paspalum glaziovii (A.G.Burm.) S.Denham*	Herb	X		Random	cer	Da Silva, D.R. 152
Paspalum sp.2	Herb	X	–	SU		Gallo, S.C. 120
Paspalum sp.5	Herb	X	–	SU		Gallo, S.C. 117
Paspalum sp.6	Herb	X	–	SU		Gallo, S.C. 113
Paspalum sp.7	Herb	X	–	SU		Gallo, S.C. 179
Rugoloa pilosa (Sw.) Zuloaga	Herb	X	X	SU	amz, atl, caa, cer, pam, pan	Gallo, S.C. 90
RUBIACEAE						
Borreria latifolia (Aubl.) K.Schum.	Herb	X	X	Random	amz, atl, caa, cer, pam	Gallo, S.C. 127
Palicourea colorata (Willd. ex Roem. & Schult.) Delprete & J.H.Kirkbr.	Herb	X		Random	amz, atl, caa, cer	Gallo, S.C. 101
Spermacoce exilis (L.O.Williams) C.D.Adams*	Herb	X		Random	amz, atl, caa, cer	Gallo, S.C.110

Only seven species present in our study area have already had their conservation status assessed by the CNCFlora. Among them, six species were found in the 'Least Concern' category, which is not a threatened status: *Aechmea bromeliifolia* (Rudge) Baker, *Bromelia balansae* Mez, *Curculigo scorzonerifolia* (Lam.) Baker, *Epiphyllum phyllanthus* (L.) Haw., *Peperomia pellucida* (L.) Kunth and *Pterolepis perpusilla* (Naudin) Cogn.. The single species classified as threatened with extinction was *Griffinia nocturna* Ravenna, which was assigned to the 'Critically Endangered' category. However, as we are providing evidence on the increasing of its distribution area, the conservation status of this species should be recalculated. Thus, we performed an exercise with GEOCAT (Bachman et al. 2011) applying the default values of

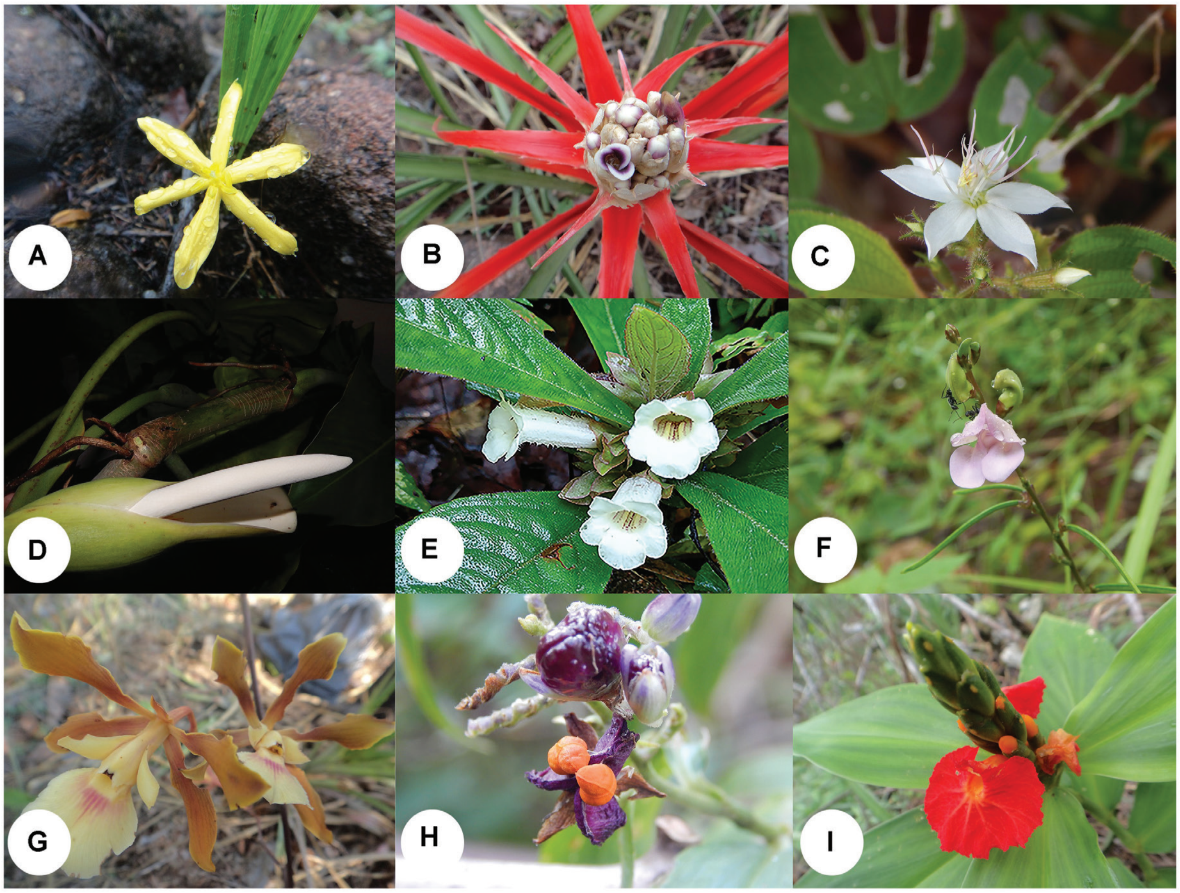

Figure 4. Herbaceous species from the Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (*in Portuguese*, *Reserva Particular do Patrimônio Natural*, RPPN) in the Southern Amazon. A = *Curculigo scorzonerifolia* (Lam.) Baker; B = *Bromelia balansae* Mez; C = *Pseudoernestia cordifolia* (O.Berg. ex Triana) Krasser; D = *Philodendron acutatum* Schott; E = *Nautilocalyx forgetii* (Sprague) Sprague; F = *Ancistrotropis peduncularis* (Kunth) A. Delgado; G = *Encyclia randii* (Barb.Rodr.) Porto & Brade; H = *Dichorisandra hexandra* (Aubl.) C.B.Clarke; I = *Chamaecostus lanceolatus* (Petersen) C.D.Specht & D.W. Stev.

the IUCN – RLS (The International Union for Conservation of Nature's Red List of Threatened Species) for Extent of Occurrence (EOO) and Area of Occupancy (AOO) analyses of *G. nocturna* (see Supplementary Material 1 for more details). According to this exercise, *G. nocturna* has an AOO of 92,000 km² (Endangered) and EOO of 1,397,712,743 km² (Least Concern). Thus, with the expansion of its geographic distribution area, *G. nocturna* would move from the 'Critically Endangered' to 'Endangered' category, thus remaining threatened with extinction.

Considering only the phytosociological survey carried out on the rock outcrop, we sampled 903 individuals of the herbaceous component, which were distributed into 31 species, 23 genera and 13 families (Table 2). The families with the highest number of species were Poaceae (eight species), Marantaceae (six species), Asteraceae and Bromeliaceae (three species each). The genera with the highest number of species were *Paspalum* (four species), *Maranta* and *Goeppertia* (three species each). *Ananas* (238), *Riencourtia* (212) and *Goeppertia* (118) were the genera with the highest number of individuals (Supplementary Material 2a), and Bromeliaceae (312), Asteraceae (244) and Marantaceae (134) were the families with the highest number of individuals (Supplementary Material 2b). The species with the highest number of individuals were *Ananas ananassoides* (238), *Riencourtia pedunculosa* (212), and *Bromelia balansae* and *Goeppertia ovata* (72 individuals each; Table 2).

Ananas, *Bromelia*, *Goeppertia* and *Riencourtia* were the genera with the highest cover value (Supplementary Material 2a), and *Ananas* and *Goeppertia* were the only genera that occurred in all SUs. Bromeliaceae, Marantaceae and Poaceae had the highest cover values and were the only families that occurred in all SUs (Supplementary Material 2b). *Ananas ananassoides*, *Bromelia balansae*, *Goeppertia ovata* and *Riencourtia pedunculosa* were the species with the highest cover values, with *A. ananassoides* being the only species that occurred in all 10 SUs (Table 2).

We found 31 (± 2.24 $IC_{95\%}$) species in the 10 sampled lines. We observed a trend towards stabilization in the rarefaction and extrapolation curves for species richness (Figure 5a; Supplementary Material 3). In this sense, if we sampled twice as many individuals, there would be an increase of 4.31% in the number of species. The species diversity was 2.43 $nats.individual^{-1}$ (Shannon), which corresponds to 11.37 (± 0.90 $IC_{95\%}$) equally common species (Shannon exponential), while the Simpson index (1/D) was 6.82 (± 0.648 $IC_{95\%}$). The curves of the Shannon and Simpson indices also stabilized (Figure 5b and 5c).

Table 2. Phytosociological parameters for species sampled in survey according to line intersection method (Canfield 1941) in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (in portuguese, *Reserva Particular do Patrimônio Natural*, RPPN) in the Amazon region of Mato Grosso.

Species	Number of individuals	Absolute frequency (%)	Relative frequency (%)m	Absolute cover (m)	Relative cover (%)
Ananas ananassoides	238	100	8.4	336	47.1
Bromelia balansae	72	80	6.7	130.8	18.3
Goeppertia ovata	72	90	7.6	48.7	6.8
Riencourtia pedunculosa	212	80	6.7	46	6.4
Goeppertia mansonis	43	70	5.9	23.8	3.3
Philodendron acutatum	25	80	6.7	22.6	3.2
Paspalum sp 2	23	60	5	16.2	2.3
Chamaecostus lanceolatus	51	40	3.4	12.1	1.7
Ichnanthus calvescens	21	60	5	11.8	1.7
Paspalum sp 5	21	40	3.4	9.8	1.4
Paspalum sp 6	10	50	4.2	8.6	1.2
Cyrtopodium andersonii	3	20	1.7	5	0.7
Hildaea tenuis	9	30	2.5	4.5	0.6
Maranta cyclophylla	7	30	2.5	4.4	0.6
Maranta phrynioides	7	50	4.2	4.5	0.6
Paspalum sp 7	9	30	2.5	4.2	0.6
Ichthyothere rufa	19	20	1.7	3.7	0.5
Rugoloa pilosa	6	40	3.4	3.8	0.5
Anturium bonplandi	3	10	0.8	1.9	0.3
Goeppertia allouia	3	20	1.7	2.3	0.3
Hildaea pallens	3	20	1.7	2.2	0.3
Microstachys corniculata	9	40	3.4	1.9	0.3
Lepidaploa remotiflora	13	20	1.7	1.3	0.2
Maranta bracteosa	2	10	0.8	1.5	0.2
Mimosa skineri	1	10	0.8	1.5	0.2
Dichorisandra hecxandra	5	20	1.7	0.6	0.1
Dioscoria piperifolia	4	10	0.8	0.5	0.1
Eleocharis minima	2	10	0.8	1	0.1
Nautilocalyx forgetii	7	30	2.5	1.1	0.1
Pitcairnia burchelli	2	10	0.8	0.6	0.1
Ancistrotropis peduncularis	1	10	0.8	0.4	<0.1

Discussion

Our study contributes to the knowledge of the herbaceous layer of the Cristalino Region, a key area for biodiversity conservation in the Amazon. Although the important project 'Flora do Cristalino' contributed to reducing the knowledge gaps about the herbaceous component of the Amazon forest in its southern limit, the sampling effort varied between the different vegetation types, being more concentrated in the Submontane Dense Ombrophilous Forest, as phytophysiognomies as the Seasonal Deciduous Forest were proportionally less sampled (Sasaki et al. 2010, Zappi et al. 2011). Thus, our study increases the sampling for the Seasonal Deciduous Forest associated with rock outcrops in the Cristalino Region.

The Orchidaceae family had the largest number of species and was also the one that most contributed to the increase of new records for the Flora of the Cristalino Region, totaling eight new records: *Aspasia*

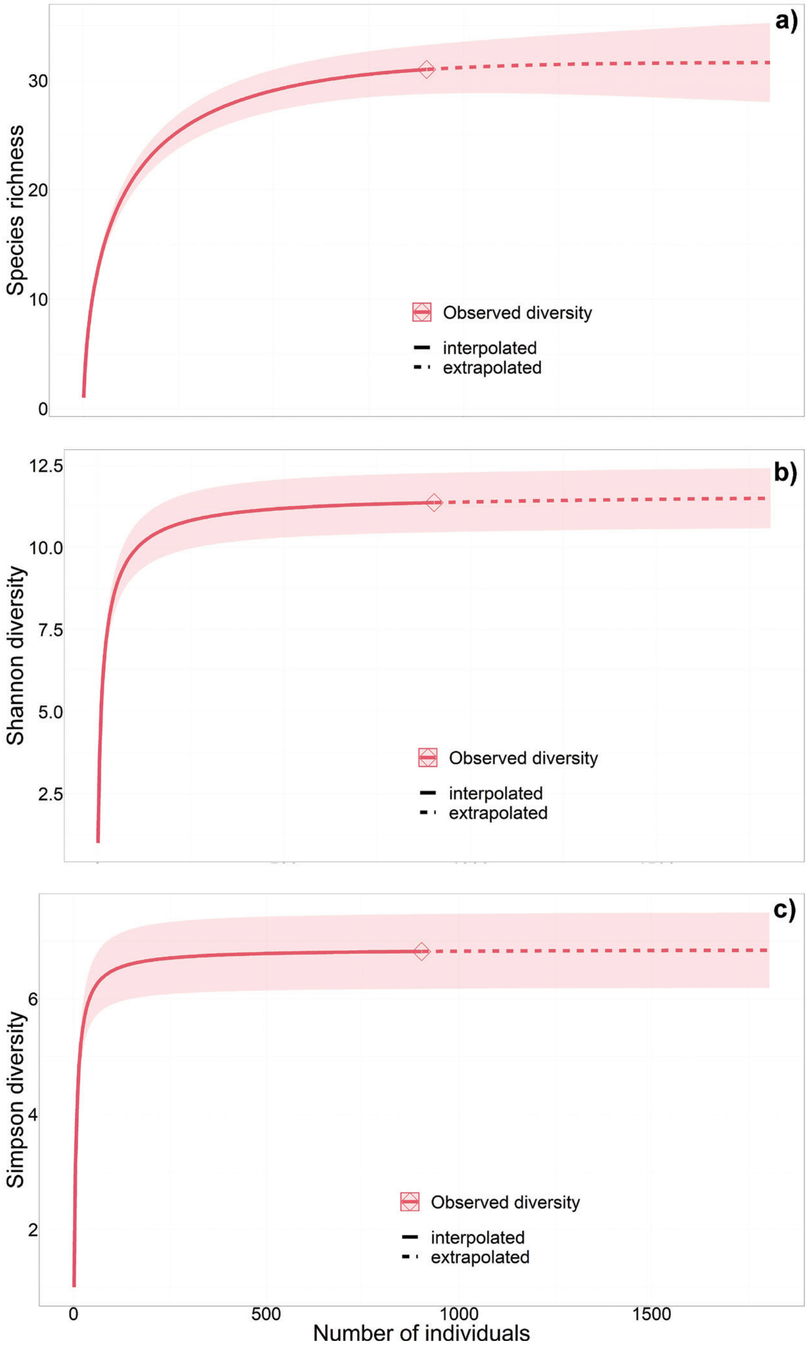

Figure 5. Interpolated and extrapolated species diversity considering twice the number of sampled species in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (*in portuguese, Reserva Particular do Patrimônio Natural, RPPN*) in the Amazon region of Mato Grosso. a) Species Richness; b) Shannon Exponential Diversity; c) Simpson Diversity (1/D).

variegata Lindl., *Campylocentrum mattogrossense* Hoehne., *Catasetum telespirense* Benelli & Soares-Lopes, *Cyrtopodium andersonii* (Lamb. ex Andrews) R.Br., *Encyclia randii* (Barb.Rodr.) Porto & Brade, *Epidendrum stiliferum* Dressler, *Sobralia augusta* Hoehne, and *Trichocentrum sprucei* (Lindl.) M.W.Chase & N.H.Williams. We believe that this increase in the Flora of the Cristalino Region may be related to the sampling effort, since the present study focused on a single area, with monthly visits, which facilitated the observation of different phenological phases of the species of this family, enabling collection and identification. A similar study found a similar increase in the species richness of Orchidaceae when the sampling effort was increased (Neto et al. 2007).

The low number of threatened species in our study area was likely due to the knowledge bias towards the herbaceous component. Such bias is well documented for the Amazon flora (BFG 2015). However, Silva et al. (2020), investigating woody species in the same study area as ours, also found a small number of species already assessed for threat (16 species already assessed and 102 not assessed). Thus, this seems to be a general gap – not only for the herbaceous stratum – in the threatened species assessment for the RPPN Mirante da Serra, and perhaps for the Amazon as a whole. Considering the Amazon as a whole, the general perception is that its plants are more widely distributed (BGF 2015), but we are aware that there is a knowledge gap regarding plant distribution and therefore of the conservation status of Amazonian plants.

G. nocturna, Critically Endangered (CR) (CNCFlora 2022) and commonly found in Seasonal Deciduous Forest associated with rock outcrops (Flora do Brasil 2020), had already been recorded for the Cerrado-Amazon transition and for the Amazon biome in savanna vegetation (voucher Sardelli, L. 920 and Engels, M.E. 3757). The occurrence of this species in a matrix of forest vegetation within the Amazon biome is a novelty. *G. nocturna* is considered CR due to the fact that a number of subpopulations of this species have become extinct due to environmental disturbances. In addition, the species has a commercially collected bulb (CNCFlora 2021). Thus, by expanding knowledge about the distribution area of *G. nocturna*, we provide support for management measures and protection of its remaining subpopulations.

Vegetation on rock outcrops generally has a high number of endemic species (Gröger & Huber 2007, Porembski 2007), but this pattern was not supported in our study area. In this sense, endemisms in rock outcrops may be associated with their degree of isolation in relation to similar habitats and also with the intensity of the barrier that the ecological conditions on the rock surface represent for the establishment of plants from the surrounding vegetation (Burke 2002a and b). Thus, although we have not evaluated the floristic composition of the forest matrix, the absence of endemisms in our study area may be related to its continuous occurrence in the forest matrix. On the other hand, we recorded species widely distributed in vegetation associated with rock outcrops, such as *Aechmea bromeliifolia* (Rudge) Baker, *Borreria latifolia* (Aubl.) K.Schum., *Microstachys corniculata* (Vahl) Griseb, *Philodendron acutatum* Schott, *Pitcairnia burchellii* Mez and *Sida linifolia* Cav. (Flora do Brasil 2020), as well as species widely distributed in rock outcrops and Seasonal Deciduous Forest, such as *Chamaecrista trichopoda* (Benth.) Britton & Rose ex Britton & Killip, *Commelina obliqua* Vah, *Curculigo scorzonerifolia* (Lam.) Baker, *Dichorisandra hexandra* (Aubl.) C.B.Clarke, *Ichnanthus calvescens* (Nees ex Trin.) Döll and *Polystachya concreta* (Jacq.) Garay & Sweet (Flora do Brasil 2020). The herbaceous layer of the Seasonal Deciduous Forest on a rock outcrop of the RPPN Mirante da Serra presents a mixture of floras, being composed mainly of species from the Amazon and/or Cerrado biomes, confirming the pattern found on the southern edge of the Amazon (IBGE 2004, Kunz et al. 2009).

The families with 100% frequency in the sampling units were Bromeliaceae, Marantaceae and Poaceae, and the greatest floristic richness was recorded for the Poaceae. In fact, Poaceae is among the most important families of rock outcrops worldwide, while Bromeliaceae is a typical component of South American rock outcrops (Porembski 2007). In the Deciduous Seasonal Forest, the scarcity of soil makes water a limiting factor for vegetation in the dry season, leading to the loss of leaves and, consequently, to the opening of the canopy (Sazaki et al. 2010), which may favour herbaceous species by providing more sunlight for the understorey plants. In this regard, leaf fall in tropical deciduous forests contributes to the increase in the litter layer which, when decomposing influences the fertility of the understory substrate (e.g. Jaramillo & Sanford 1995). In addition, the opening of the canopy contributes to the anemochoric dispersion (Howe & Smallwood 1982), a common syndrome in representative families in the study area, such as Asteraceae, Bromeliaceae, Cyperaceae, Orchidaceae and Poaceae.

The largest number of individuals sampled belonged to the Bromeliaceae family, with *Ananas ananassoides* (Baker) L.B.Sm. as the most abundant. This species also had the highest frequency and the greatest coverage in our study area. In a savanna area in the Amazon-Cerrado transition, Elias et al. (2017) also found high abundance and frequency of *A. ananassoides*. This abundance may be related to the fact that the propagation of *A. ananassoides* occurs both vegetative and sexually (Paula & Silva 2004). We found *A. ananassoides* both in places exposed to intense light and in shaded places, demonstrating its tolerance to different light conditions (Proença & Sajo 2007). This fact may be related to the adaptation of the species in different environments of the seasonal forest understory. In addition, its leaf structure is rigid, succulent, and thick (Crayn et al. 2015), which ensures greater resistance to water stress and high temperatures, favoring its occupation (Proença & Sajo 2007) in rock outcrops.

Marantaceae had the second largest number of individuals and was represented by two genera in the sample units, *Goeppertia* and *Ischnosiphon*, with *Goeppertia* being one of the two genera in our quantitative survey with 100% frequency. *Goeppertia* is the most diverse genus of the Marantaceae (Borchsenius et al. 2012), preferentially inhabiting humid environments. When they occur in environments with pronounced seasonality, the leaves perish in response to water deficit and are renewed at the beginning of the rainy season, using the starch reserves present in their tubers (Kennedy 1978). Among the *Goeppertia* species, *Goeppertia ovata* (Nees & Mart.) Borchs. & S.Suárez was the one with the highest number of individuals, locally known as *ariá*, with nutritious tubers often used as a source of starch in the Amazon (Barros et al. 2021).

The cover of a species in a given environment can be influenced by its morphology or way of life (Munhoz & Felfili 2008). For example, *Bromelia balansae* Mez, with leaves that can range between 89–187 x 2–2.9 cm (Araújo, 2016), and *G. ovata,* with leaves that can reach an average of 65.7–79.4 x 14.5−16.7 cm (Saka 2016), had the second and third highest relative cover (18.3 and 6.8%), respectively, although they had only 72 individuals each. In turn, *Riencourtia pedunculosa* (Rich.) Pruski, a delicate annual herb with linear and narrow leaves ranging from 1.2–7.5 x 0.1–1.6 cm, with width varying between 0.1–0.4 mm in rock outcrops (Bringel 2014), presented more than twice the number of individuals (212) in relation to the aforementioned species, but had only the fourth highest relative cover (6.4%). Thus, the size of the leaf blade seems to have been more important in determining the relative cover of these species in the study area, as species with fewer individuals, but larger leaves, had greater relative cover.

Our species diversity estimates were higher than those recorded for herbaceous communities in the Cerrado-Amazon transition (Ivanauskas et al. 2004, Melo-Santos et al. 2013). This fact seems to be related to the fact that these studies were carried out in semideciduous or evergreen forests, and in the deciduous forests the higher incidence of light contributes to the increase in the diversity of herbaceous species (*e.g.* Sagar et al. 2012). However, in Central Amazonia, Costa et al. (2005) recorded 87 species for an herbaceous community; in such a study, the higher number of species may be related to the method and sampling effort adopted, since the collections were carried out in 59 plots of 250 x 2 m, being superior to that carried out in the RPPN Mirante da Serra. When we compare our results with studies carried out in herbaceous communities located in rock outcrops of southern Amazonia, such as the Carajás National Forest (Nunes et al. 2009), the Shannon diversity values (H') of these communities were higher than the values found at the RPPN Mirante da Serra (3.3 nats.individual^{-1} and 2.43 nats. individual^{-1}, respectively). Here again, the method and sampling effort differed, and the Shannon index is strongly influenced by the variation in sampling effort (Magurran 2013). In this sense, more standardized studies in herbaceous communities in the Southern Amazon would allow a better understanding of their patterns of diversity. Herbaceous component inventory networks can be a strategy to fill this gap.

In view of the anthropic pressures faced by existing in the southern Amazon, we reinforce the importance of carrying out inventories of its herbaceous communities, since the risk of species loss is even more alarming once we consider the undersampling of this component. The increments to the Cristalino Flora, as well as the convergence of both Amazonian and Cerrado species in the study area, reinforce the need for conservation and expansion of investigations of rock outcrops.

Supplementary Material

The following online material is available for this article:

Supplementary Material 1 – *Griffinia nocturna* Ravenna had its first occurrence records in a matrix of forest vegetation within the Amazon biome.

Supplementary Material 2 – a: Phytosociological parameters for all genera sampled using the line intersection method in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (in portuguese, Reserva Particular do Patrimônio Natural, RPPN) in the Southern Amazon. b: Phytosociological parameters for families sampled in survey according to line intersection method in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (in portuguese, *Reserva Particular do Patrimônio Natural*, RPPN) in the Southern Amazon.

Supplementary material 3 – Diversity species estimates for the herbaceous component in a Seasonal Deciduous Forest associated with a granitic rock outcrop of the Mirante da Serra Private Natural Heritage Reserve (in portuguese, *Reserva Particular do Patrimônio Natural,* RPPN) in the Southern Amazon. a) Species Richness; b) Shannon Exponential Diversity; c) Simpson Diversity (1/D). qD: the diversity estimate of order q; qD.LCL and qD.UCL: the 95% lower and upper confidence limits of diversity, respectively; SC: sample coverage estimate; SC.LCL and SC.UCL: the 95% lower and upper confidence limits of sample coverage, respectively.

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Author Contributions

Sandra Cristina Gallo: led the study, carried out fieldwork and wrote the first version of the manuscript.

Mônica A. Cupertino-Eisenlohr: reviewed the floristic data, analyzed the data and contributed to the final writing.

Dennis Rodrigues da Silva: carried out field work and contributed to the review of floristic data.

Cassia Beatriz Rodrigues Munhoz: co-supervised the work and contributed to the final writing.

Pedro V. Eisenlohr: guided the work, coordinated the project, analyzed the data and contributed to the writing in all its stages.

Conflicts of Interest

None.

Ethics

Authors have complied with the guidelines established by the ethics committees of their respective research institutions.

Data Availability

All data used to run our numeric analysis are available at:

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Article

Breeding biology of Hooded Gnateater *Conopophaga roberti* Hellmayr, 1905 (Aves: Conopophagidae)

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Abstract: The Hooded Gnateater *Conopophaga roberti* Hellmayr, 1905 is an insectivorous understory passeriform with discrete behavior, whose reproductive attributes are poorly-known. In the present study, we describe the reproductive biology of the species and the growth pattern of the nestlings, based on observations conducted in remnants of the Cerrado savanna in eastern Maranhão state, in Brazil. The nests were identified during active searches conducted between June, 2018 and March, 2021. A total of 22 nests were found over the course of three breeding seasons. The cup-shaped nests were supported by small branches and were constructed at a mean height of 40.6 ± 16.1 cm (N = 21) above the ground. The nests were 23.1 ± 3.9 cm in length and 14.1 ± 1.6 cm in width (N = 21). The eggs were beige in color, with irregular brown mottling only at the rounded end of the egg, which had a mean length of 21.3 ± 0.8 mm, width of 17.2 ± 0.8 mm, and mass of 3.1 ± 0.1 g (N = 23). Hatchlings are completely naked and weigh 3.1 ± 0.2 g (N = 7), and when they abandon the nest, they have yet to reach full adult size, with the total length being 65.4% of that of the adult, the wing, 65.4%, the head, 73.9%, the culmen, 74.2%, the body mass, 73.3%, and the tarsus, 89.0% that of the adult. The growth curves are sigmoidal and all the coefficients of determination are at least 0.96, with the body length having the highest value ($R^2 = 0.98$). During the breeding season, the adult pair emitted alarm calls constantly when observers were in the vicinity of the nest. On a number of occasions, members of the breeding pair were observed moving away from the nest as it was approached by observers, while engaging in broken-wing display. The nest architecture, the color of the eggs, and the behaviors presented by this gnateater were similar to those described for other *Conopophaga*. With this work we contributed to improve the knowledge on the breeding behavior of this poorly know group of understory insectivorous birds.

Keywords: *Cerrado; natural history; nesting success; Passeriformes; predation; reproduction.*

Biologia reprodutiva de *Conopophaga roberti* Hellmayr, 1905 (Aves: Conopophagidae)

Resumo: O chupa-dente-de-capuz *Conopophaga roberti* Hellmayr, 1905 é um passeriforme insetívoro de sub-bosque, de comportamento discreto e cujos atributos reprodutivos são pouco conhecidos. Aqui descrevemos a biologia reprodutiva da espécie e o padrão de desenvolvimento dos ninhegos, com base em observações realizadas em remanescentes de Cerrado no leste do Maranhão, Brasil. Os ninhos foram localizados por busca ativa entre junho de 2018 e março de 2021. Um total de 22 ninhos foram encontrados ao longo de três estações reprodutivas. Os ninhos, em forma de taça, foram sustentados por pequenos galhos e construídos a uma altura média de 40,6 ± 16,1 cm (N = 21) acima do solo. Mediram 23,1 ± 3,9 cm de comprimento por 14,1 ± 1,6 cm de largura. Os ovos são branco-amarelados e mediram 21,3 ± 0,8 mm por 17,2 ± 0,8 mm, com massa de 3,1 ± 0,1 g (N = 23). Ao eclodir, os ninhegos estão completamente nus e pesaram 3,1 ± 0,2 g (N = 7). Abandonam o ninho antes de atingirem o tamanho dos adultos, sendo o comprimento total equivalente a 65,4% do adulto, a asa 65,4%, a cabeça 73,9%, o cúlmen 74,2%, a massa corporal 73,3% e o tarso 89%. As curvas de crescimento apresentaram padrão sigmóide e todos os coeficientes de determinação foram maior ou igual a 0,96, sendo o comprimento do corpo o valor mais alto ($R^2 = 0.98$). Durante o período reprodutivo, o casal adulto emitia alertas constantemente quando os observadores se aproximavam dos ninhos. Em diversas ocasiões foi observado o comportamento de defesa de “asa quebrada” pelo casal reprodutor. A arquitetura do ninho, a cor dos ovos e os comportamentos apresentados por *Conopophaga roberti* se assemelham aos descritos para outras espécies do gênero. Com este trabalho, melhoramos o conhecimento sobre a biologia reprodutiva deste grupo de aves insetívoras de sub-bosque pouco conhecido.

Palavras-chave: *Cerrado; história natural; Passeriformes; reprodução; sucesso reprodutivo.*

Introduction

The natural history of most birds, in particular their reproductive biology, is still poorly documented, and the breeding patterns of less than a third of the world's species have been described in detail (Xiao et al. 2017). However, this scenario has been changing gradually in recent years, with the constant publication of new data (*e.g.* Beier & Fontana 2019, Floriano et al. 2020, Lara et al. 2020, Studer & Crozariol 2020, Nunes et al. 2020, Martins et al. 2020, Cardona-Salazar et al. 2021, Larre et al. 2022).

Birds of the family Conopophagidae is endemic to the Neotropical region, being distributed between Costa Rica and southern Paraguay (Ohlson et al. 2013, Whitney 2020). Conopophagids are small birds with long tarsus, short tail and, in most species, an elongated post-ocular tuft usually white (Sick 1997). The family has two genera – *Conopophaga* and *Pittasoma* – and 11 species, of which nine (*aurita*, *melanops*, *lineata*, *cearae*, *roberti*, *peruviana*, *ardesiaca*, *castaneiceps*, and *melanogaster*) are members of the genus *Conopophaga* (Winkler et al. 2020).

Conopophaga is a clade of exclusively forest-dwelling species, which are typically solitary or form pairs with well-defined territories. Few data are available on the reproductive biology of the species of this genus, and the findings of a few case studies have been extrapolated to cover the remaining species (Whitney 2020). In some cases, the only information available on breeding patterns is a basic description of the nests and eggs (Peixoto 1932, Alves et al. 2002, Hillman & Hogan 2002, Sánchez & Aponte 2006, Leite et al. 2012), and even these characteristics are unknown in many species.

The Hooded Gnateater, *C. roberti*, is endemic to Brazil, where it is distributed in the states of Ceará, Piauí, Maranhão, and Pará (Whitney & Kirwan 2020), inhabiting densely vegetated and tangled portions of forest, often near the edge (Greeney 2020). The reproductive biology of the species is still poorly-known (Greeney 2018). Peixoto (1932) described two eggs collected by Emilie Snethlage in Pará, which were possibly obtained from the nest described subsequently by Snethlage (1935). In the present study, we describe the reproductive biology and growth patterns of the nestlings of *C. roberti.*

Material and Methods

1. *Study Area*

The present study was conducted in the Inhamum Environmental Protection Area (APA Inhamum; −4.891667, −43.414722) in the municipality of Caxias, eastern Maranhão, Brazil. The APA Inhamum has approximately 3,500 ha, and is located around two kilometers from the urban zone of the town of Caxias. The predominant vegetation is *sensu stricto* Cerrado (a savanna-like vegetation), with smaller patches of other habitats, such as Cerradão woodland, gallery forests, and stands of buriti palm (*Mauritia flexuosa*) along the margins of the local streams. The flora and fauna of the more humid environments in the vicinity of water bodies include many Amazonian elements, while the drier environments present many elements more typical of the Caatinga dry forest biome. The region's climate is "Aw" according Köppen-Geiger classification (Peel et al. 2007), with two well-defined seasons, a dry season, between June and November, and a rainy season, from December through May, with a mean annual precipitation of 1600 mm and a mean annual temperature of 27.8°C. The APA Inhamum is located in the middle basin of the Itapecuru River, and encompasses both perennial streams and some other intermittent watercourses.

2. *Identification of territories and monitoring of the nests*

During the first steps of the fieldwork, existing roads and trails were surveyed within the APA Inhamum to locate *C. roberti* territories. Once a territory was identified, the resident adults were captured using ornithological mist-nets. These individuals were weighed and measured (the length of the body, tarsus, culmen, wing, and head), and then banded with a numbered metallic ring provided by the Brazilian National Center for Bird Conservation (CEMAVE) and an additional set of unique, color-coded rings. The capture and handling of the birds was authorized by SISBIO (license 54623) and CEMAVE (protocol 3827).

As the period of the *C. roberti* breeding season is not well-known (Peixoto 1932), the territories identified in the APA Inhamum were monitored weekly between June 2018 and March 2021. Nest searches were based on the method proposed by Martin & Geupel (1993), which involves the careful inspection of all the vegetation within the territory and following individuals carrying nest-building materials or food items for nestlings. Attention was also paid to agonistic behaviors, such as constant vocalizations in response to the presence of observers in the vicinity of the nest.

Once found, the nests were monitored at intervals of one to four days for as long as they were active. The nests, eggs, and nestlings were measured using a metal ruler (1 mm scale) and caliper (accurate to 0.05 mm), and weighed with a portable digital balance (accurate to 0.01 g). The growth pattern of the nestlings was determined based on their body mass and the measurements of body length, and the tarsus, culmen, wing, and head. The nests were only measured when active, i.e., when they contained eggs or nestlings. The nest structure was classified according to the categories proposed by Simon & Pacheco (2005).

3. *Analyses*

The nests were classified as successful, abandoned or depredated, and the percentage of each category was calculated for the study period. The annual production of fledglings (APF) was calculated by the formula: APF = total number of fledglings/total number of clutches (Ricklefs & Bloom 1977). The apparent success corresponds to the number of successful nests/total number of nests, and is a parameter used primarily for comparisons with older studies, given that it does not take into account the phase of the nest when it was first identified, and thus provides an overestimate of the actual success (Johnson 1979, Jehle et al. 2004).

The growth curves of the nestlings were adjusted using a second degree polynomial regression. A polynomial equation was generated for each morphological parameter, and its coefficient of determination (R^2) was calculated. The comparison of the morphometric parameters of the nestlings was based on the data collected from 54 adults (35 males and 19 females) during the banding. The analyses were run in the R program (R Core Team 2019) using the ggplot2 (Wickham 2016), ggpmisc (Aphalo 2021), and dplyr (Wickham et al. 2020) packages.

Results

The surveys and monitoring of the nests were based on a total sampling effort of 340 hours in the field. A total of 22 active nests were identified over three breeding seasons (2018-2019, 2019-2020, and 2020-2021), all in Cerradão woodland understory. Overall, 40.9% of the nests were successful, 45.5% were preyed upon, and 13.6% were abandoned. The fledgling production rate was 0.7 fledglings/clutch for the study period as a whole, although it was 1.3 in 2018-2019 (N = 3), 0.3 in 2019-2020 (N = 7), and 0.5 in 2020-2021 (N = 12). The annual production of fledglings by *C. roberti* was 0.58 per adult female.

The earliest active nest was identified during the incubation phase in the first half of November, while the latest (with two nestlings that were lost to predators) was found in the first half of March. These findings indicated that the *C. roberti* breeding season lasts from November to March, which coincides with the rainy season in the study region.

Whenever observers approached a nest to within a distance of 10–15 m, the breeding pair emitted alarm calls continuously and insistently. This behavior was in fact the most reliable indicator of reproductive activity and ensured the identification of the majority (N = 12) of the nests. This defensive behavior was observed as soon as nest construction was initiated. On a number of occasions, members of the breeding pair were observed engaging in broken-wing display, in particular toward the end of the incubation and in the nestling stages.

The monitoring of color-banded adults permitted the confirmation of three events of a second attempt at reproduction in breeding pairs whose first nests had been depredated or abandoned. In one case, the breeding pair was observed building a second nest 83 days after the depredation of their original nest. In the second case, the pair was observed building a second nest 73 days after abandoning the first site, while in the third, the new nest was found in incubation phase 64 days after the depredation of the first clutch. The nests were never reused.

The nests were of the low cup/base type, and were built in a number of different substrates, including small branches and tangles of lianas, tufts of grass, and in the leaves of babaçu (*Attalea speciosa*) or tucum (*Bactris* sp.) palms or bromeliads (*Bromelia* sp.). All the nests were built in the understory at a mean height of 40.6 ± 16.1 cm (range = 15–75) above the ground. Five nests were collected and deposited in the Marcelo Bagno Ornithological Collection (COMB) of the University of Brasília, under catalog numbers N0730, N0731, N0732, N0733, and N0734.

Nest construction started with the establishment of a base formed by a pile of dry leaves and twigs, which measured 23.1 ± 3.9 cm × 14.2 ± 1.5 cm (N = 21) when complete. A smaller, cup-shaped structure is then built on top of the base using dry leaves and tree pericambium, arranged in a circular shape and lined with fine petioles, forming a chamber in which the eggs are deposited (Figure 1A). This structure has a mean depth of 40.6 ± 16.1 mm, internal diameter of 59.4 ± 7.2 mm, and external diameter of 79.1 ± 11.1 mm (N = 21). The construction process took eight days to complete (N = 1).

The eggs were beige and had irregular brown mottling on the more rounded extremity (Figure 1A). All the clutches contained two eggs (N = 17), which were laid at intervals of one or two days. Both members of the breeding pair incubated the eggs and cared for the nestlings.

When the nestlings hatch, they are completely naked, with dark brown skin and closed eyes (Figure 1B). The labial commissure is whitish and the inner surface of the bill is orange. When they hatch, the nestlings had a mean weight of 3.1 ± 0.2 g (N = 7) and one day before fledging, they weigh 16.2 ± 1.0 g (N = 4). On the second day of life, the pterylae were apparent, with darker tones in the alar, capital, dorsal, femoral, humeral, and ventral zones (Figure 1C). Dark gray feather sheaths are visible by the fourth day, when they appear in the

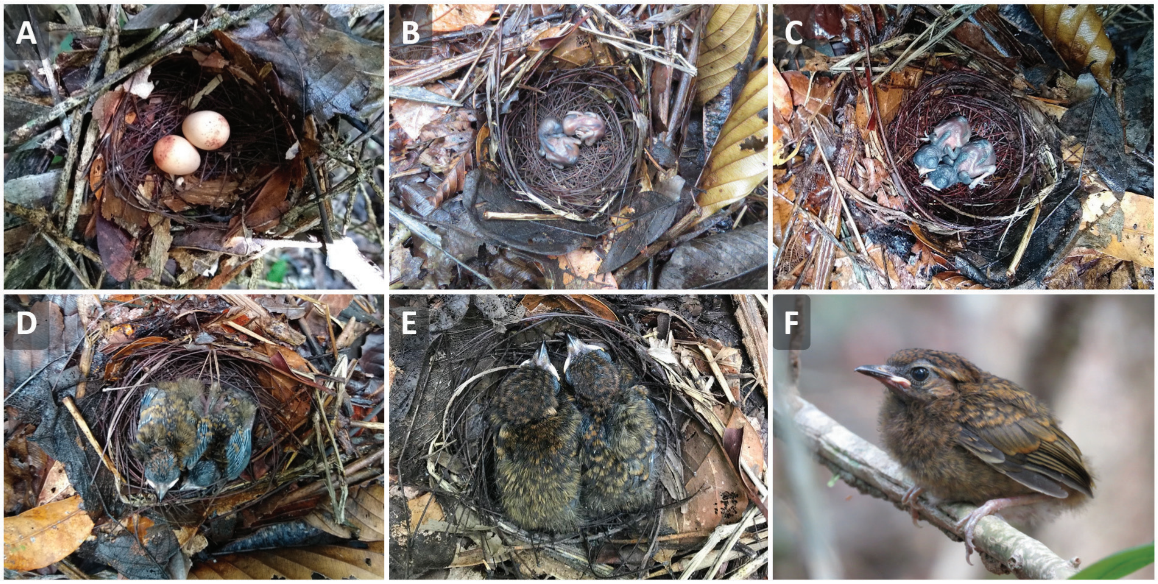

Figure 1. Eggs (A) and nestlings of Hooded Gnateater *Conopophaga roberti* at 1–2 (B), 2–3 (C), 7–8 (D), and 9–10 day after hatching (E), and after fledging (F), showing no clear sexual dimorphism.

alar, crural, capital, dorsal, femoral, humeral, and ventral pterylae, which is also when the eyes begin to open.

The bill begins to darken and the commissure acquires a more yellowish tone over the course of the development of the nestling. At around day eight, the body is partially covered with yellowish down, while the shafts of the remiges and the feathers on the head are clearly visible (Figure 1D). By the tenth day, the body is covered entirely with feathers and the remiges are well-developed (Figure 1E). At this stage, the nestlings are already able to produce vocalizations similar to those of the adults, but not as loud. Fledglings had poorly-developed tail, were still covered with down (Figure 1F). Two nestlings were monitored from the first day of life and fledged on days 13 and 14. No clear sexual dimorphism was observed in any of the fledglings (Figure 1F).

When they fledge, the fledglings have yet to reach full adult size (Figure 2), and their total length is 65.4% of that of the adult, while the wing is 65.4%, the head is 73.9%, the culmen is 74.2%, body mass is 73.3%, and the tarsus is 89.0% of the length of that of the adult. The growth curves are sigmoidal and all the coefficients of determination (R^2) are at least 0.96.

Few data are available on the reproductive biology of the species of the genus *Conopophaga* (Table 1). In most cases, the studies present no more than basic descriptions of the nests, eggs, and some associated behaviors. The best-studied species is the Black-cheeked Gnateater *C. melanops*.

Discussion

In general, the reproductive parameters of *C. roberti* are similar to those of other species of the genus *Conopophaga*. However, the predation nest rate of *C. roberti* (45,5%) were lower than that observed for *C. melanops* (64,9%), for example (Studer et al. 2019). Bodrati & Di Sallo (2020) also recorded only one successful nest from the five sites monitored in a study of Rufous Gnateater *C. lineata.* The nest

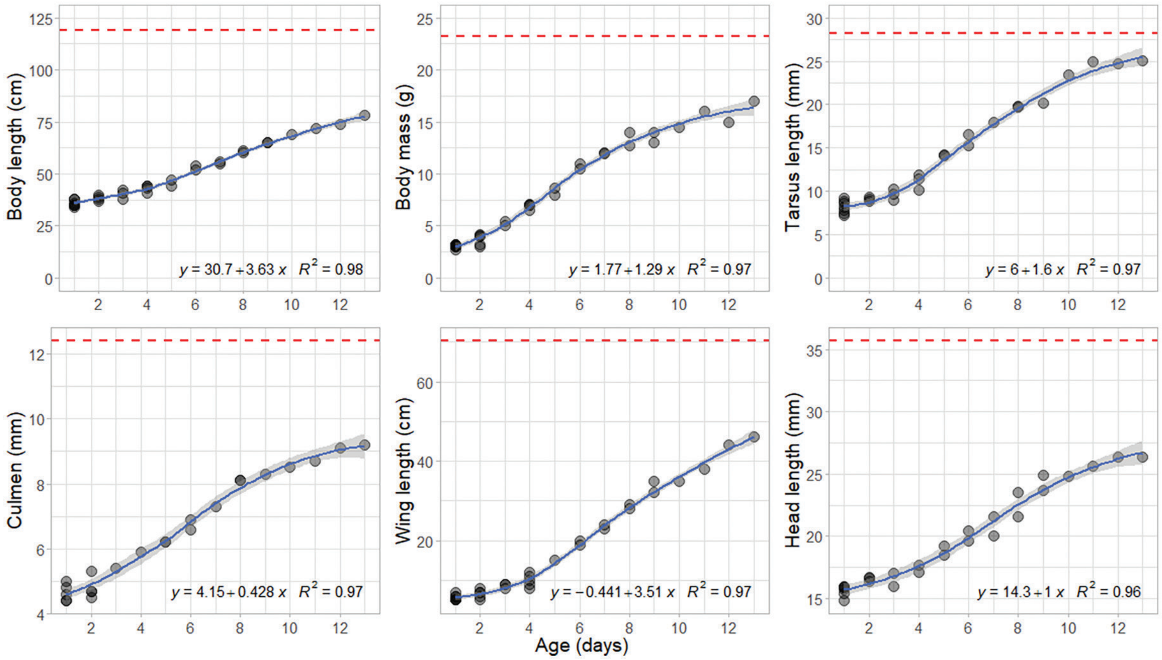

Figure 2. Growth curves of the Hooded Gnateater *Conopophaga roberti* nestlings fit using a second-degree polynomial regression. The dashed red lines represent the mean values for the adults (N = 54).

Table 1. Published data available on the reproductive biology of the species of the genus *Conopophaga*.

Species	Clutch	Incubation (days)	Nestling period (days)	Parental care	Source
melanogaster	–	–	–	–	–
melanops	2	12–18	13–18	Biparental	Straube (1989), Alves et al. (2002), Stenzel and Souza (2014), Studer et al. (2019)
aurita	1–2	–	–	Biparental	Leite et al. (2012), Greeney (2020)
peruviana	2	–	–	Biparental	(Hillman and Hogan 2002)
cearae	–	–	–	–	–
roberti	2	–	13–14	Biparental	Peixoto (1932), Greeney (2020)
lineata	1–3	–	13–14	Biparental	Marini et al. (2007), Lopes et al. (2013), Whitney et al. (2020), Bodrati and Sallo (2020)
castaneiceps	2	–	–	–	Steven and Hilty (1974)
ardesiaca	2	–	–	–	Sánchez and Aponte (2006)

success rate recorded here for *C. roberti* (40.9%) was nevertheless much higher than those found in *C. melanops* by Lima & Roper (2009), who registered a success rate of 22%, and Studer et al. (2019), who recorded a rate of 20%. Depredation and abandoning the nest are two of the principal factors that determine the low clutch success rates in most bird species from the Neotropical region (Marini et al. 2009, Nóbrega & Pinho 2010). In the present study period, in fact, all the nests were lost during one of the breeding seasons monitored, which had a major impact on the overall production of fledglings. The reproductive biology of most bird species is still poorly known, in terms of published data (Xiao et al. 2017), and this is especially true for forest-dwelling species, which hampered the systematic comparison of the data on the annual production of fledglings by *C. roberti* with other *Conopophaga* species or birds that are found in similar habitats. The only *Conopohaga* species with available data is *C. melanops*, with annual production of fledglings of 0.36 (Lima & Roper 2009), versus 0.58 of *C. roberti*.

The biparental behavior observed in *C. roberti* is typical of the genus, with both adults participating in territorial defense, nest-building, and infant caregiving. The broken wing display employed by *C. roberti* has also been observed in most other *Conopophaga* species, including *C. melanops* (Straube 1989), Ash-throated Gnateater *C. peruviana* (Hillman & Hogan 2002), *C. lineata* (Marini et al. 2007), and Chestnut-belted Gnateater *C. aurita* (Leite et al. 2012). This is a common behavior in many birds, and serves to distract the attention of a potential predator and lead it away from the nest and the nestlings (de Framond et al. 2022).

Many birds are known to engage in multiple attempts to reproduce following the loss of a first clutch (Rubio & Pinho 2008, Murcia et al. 2022). While it was not previously known whether this was also the case in *Conopophaga* (Winkler et al. 2020), the present study represents the first record of multiple breeding events in a species of this genus.

The general architecture of the nest of *C. roberti* is also similar to the patterns described for *C. aurita* (Leite et al. 2012), *C. melanops* (Alves et al. 2002), *C. lineata* (Marini et al. 2007), *C. peruviana* (Hillman & Hogan 2002), and Chestnut-crowned Gnateater *C. castaneiceps* (Hilty 1975). The dimensions and coloration of the *C. roberti* eggs observed in the present study were similar to the description of specimens collected in the Brazilian state of Pará by Emilie Snethlage, which measured 20 mm × 17 mm and were yellowish-white with a crown of reddish mottling around the upper pole (Peixoto 1932). The eggs of *C. roberti* are also similar to those of the congeners *C. lineata* (Willis et al. 1983), *C. melanops* (Straube 1989), and Slaty Gnateater *C. ardesiaca* (Sánchez & Aponte 2006).

The development of the *C. roberti* nestlings in the first days of life was similar to that presented (in photos) in *C. melanops* (Stenzel & Souza 2014), as was the period the nestlings: 14–15 days to *C. melanops* (Stenzel & Souza 2014); 13–14 to *C. lineata* (Bodrati & Di Sallo 2020); 13–14 days to *C. roberti* (present study). Stenzel & Souza (2014) observed that most of the *C. melanops* nestlings monitored in remnants of the Atlantic Forest in the Rio de Janeiro Botanical Garden remained in the nest for 15 days, although in one case, a fledgling abandoned the nest after 14 days. In other studies of *C. melanops*, the nestlings remained in the nest for between 13 and 18 days (Straube 1989, Alves et al. 2002, Studer et al. 2019). This variation in nestling period may be related to climatic and latitudinal factors within the ample geographic range of the species. However, the reproductive parameters of *C. roberti* may be less variable, given that the species occurs within the region of the transition among the Cerrado, Caatinga, and Amazonian biomes, which has well-defined climatic seasons.

The morphometric growth parameters of the nestlings analyzed in the present study are still unknown in other species of the family Conopophagidade. When the fledged abandoned the nest, the length of the tarsus was the parameter closest to that of the adult, which is consistent with the pattern observed in Yellow-olive Flycatcher *Tolmomyias sulphurescens* (Anciães et al. 2012).

When the *C. roberti* fledged, the feathers of their wings and tail are still poorly developed, which means that they are unable to undertake long-distance flights. When they fledged, the nestlings weighed 73.3% of the weight of the adults and did not go through a pre-fledgling peak in development, as observed in many bird species (*e.g.* Antas et al. 2010). In fact, some passeriform fledglings, such as those of *T. sulphurescens* (Anciães et al. 2012) and Cinnamon Flycatcher *Pyrrhomyias cinnamomeus* (Collins & Ryan 1995), are actually heavier than the adults when they abandon the nest, with the former reaching 107% of the weight of the adult, and the latter, 102%.

In most cases, the previous studies of the reproductive parameters of conopophagids have provided only basic descriptions of the nests, eggs, and some associated behaviors (Table 1), and even these data are lacking for *C. melanogaster* and Ceara Gnateater *C. cearae* (Greeney 2020, del Hoyo et al. 2020). In the specific case of *C. cearae*, the only evidence is a photograph (but no written description) of a nest containing two eggs, which was found on 17/03/2020, in the municipality of Guaramiranga, in the Brazilian state of Ceará (Vieira 2020). It is important to note that reliable data on the reproductive parameters of a species and the habitats in which it builds its nests represent an essential set of information for the development of effective strategies for the conservation and management of the species' natural habitats.

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Author Contributions

Surama Pereira: Substantial contribution in the concept and design of the study, data collection, data analysis and interpretation and manuscript preparation.

Bruna Stefane da Silva Santos: Substantial contribution to data collection, data analysis and critical revision, adding intelectual content.

Flávio Kulaif Ubaid: Substantial contribution in the concept and design of the study, data collection, data analysis and interpretation and manuscript preparation.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

We declare that the procedures used in this study have no conflict with the Brazilian Laws regarding the use of vertebrates in scientific research.

Data Availability

Besides the map, photographs and descriptions included here, other data was compiled from published literature, and appropriated cited along the manuscript.

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Article

Paullinieae (Sapindaceae) of the restingas of Rio de Janeiro, Brazil: taxonomy and distribution

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Abstract: Paullinieae is a predominantly neotropical tribe comprising six genera (*Cardiospermum*, *Lophostigma*, *Paullinia*, *Serjania*, *Thinouia* and *Urvillea*), of which *Lophostigma* is the only one not found in Brazil. This study was conducted in the sandy coastal plains (restingas) of Rio de Janeiro state, which from the mouth of the Itabapoana river in the north, bordering Espírito Santo state, to Ponta da Trindade (including Ilha Grande) in the south, bordering São Paulo state. This ecosystem has great biodiversity, but has been constantly threatened by deforestation, human occupation and degradation resulting from tourism. In this area we found 30 species in five genera: *Cardiospermum* (1 sp.), *Paullinia* (9 spp.), *Serjania* (15), *Thinouia* (2) and *Urvillea* (3). The taxonomic treatment includes a key to identify the taxa, and for each species a morphological description, illustrations, a map of its geographical distribution, ecological information, phenological data, and conservation status. Most species occurred in ridge forests, followed by dune thicket and non-flooded scrub formations. Among of the 30 species, four (*Paullinia coriacea, P. ternata, Serjania fluminensis* and *S. littoralis*) were recorded only in the sandy coastal plains, and four are endemic to Rio de Janeiro state (*Serjania eucardia, S. fluminensis, S. littoralis* and *S. tenuis*). In addition, four species are already included in the Red List of Brazilian Flora and another three are indicated in this study as threatened. This research is important not only to improve knowledge of Paullinieae species found in Rio de Janeiro's sandy coastal plains, but also to provide information to be used for conservation measures in the State, as well as in other coastal plains of Brazil.

Keywords: *Climbing plants; Atlantic Forest; southeastern Brazil; conservation; coastal vegetation.*

Paullinieae (Sapindaceae) das restingas do estado do Rio de Janeiro, Brasil: taxonomia e distribuição

Resumo: Paullinieae é uma tribo predominantemente neotropical e compreende seis gêneros (*Cardiospermum*, *Lophostigma*, *Paullinia*, *Serjania*, *Thinouia* e *Urvillea*), dos quais *Lophostigma* é o único gênero não encontrado no Brasil. Este estudo foi conduzido nas restingas do estado do Rio de Janeiro, que começam na foz do rio Itabapoana, na fronteira com o estado do Espírito Santo e se estende até a Ponta da Trindade (incluindo a Ilha Grande), próximo à fronteira com o estado de São Paulo. Este ecossistema possui grande biodiversidade, mas tem sido constantemente ameaçado pelo desmatamento, ocupação humana e ações de degradação decorrentes do turismo. Nesta área foram encontradas 30 espécies pertencentes a cinco gêneros: *Cardiospermum* (1 spp), *Paullinia* (9 spp), *Serjania* (15), *Thinouia* (2) e *Urvillea* (3). O tratamento taxonômico incluiu descrição e chave para identificação das espécies, informações sobre as formações vegetacionais das restingas onde cada táxon ocorre, além de ilustrações e mapas de distribuição geográfica das espécies. A maioria das espécies ocorre em floresta de cordão arenoso, seguidas das espécies de vegetação arbustiva fechada de cordão arenoso e arbustiva aberta não inundável. Entre as 30 espécies, quatro delas (*P. coriacea, P. ternata, S. fluminensis* e *S. littoralis*) são encontradas apenas nas formações de restinga e quatro espécies são endêmicas do Rio de Janeiro (*S. eucardia*, *S. fluminensis*, *S. littoralis* e *S. tenuis*). Além disso, quatro espécies já estão incluídas na Lista Vermelha da Flora do Brasil e outras três estão indicadas neste estudo.

Este trabalho é importante não apenas para melhorar o conhecimento das espécies de Paullinieae encontradas nas restingas do Rio de Janeiro, mas também para fornecer informações a serem utilizadas em medidas de conservação no Estado e nas demais regiões de restinga do Brasil.

Palavras-chave: *Trepadeiras; Floresta Atlântica; sudeste do Brasil; conservação; vegetação costeira.*

Introduction

The family Sapindaceae comprises approximately 1,900 species, distributed mainly in tropical and subtropical regions, with a few genera in temperate regions (Buerki et al. 2021). It is distributed throughout Brazil (Radlkofer 1931–1934; Somner 1997) and has the largest and richest area of distribution in the Amazon region (Barroso et al. 1991). In Brazil there are 32 genera with 436 species (Sapindaceae in Flora e Funga do Brasil 2022). The representatives of this family are trees, treelets, shrubs, lianas and herbaceous climbers (Acevedo-Rodríguez 2011), the two latter life forms showing a pair of tendrils at the base of the inflorescence rachis (Ferrucci 1991, Somner 1997). The species of greatest economic interest in the family is *Paullinia cupana* Kunth, popularly known as *guaraná*, and mostly used in high energy foods, drinks and dietary supplements, as well as a medication to reduce fever, stimulate metabolism, antioxidant and antibacterial activity and induce antiplatelets (Guarim Neto et al. 2000, Hamerski et al. 2013).

Radlkofer (1931–1934) divided the Sapindaceae into, 14 tribes and four subtribes, with the genus comprising climbing plants included in the Paullinieae tribe. A recent study on the phylogeny of this tribe (Acevedo-Rodríguez et al. 2017) corroborates the Radlkofer classification and includes six genera: *Cardiospermum* L. (15 spp), *Lophostigma* Radlk. (2 spp), *Paullinia* L. (220 spp), *Serjania* Mill. (240 spp), *Thinouia* Triana (12 spp) & Planch. and *Urvillea* Kunth. (20 spp) (Acevedo-Rodríguez et al. 2017, Chery et al. 2019, Ferrucci & Steinmann 2019, Medeiros et al. 2020).

Paullinieae (509 spp) is a predominantly neotropical tribe with a couple of species naturally extending into Africa and Madagascar, however, the most of species are distributed in tropical and subtropical areas of the American continent (Acevedo-Rodríguez et al. 2017, Ferrucci & Steinmann 2019), concentrated in South America. We can find a large number of *Paullinia* in the Amazon region (Somner 2001), and *Serjania* has three major distribution centers: one in the southern region of Mexico, another in the central plateau of Brazil and the third in the Brazilian Atlantic Forest (Acevedo-Rodríguez 1993). In Brazil we can find about 50% (258 spp) belonging to the Paullinieae tribe: *Paullinia* (102), *Serjania* (121), *Cardiospermum* (7) *Thinouia* (11) and *Urvillea* (16) (Sapindaceae in Flora e Funga do Brasil 2022).

The family has been recorded in the cerrado, caatinga, pampa, pantanal and Atlantic Forest domains (Araujo 2000, Guarim Neto 1994, Reitz 1980, Sapindaceae in Flora e Funga do Brasil 2022). In Rio de Janeiro state, 134 species were recorded in 20 genera, 63% of these species belong to the tribe Paullinieae, represented by *Cardiospermum* (4 spp.), *Paullinia* (22), *Serjania* (48), *Urvillea* (6) and *Thinouia* (5) (Sapindaceae in Flora e Funga do Brasil 2022, Somner et al. 2014).

According to Gentry (1991), lianas are concentrated in a few families, including the Sapindaceae, which is among the richest in number of species. Floristic and phytosociological surveys of lianas conducted in some regions of the semideciduous seasonal forest in São Paulo state (Hora & Soares 2002, Udulutsch et al. 2004, Rezende & Ranga 2005, Tibiriçá et al. 2006) and at the Ecological Reserve of Macaé de Cima in Rio de Janeiro state (Lima et al. 1997) highlighted this family as among the three with the largest number of species. In the sandy coastal plains in Rio de Janeiro, the family is considered one of the ten richest, of which almost 75% of the species are lianas (Araujo 2000).

The sandy coastal plains were formed by sedimentation during the Quaternary Period along the Brazilian coast (Suguio & Tessler 1984). This ecosystem covers an area of approximately 1,200 km², about 2.8% of the Rio de Janeiro state's territory (Araujo & Maciel 1998). It consists of a set of physiognomically distinct plant communities under marine and fluvial-marine influence (CONAMA 1996), which are collectively termed *restinga* by Araujo (1992). Floristic surveys show that sandy coastal plains have 356 restricted to this vegetation type, including 295 endemic species (BFG 2015), and the ecosystem has undergone intensive and extensive deforestation, mainly due to human occupation (real estate speculation and tourism), making the study of the flora a priority for knowledge acquisition and conservation (Rocha et al. 2004).

According to Rizzini (1997), the restinga flora originated from the Atlantic Forest and is so recent that there has been little species divergence, given that its species are very similar to those found in other areas of the Atlantic Forest (Araujo & Scarano 2007). However, Araujo & Lacerda (1987) report that species from other ecosystems are also found, namely from the Atlantic Forest to the Amazon Rainforest.

The main objectives of the present taxonomic study were thus to identify and describe the species of Paullinieae that occur in the different restinga vegetation formations of the state of Rio de Janeiro, and respectively indicate and classify the endemic species and those threatened with extinction.

Material and Methods

1. *Study area and field expeditions*

The coast of Rio de Janeiro is in four state government regions: Costa verde, Metropolitana, Baixadas Litorâneas e Norte Fluminense. In the north, it starts at the mouth of the Itabapoana river (21°17'S; 40°57'W), on the border with Espírito Santo state, and extends southeast to Ponta da Trindade (including Ilha Grande) (23°21'S; 44°43'W), on the border with São Paulo state. In this study, the nine subdivisions of Rio de Janeiro's sandy coastal plains proposed by Menezes & Araujo (2005) and Araujo (2000) were adopted. Sampling was carried out in the following areas: municipality of São Francisco de Itabapoana (Santa Clara and Gargaú districts); sandy coastal plain of Jurubatiba (Quissamã, Carapebuss and Macaé), Rio das Ostras (ARIE de Itapebussus, Praia das Virgens, Areias Negras and Praia da Joana), Armação de Búzios (Praia da Gorda, Praia da Ferradura and Praia de Tucuns), Cabo Frio (APA Pau-brasil, Praia do Peró, Cabo Frio dunes, Marine Radiogoniometric Station and Florestinha condominium), Araruama (Massambaba APA), Saquarema (Reserva Ecológica Estadual de Jacarepiá), Rio de Janeiro (Restinga de Grumari and Restinga da Marambaia) and Paraty (Praia de São Gonçalo, Paraty-Mirim, Juatinga, Praia do Sono, Trindade and

Praia Brava). No collections were made by the authors of this study in the State Biological Reserve (REBIO) at Praia do Sul; however, a thorough collection was made there by Dorothy Dunn de Araujo in the 1990s, which is well represented by exsiccates in the herbarium of the Botanical Garden of Rio de Janeiro (RB).

2. *Sampling and taxonomic treatment*

Periodic field expeditions were carried out to the selected areas from June 2007 to September 2008. The dried specimens prepared from field collections were incorporated into the herbaria of the Research Institute of the Botanical Garden of Rio de Janeiro (RB) and the Botany Department of the Federal Rural University of Rio de Janeiro (RBR). Fertile samples were also preserved in 70% alcohol, thus facilitating the observation of morphological characteristics.

The collections of Sapindaceae found in the main herbaria of Rio de Janeiro state (GUA now included in RB, HB, R, RB and RBR) were studied and reviewed. In addition, the digital databases available on the websites of INCT – Herbário Virtual da Flora e dos Fungos (speciesLink Website 2021) and Reflora (Reflora – Herbario virtual 2020) were consulted to obtain more records of species in the restingas of Rio de Janeiro.

In this study, all genera of Paullinieae, with the exception of *Lophostigma* (two species occur in Bolivia, Ecuador and Peru), were taxonomically treated.

Specimens were identified using the specialized literature (especially Radlkofer 1931–1934 and Flora do Brasil 2020), and by comparison with the materials deposited in herbaria RB and RBR, and determined by specialists of the family.

The geographical distributions of the taxa were established from the collections found in the herbaria of the state of Rio de Janeiro, other herbaria available online, and from specialized literature which deals with the species studied: Radlkofer (1931–1934), Reitz (1980), Somner & Barroso (1988), Acevedo-Rodríguez (1990), Ferrucci (1991), Acevedo-Rodríguez (1993), Guarim Neto (1994), Martinez (1997), Somner (1997), Ferrucci (1998), Somner (2001 b) and Somner et al. (2009).

The taxa were described morphologically and illustrated using a Carl Zeiss stereoscopic microscope, equipped with a camera lucida. Subsequently, an analytical key was constructed to identify the species treated here. The abbreviation of the names of the authors of species binomials follow Flora do Brasil (2020), The International Plant Name Index (IPNI 2021) and The World Flora Online (WFO 2022). The acronyms for the herbaria are in accordance with the Index Herbariorum (Thiers 2017). The terminology used for leaf architecture and indument follows Hickey & King (2000), and that for fruits is according to Barroso et al. (1999). The abbreviations used are: fl. – flowers; fr. – fruits; s.d. – no dates; s.n. – no numbers; st. – sterile.

For every species catalogued in the study area, we recorded its occurrence in each restinga vegetational formation, and its geographic distribution in Brazil and other countries. For the description of the vegetation of Brazil we used the classification of Veloso et al. (1991), and for the restinga vegetation formations we adopted Menezes & Araujo (2005).

For citation of examined material, at least one specimen per municipality (Mun.) was selected when there were many specimens for the same location, and a list of all studied specimens is presented (see in the section "Data availability").

For making the distribution maps we used the geographic coordinates when available in the specimen label data, and when these were absent, we used Google Earth (Google Earth website 2022) to georeference the points using precise information from the specimen localities, and these data were used to build the maps with QGis software (QGIS.org 2020).

The extinction threats of all species were examined and their conservation status was then classified according to IUCN (2019) categories and criteria: for the extent of occurrence (EOO) a polygon was made on the map to measure the area formed by the triangulation of the points of occurrence for each taxon, and the quantitative criteria and subcategories was based on geographic range information. Important references were also consulted, such as Livro Vermelho da Flora do Brasil (Martinelli & Moraes 2013), Livro Vermelho da Flora Endêmica do Estado do Rio de Janeiro (Martinelli et al. 2018) and the Centro Nacional de Conservação da Flora (CNCFlora) database.

In this work we presented morphologic descriptions and identification key of the species, as well as taxonomic comments, phenological data, geographic distribution, occurrence in the vegetation formations and conservation status of the taxa.

Results

The climbing plants of tribe Paullinieae (Sapindaceae) are represented in Rio de Janeiro's restinga vegetation by 30 species in five genera: *Cardiospermum* (Fig. 1A,D), *Paullinia* (Fig. 1C,E), *Serjania* (Fig. 1B,F), *Thinouia* (Fig. 1G) and *Urvillea* (Fig. 1H): *Cardiospermum corindum* L., *Paullinia coriacea* Casar., *P. ferruginea* Casar., *P. meliifolia* Juss., *P. micrantha* Cambess., *P. pseudota* Radlk., *P. revoluta* Radlk., *P. ternata* Radlk., *P. trigonia* Vell., *P. weinmanniifolia* Mart., *Serjania caracasana* (Jacq.) Willd., *S. clematidifolia* Cambess., *S. communis* Cambess., *S. confertiflora* Radlk., *S. corrugata* Radlk., *S. cuspidata* Cambess., *S. dentata* (Vell.) Radlk., *S. eucardia* Radlk., *S. fluminensis* Acev. Rodr., *S. ichthyoctona* Radlk., *S. littoralis* Somner & Ferrucci, *S. pernambucensis* Radlk., *S. salzmanniana* Schltdl., *S. tenuis* Radlk., *S. thoracoides* Radlk., *Thinouia mucronata* Radlk., *T. restingae* Ferrucci & Somner, *Urvillea glabra* Cambess., *U. rufescens* Cambess. and *U. stipitata* Radlk.

Among these species, 23 are restricted to Brazil (only *Cardiospermum corindum*, *Paullinia meliifolia*, *Serjania caracasana*, *S. clematidifolia*, *S. communis*, *S. confertiflora* and *Thinouia mucronata* also occur in other countries) and these are mainly found in the southeastern and southern regions of the country. Twenty-eight species also occur in three other vegetation formations of the Atlantic Forest domain (dense ombrophilous forests, seasonal deciduous forests, seasonal semi deciduous forests). Sixteen species are distributed in the coastal regions of Brazil, of which four are endemic to Rio de Janeiro state (*Serjania eucardia*, *S. fluminensis*, *S. littoralis* and *S. tenuis*), and only two are restricted to the sandy coastal plains (*Serjania fluminensis* and *S. littoralis*). In addition, 11 species were also found in other phytogeographic domains such as savanna (*cerrado*), *caatinga* and gallery forests (Table 1).

In the sandy coastal plains, woody climbers of the Sapindaceae were recorded in eight vegetation formations. The formation with the highest species richness was the ridge forest (27 species), followed by dune thickets (12), non-flooded scrub (10), seasonally flooded forests (5),

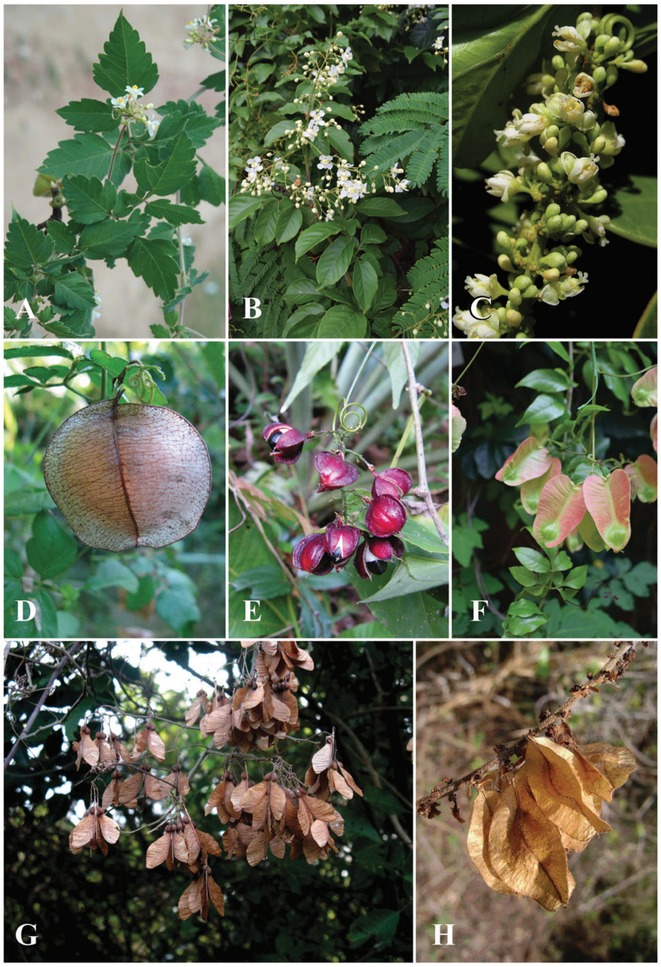

Figure 1. Flowers of – A. *Cardiospermum corindum* L.; B. *Serjania corrugata* Radlk.; C. *Paullinia weinmanniifolia* Mart. Fruits of – D. *Cardiospermum corindum* L.; E. *Paullinia meliifolia* Juss.; F. *Serjania corrugata* Radlk.; G. *Thinouia restingae* Ferrucci & Somner; H. *Urvillea rufescens* Cambess.

flooded scrub (4), ridge palmoids and beach thickets (2 species each), and only *Cardiospermum corindum* was found in beach graminoid (Table 2). *Serjania truncata* was recorded by Radlkofer (1931–1934) for Rio de Janeiro state as occurring in the municipality of Cabo Frio, collected by H. Schenck (without collector's number). However, this species was not found in any of the national or international herbaria consulted (online search), nor was it observed in the field survey, and so we were not able to describe it or confirm its occurrence in the sandy coastal plains.

Paullinieae (Kunth) DC., Prodr. 1: 601. 1824

Woody or herbaceous climbers, exceptionally erect shrubs or hemicryptophytic shrubs, monoecious, with a pair of tendrils, lenticellate; very often with white, milky latex; stems in cross section with a single vascular cylinder or multiple vascular cylinders; stipules minute to foliaceous, persistent or deciduous. Leaves alternate, with a distal leaflet, variously pinnate trifoliolate, biternate, partially tripinnate, rarely unifoliolate; leaflets generally with pilose domatia on the abaxial surface. Thyrse axillary or terminal, racemiform, spiciform or paniculiform, or cauliflorous. Flowers functionally unisexual, zygomorphic or actinomorphic (*Thinouia*); sepals 4–5, concave; petals 4–5, free, unguiculate; petals 5, spathulate, each leading to a basal, petaloid, bifid appendage (*Thinouia*) or petals 4 (other genera), with glandular trichomes, and hooded appendages with fleshy yellow crests, the two symmetrical posterior ones having a deflected ligule just below the crest, the other two anterior appendages asymmetrical and unilobed; disk extrastaminal, less often annular (*Thinouia*) or unilateral (other genera) and 2- or 4-lobed; stamens 8, surrounding a pistillode; anthers dorsifixed and introrse, rimose; ovary superior, tricarpellar, trilocular, one ovule per carpel; staminodes 8, similar to stamens, surrounding a gynoecium; stigma trifid. Fruits a septifragal capsule or schizocarps with three samaroid mericarps, with seminiferous portion of the mericarp proximal (*Thinouia*) or distal (*Serjania*); seeds arilloid or exarillate; embryo with straight, curved or plicate cotyledons; radicle-hypocotyl axis short.

Key for identification of Paullinieae species in the restingas of the state of Rio de Janeiro

1. Fruit a schizocarp, with three samaroid mericarps
    2. Thyrse umbelliform; flowers actinomorphic; petals 5, samaroid mericarps with seminiferous portion in the proximal part of mericarp, with upward vertical wings
        3. Leaflet sub-coriaceous, with entire margin .... *Thinouia restingae*
        3. Leaflet chartaceous, with serrate-dentate margin ……... *Thinouia mucronata*
    2. Thyrse never umbelliform, generally racemiform, rarely subspiciform; flower zygomorphic; petals 4; samaroid mericarps with seminiferous portion in the distal part of mericarp, with descending vertical wings
        4. Stem in cross section with only one vascular cylinder
            5. Leaves trifoliolate
                6. Stem puberulous when young, glabrescent when mature, with orange glandular trichomes, not hollow; leaflets not conduplicate, margin entire, less frequently with 1 or 2 glandular obtuse teeth in basal third, with a yellowish cartilaginous line; samaroid mericarps 1.4–2.4 × 1.3–2.5 cm ….. *Serjania littoralis*
                6. Stem hollow, glabrous, without glandular trichomes; leaflets conduplicate, margin dentate-repand, without a yellow cartilaginous line; samaroid mericarps 3.2–3.4 × 2.7–3 cm …......................... *Serjania dentata*
            5. Leaves biternate or 5-foliolate
                7. Stem ferruginous-tomentose; samaroid mericarps sub-coriaceous, ferruginous-tomentose ….. *Serjania pernambucensis*
                7. Stem pubescent or velutinous-pubescent; samaroid mericarps chartaceous, glabrous or puberulous
                    8. Stem velutinous-pubescent; leaves always biternate, not bullate, leaflets densely velutinous-pubescent on both surfaces; samaroid mericarps 3.8–5 × 3.6–4.5 cm, puberulous, with dorsal crest 2–5 mm wide …................................ *Serjania eucardia*

8. Stem pubescent; leaflet 5-foliolate or biternate, bullate, leaflets pubescent on both surfaces; samaroid mericarps 1.7–2.8 × 1.5–2 cm, glabrous, lacking dorsal crest …............. *Serjania salzmanniana*

4. Stem compound or divided, with 5 radiate vascular cylinder

9. Stem in cross section divided, with 5 radiate vascular cylinders and one tiny central vascular cylinder; leaves fragrant when dry; reddish glandular trichomes distributed throughout the plant …... *Serjania corrugata*

9. Stem in cross section composed of one central vascular cylinder and 3–10 smaller peripheral vascular cylinders; leaves not fragrant when dry; without reddish glandular trichomes distributed throughout the plant

10. Stem composed of one central vascular cylinder and 8–10 smaller peripheral vascular cylinders

11. Terminal leaflets elliptic, margin entire or dentate-repand; schizocarp sub-coriaceous, up to 4.7 cm long, seminiferous portion of mericarp with a dorsal crest …......... *Serjania fluminensis*

11. Terminal leaflets lanceolate or rhomboidal to ovate, margin serrate-dentate or serrate-crenate; schizocarp chartaceous, up to 2.9 cm long, seminiferous portion of mericarp without a dorsal crest

12. Stem with conspicuous ribs; stipules ovate, 0.5–1 mm long; terminal leaflet rhombic to ovate, margin serrate-crenate; ovary tomentose; schizocarp chartaceous, 2.5–2.7 × 2–2.2 cm, with a lateral depression in the seminiferous portion of the mericarp …........................... *Serjania clematidifolia*

12. Stem with inconspicuous ribs; stipules triangular; 1–1.5 mm long; terminal leaflet lanceolate, margin serrate-dentate; ovary puberulous; schizocarp sub-coriaceous, 2.7–4.7 × 2.4–4.4 cm, without a lateral depression in the seminiferous portion of the mericarp …................. *Serjania caracasana*

10. Stem composed of one central vascular cylinder and 3 smaller vascular peripheral cylinders

13. Stem 6-costate, leaflets with dentate-incise margin, with a pair of basal incisions .... *Serjania confertiflora*

13. Stem 3-costate; leaflets with margin entire, serrate-crenate or serrate-dentate, lacking a pair of basal incisions

14. Leaves biternate

15. Margin of leaflets serrate-crenate; sepals 4; samaroid mericarp with seminiferous portion laterally flattened; seeds elliptic-lenticular …......................... *Serjania communis*

15. Margin of leaflets entire or serrate-dentate; sepals 5; samaroid mericarps with seminiferous portion globose; seeds globose

16. Leaflets coriaceous, both surfaces glabrous, margin entire; crest of posterior appendage of petals bicorniculate; schizocarp 2.7–2.8 cm long; cotyledons more-or-less straight …......... *Serjania ichtyoctona*

16. Leaflets chartaceous, adaxial surface pubescent on the midvein and abaxial surface rarely puberulous, margin serrate-dentate; crest of posterior appendage of petals erose; schizocarp 1.5–1.7 cm long; cotyledon externally curved and internally biplicate …................... *Serjania thoracoides*

14. Leaves trifoliolate

17. Stipules linear; leaflets with acute or cuspidate apex; stem ferruginous-hirsute at the angles; samaroid mericarps pubescent; cotyledons more-or-less straight …........... .... *Serjania cuspidata*

17. Stipules deltoid; leaflets with acuminate apex; stem lacking ferruginous-hirsute trichomes at the angles; samaroid mericarps glabrous; cotyledon externally curved and internally biplicate …......... *Serjania tenuis*

1. Fruit a septifragal capsule

18. Capsules sub-chartaceous, seeds with small aril around the hilum

19. Stem 5–6-costate; leaves biternate; capsule not winged, subglobose to globose or large-obovoid, totally inflated ….. *Cardiospermum corindum*

19. Stem tricostate; leaves trifoliolate; capsule three winged, ellipsoid, inflated only in the central portion

20. Leaflets with margin serrate, with 2 or 3 pairs of teeth close to the apex; capsules glabrous …...................... .... *Urvillea glabra*

20. Leaflets with margin dentate-crenate or serrate-dentate, with teeth along the entire margin; capsule pubescent

21. Adaxial surface of leaflets with orange glandular trichomes; leaflet margin dentate-crenate; flowers ca. 2.5 mm long; capsules 1.8–2.2 cm long …....... .... *Urvillea rufescens*

21. Adaxial surface leaflets without orange glandular trichomes; leaflet margin serrate-dentate; flowers 5–6 mm long; capsules 2.3–2.8 cm long …......... .... *Urvillea stipitata*

18. Capsules crustaceous or coriaceous, seed with fleshy arilloid, covering the seed entirely or up to 3/4 of its surface

22. Leaflet abaxial surface and fruit epicarp densely ferruginous-tomentose; capsules not winged, crustaceous, stipe 1.8–3 cm long …... *Paullinia ferruginea*

22. Leaflet abaxial surface and fruit epicarp not densely ferruginous-tomentose; capsules winged, coriaceous, stipe 0.5–1.5 mm long
    23. Leaves trifoliolate
        24. Capsules suborbicular, with extra triangular appendages ….............. *Paullinia weinmanniifolia*
        24. Capsules obovate or obtriangular, without extra triangular appendages
            25. Leaves deciduous in the flowering period; leaflets sub-chartaceous, margin obtuse-dentate; thyrses cauliflorous, fasciculate; sepals 5; capsules obtriangular, 2.6–3 cm long, pubescent …........................ *Paullinia ternata*
            25. Leaves not deciduous in the flowering period; leaflets sub-coriaceous, margin entire; thyrses not cauliflorous; sepals 4; capsules obovate, 1.4–1.7 cm long, glabrous …............ .... *Paullinia coriacea*
    23. Leaves pinnately 5-foliolate, or biternate, or 11–13-foliolate
        26. Leaves pinnately 5-foliolate
            27. Capsules suborbicular, with extra triangular appendages …......... *Paullinia weinmanniifolia*
            27. Capsules obovate or ob-triangular, without triangular appendages
                28. Leaflets glabrous on both sides; basal leaflets generally with one or two pairs of extra basal reduced leaflets; capsules obovate, glabrous, with laterally inflected margin …................. *Paullinia pseudota*
                28. Leaflets pubescent on both sides or abaxial surface pubescent only on midvein; basal leaflets without extra basal reduced leaflets; capsules obtriangular, pubescent, without laterally inflected margin …................... *Paullinia revoluta*
        26. Leaves biternate or pinnately 11–13-foliolate
            29. Stipules leafy, falcate, cuneiform or asymmetric; sepals 5; capsules with lanose endocarp; cotyledons more-or-less straight …. .... *Paullinia meliifolia*
            29. Stipules not leafy, deltoid; sepals 4; capsules with endocarp tomentose only on the valve margins; cotyledons curved externally and biplicate internally
            30. Stem sub-cylindric, 5-costate; stipules triangular; petiole unwinged, bicanaliculate; leaflet margins entire; capsules obtriangular .... *Paullinia revoluta*
            30. Stem cylindric, striate; stipules deltoid; petiole marginate; leaflet margins serrate-dentate; capsules elliptic or obovate
                31. Stem brown or dark brown …................... .... *Paullinia trigonia*
                31. Stem yellowish brown …......................... .... *Paullinia micrantha*

Cardiospermum corindum L., Sp. pl. ed. 2: 526. 1762

Semi-woody climbers; stem greenish, 5–6 costate, hollow, pubescent, with a single vascular cylinder in cross section; stipules subulate, 1–1.5 mm long; petiole unwinged, canaliculate; rachis marginate or canaliculate. Leaves biternate; leaflets 1.4–4 × 0.5–2 cm, ovate, sub-chartaceous, apex attenuate to acuminate, mucronate, margin serrate-dentate, adaxial surface puberulous on the midvein, abaxial surface puberulous, without domatia, mixed craspedodromous venation. Thyrse axillary, racemiform, 0.6–1.4 long, with (3)4 or more sub-verticillate cincinni, peduncle of cincinni 0.6–1.5 cm long, pilose; bracts triangular. Flowers zygomorphic, 6–8 mm long; sepals 4; petals 4, obovate, crest of posterior petal appendage erose or emarginate; nectariferous lobes 4, posterior ovoid, anterior ovoid, much reduced; stamens 1.5–3.5 mm long; puberulous fillets, staminodes 2–2.5 mm long; ovary ca. 2 mm long, trigonous-ellipsoid, villose. Capsules 2.7–4.3 × 2.2–4 cm, unwinged, subglobose to globose, or large-obovoid, totally inflated, chartaceous, puberulous, stipe 1–5 mm long, endocarp glabrous; seeds 3, globose; aril semi-circular, sometimes emarginate; embryo with outer cotyledon curved and inner biplicate (Figures 1A, 4A–D).

Cardiospermum corindum is a cosmopolitan species. In America, it extends from the United States to central Argentina, and in Brazil occurs in all most states. It is found in the following plant formations: restinga, dense ombrophilous forests, seasonal deciduous forests, seasonal semi-deciduous forests and savanna (Figures 2A, 3). In the restinga, this species is found in the beach graminoid, non-flooded scrub and ridge forest formations. Flowering and fruiting occur throughout the year. According to CNCFlora (2012), this species is evaluated by its conservation status as endangered Least Concern (LC).

This species can be identified easily by the thyrses, comprising three, four or more sub-verticillate cincinni, and the sub-globose to globose or large-obovoid, totally inflated fruits with three seeds.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação dos Búzios, Restinga da Praia Gorda, 9.VI.2008, fl. e fr., *M.S. Faria et al. 86* (RB, RBR); idem, 9.VI.2008, fl., *M.S. Faria et al. 87* (RB); Mun. Cabo Frio, Estação Radiogonométrica da Marinha, 2.IV.2008, fr., *M.S. Faria et al. 69* (RB, RBR); Mun. Niterói, Ponta de Itaipu, 6.IX.78, fl. e fr., *G. Martinelli 4907* (RB); Mun. Rio das Ostras, Restinga de Balneário das Graças, 1.V.1999, fl., *H.N. Braga 262* (RB); Mun. Rio de Janeiro, Restinga da Barra da Tijuca, 3.IX.1979, fr., *Paulino s.n* (HB 68460); Mun. Saquarema, R. E. E. de Jacarepiá, restinga de Ipitangas, 28.IX.1990, fl. e fr., *G.V. Somner et al. 618* (RBR).

Paullinia coriacea Casar., Nov. Stirp. Bras. Dec. 3: 27. 1842

Woody climbers or suberect shrubs; stem brown, grayish-brown or yellowish brown, sub-cylindrical, striate, glabrous, with a single vascular cylinder in cross section; stipules deltoid, 0.5–1 mm long; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 2.2–8 × 1.3–4 cm, elliptic or ovate-lanceolate, sub-coriaceous, apex acute or obtuse, margin revolute, both side glabrous, with domatia, venation brochidodromous. Thyrse axillary and terminal, racemiform, 1–4.5 cm long, pubescent;

Table 1. Brazilian vegetational formations where the climbing Sapindaceae species studied here are found.

Espécies	**Rest.**	**DOF**	**SDF**	**SSF**	**Sav.**	**Caat.**	**GF**
Cardiospermum corindum	x	x	x	x	x		
*Paullinia coriacea**	x						
*Paullinia ferruginea**	x	x					
Paullinia meliifolia	x	x		x			
*Paullinia micrantha**	x	x	x				
*Paullinia pseudota**	x	x			x		
*Paullinia revoluta**	x	x		x		x	
*Paullinia ternata**	x						
*Paullinia trigonia**	x	x		x			
*Paullinia weinmanniifolia**	x	x		x			
Serjania caracasana	x	x	x	x	x		
Serjania clematidifolia	x	x	x		x		
Serjania communis	x	x		x	x		
Serjania confertiflora	x	x			x		
*Serjania corrugata**	x	x					
*Serjania cuspidata**	x	x					
*Serjania dentata**	x	x	x				
*Serjania eucardia***	x	x					
*Serjania fluminensis***	x						
*Serjania ichthyoctona**	x	x	x	x			
*Serjania littoralis***	x						
*Serjania pernambucensis**	x	x		x	x		
*Serjania salzmanniana**	x	x		x	x		
*Serjania tenuis***	x	x					
*Serjania thoracoides**	x	x					
Thinouia mucronata	x	x		x			x
*Thinouia restingae**	x	x		x			
*Urvillea glabra**	x	x					
*Urvillea rufescens**	x	x		x			
*Urvillea stipitata**	x	x			x		
Total	30	26	6	13	9	1	1

Restinga (Rest.); Dense Ombrophylous Forest (DOF); Seasonal Deciduous Forest (SDF); Seasonal Semideciduous Forest (SSF); Savana (Sav.); Caatinga (Caat.); Gallery Forest (GF). *: restricted species to Brazil; **: restricted species to Rio de Janeiro.

bracts triangular. Flowers zygomorphic, 3.5–4.5 mm long; sepals 4; petals 4, crest of posterior petal appendage erose or emarginate; nectariferous lobes 4, posterior ovoid, anterior orbicular, reduced; stamens 1.5–2 mm long, pubescent fillets, surrounding a pistilode, staminodes 1–2 mm long, surrounding a gynoecium; ovary 1–1.5 mm long, trigonous-ovoid, puberulous on the angles. Capsules 1.4–1.7 × 1–8 cm, winged, obovate, sub-coriaceous, glabrous, stipe ca. 0.5 mm long, endocarp tomentose on the valve margins; seeds 1–3, obovoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 4E–I).

Paullinia coriacea is endemic to Brazil, occurring in the states of Paraná, Rio de Janeiro and São Paulo (Figures 2A, 3). It is found exclusively in the sandy coastal plain formations, and occurs in the ridge palmoid, non-flooded scrub, dune thicket, seasonally flooded swamp and ridge forest formations. Flowering occurs from December to July and fruiting from January to October. The conservation status of this species is evaluated here as vulnerable (VU), with an extent of occurrence (EOO) of approximately 10600 km^2 (B1 <20000 km^2). It occurs exclusively in some restinga areas, environments that have been suffering from degradation (B2b (i,iii).

In this study, this species differs from other *Paullinia* by the following characters: trifoliolate leaves; leaflet glabrous, with entire margin, venation brochidodromous; endocarp tomentose on the valve margins; seeds 1–3.

Table 2. Climbing Sapindaceae species and their occurrence in the vegetation formations of the fluminenses's restingas.

Species	BG	RP	nFS	FS	DT	BT	SFF	RF
Cardiospermum corindum	x		x					x
Paullinia coriacea		x	x		x		x	x
Paullinia ferruginea								x
Paullinia meliifolia						x		x
Paullinia micrantha								x
Paullinia pseudota					x	x		x
Paullinia revoluta								x
Paullinia ternata								x
Paullinia trigonia							x	x
Paullinia weinmanniifolia		x	x	x	x			
Serjania caracasana							x	x
Serjania clematidifolia								x
Serjania communis								x
Serjania confertiflora								x
Serjania corrugata			x					
Serjania cuspidata			x		x			x
Serjania dentata			x	x	x			x
*Serjania eucardi*a			x		x			x
Serjania fluminensis								x
Serjania ichthyoctona			x	x				x
Serjania littoralis								x
Serjania pernambucensis								x
Serjania salzmanniana			x	x	x		x	x
Serjania tenuis								x
Serjania thoracoides					x			
Thinouia mucronata					x			x
Thinouia restingae					x			x
Urvillea glabra			x					x
Urvillea rufescens					x		x	x
Urvillea stipitata					x			x
Total	1	2	10	4	12	2	5	27

BG – Beach Graminoid; DT – Dune Thicket; nFS – non-Flooded Scrub; FS – Flooded Scrub; RP – Ridge Palmoid; BT – Beach Thicket; SFF – Seasonally Flooded Forest; RF – Ridge Forest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Angra dos Reis, Ilha Grande, Reserva Biológica Estadual da Praia do Sul, Praia do Leste, 15.V.1984, fr., *D. Araujo, 6270* (GUA); Mun. Armação de Búzios, Praia Rasa, sítio Tauá, 8.I.2002, fl., *R.C.C. Reis et al. 247* (RB); Mun. Arraial do Cabo, próximo a enseada de Tucuns, 29.III.2005, fr., *D. Araujo 10874* (GUA); Mun. Cabo Frio, Estação Radiogonométrica da Marinha, 2.IV.2008, fr., *M.S. Faria et al. 72* (RB); Mun. Mangaratiba, Ilha da Marambaia, próximo a lagoa vermelha, 6.VII.1993, fr., *G.V. Somner & A. Ururahy 761* (RBR); Mun. Maricá, Restinga de Maricá, 18.VI.1937, fl., *A. Souza 1684* (R); Mun. Niterói, Itaipuaçu, 15.II.1985, fr., *V.F. Ferreira 3953* (GUA); Mun. Parati, próximo ao Rio São Gonçalo, 10.VII.2008, fr., *M.S. Faria 109* (RB); Mun. Rio de Janeiro, Restinga da Marambaia, 2.IX.2007, fr., *M.S. Faria & A. Pacheco Jr. 27* (RB).

Paullinia ferruginea Casar., Nov. Stirp. Bras. Dec. 3: 28. 1842

Woody climbers or erect shrubs; stem yellowish brown, cylindrical, 8–10-costate, hollow, young densely ferruginous-tomentose, mature glabrescent, with a single vascular cylinder in cross section; stipules triangular, 1–1.5 mm long; petiole and rachis unwinged, canaliculate. Leaves 5-foliolate; leaflets 4–10.7 × 2.8–6 cm, ovate or elliptic, sub-coriaceous, apex obtuse, acute or acuminate, margin remotely dentate, adaxial surface sub-glabrous or pubescent ferruginous, abaxial surface densely ferruginous hirsute-tomentose, sometimes with pocket domatia, venation semicraspedodromous. Thyrse axillary and terminal, spiciform, 2.5–9 cm long, ferruginous hirsute-tomentose; bracts triangular. Flowers zygomorphic, 3.5–4 mm; sepals 4; petals 4, crest of posterior petal appendage emarginate or bifid; nectariferous lobes 2, posterior ovoid,

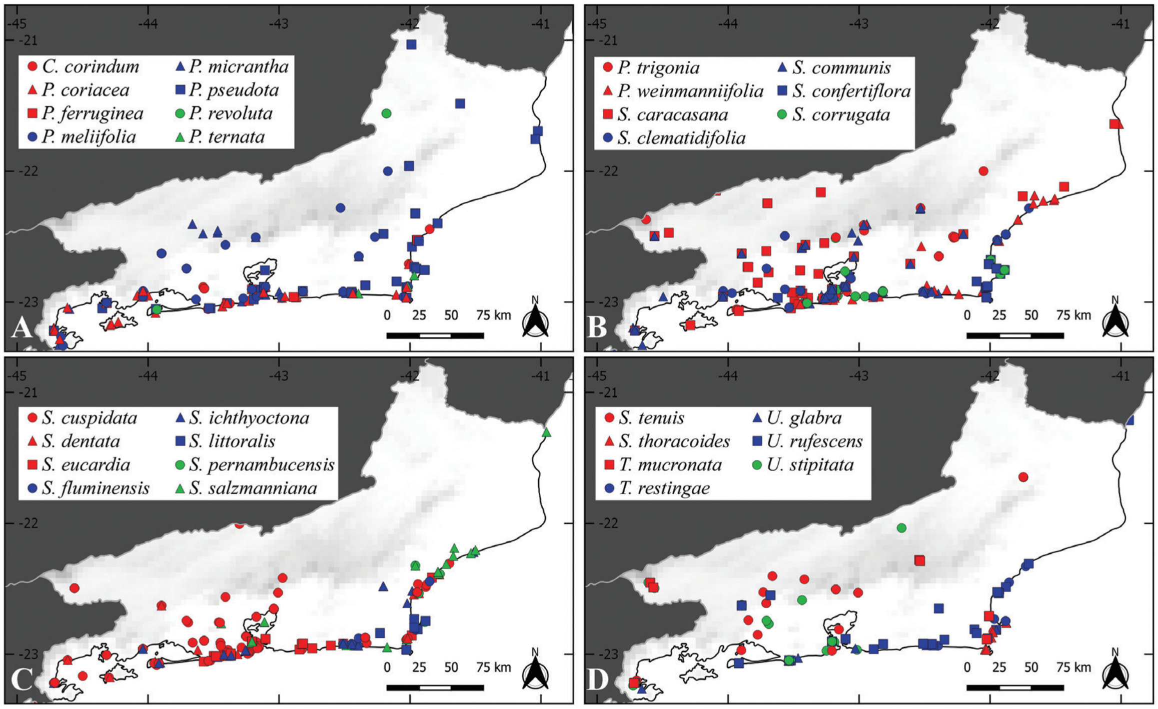

Figure 2. Distribution maps of climbing species of Sapindaceae in Rio de Janeiro.

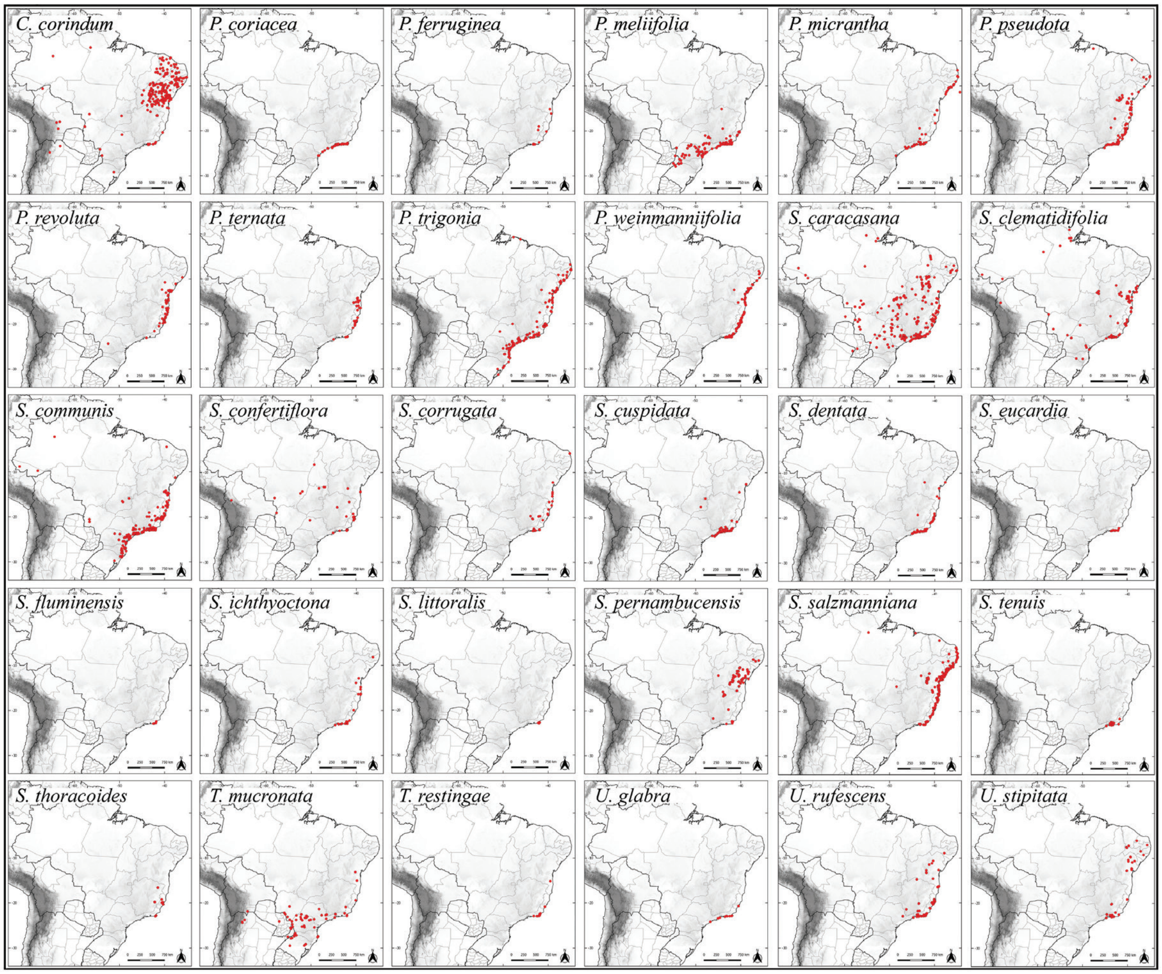

Figure 3. Maps of the complete distribution of climbing species of Sapindaceae studied here.

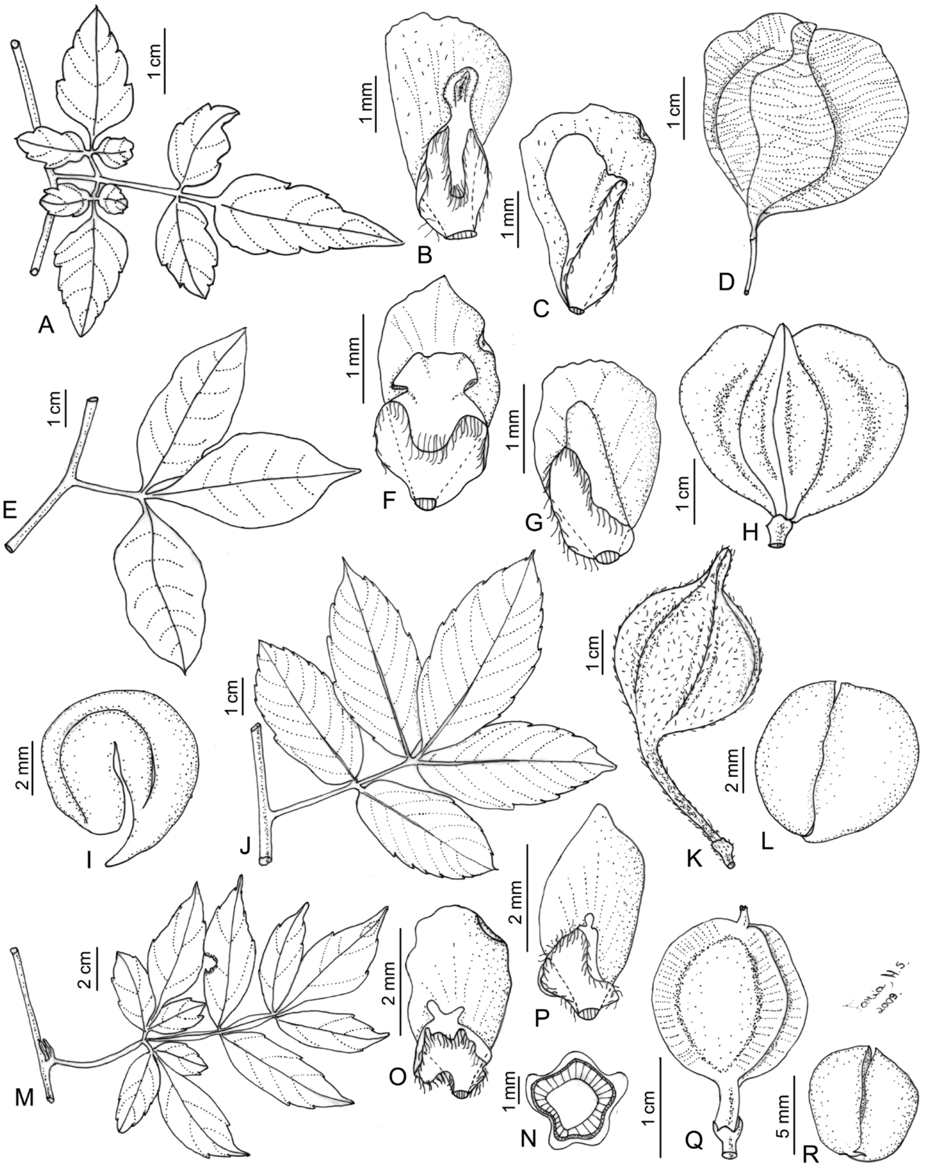

Figure 4. *Cardiospermum corindum* – A. biternate leaf; B. posterior petal; C. anterior petal; D. fruit. *Paullinia coriacea* – E. trifoliolate leave; F. posterior petal; G. anterior petal; H. fruit; I. embryo. *P. ferruginea* – J. 5-foliolate leaf; K. fruit; L. embryo. *P. meliifolia* – M. biternate leaf; N. cross section of the stem; O. posterior petal; P. anterior petal; Q. fruit; R. embryo. (A–D: M. S. Faria & L. Pederneiras 86; E: M. S. Faria et al. 72; F–G: D. Sucre et al. 6443; H–I: M. S. Faria & A. Pacheco Jr. 27; J–L: A.P. Duarte 110; M–N: D. Sucre 1913; O–P: D. Sucre 3964; Q–R: D. Sucre 3139. Illustrator M. S. Faria)

anterior absent; stamens 2–3 mm long, villose fillets, surrounding a pistilode, staminodes 2–2.2 mm long, surrounding a gynoecium; ovary ca. 2 mm long, ellipsoid, densely ferruginous-tomentose. Capsules 1.4–1.7 × 1.1–1.9 cm, unwinged, globose, crustose, densely ferruginous-tomentose, stipe 1.8–3 cm long, endocarp pubescent; seed solitary; arilloid bilobate; embryo with cotyledons more-or-less straight (Figures 4J–L).

Paullinia ferruginea is endemic to Brazil, occurring in the states of Bahia, Espírito Santo, Minas Gerais and Rio de Janeiro in restinga (ridge forest) or in dense ombrophilous forests (Figures 2A, 3). Flowering occurs in October and fruiting in April and July. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: densely ferruginous-tomentose indumentum in the whole plant, long-petiolate; capsules unwinged, globose, 6-costate, crustose; seed solitary.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Rio de Janeiro, Restinga da Gávea, 7.X.1867, fr., *A. Glaziou 1323* (R); Mun. Maricá, Área de Proteção Ambiental (APA) de Maricá, em frente à INFRAERO, borda da floresta de restinga, 26.V.2010, fl. fr., *G.V. Somner et al. 1521* (RBR); Entre Paineira e Corcovado, 19.V.1959, fr., *A.P. Duarte 478 & E. Pereira* (US); Mun. Botafogo, Mundo Novo, IV.1920, fl., fr., *J.G. Kuhlmann s/n* (RB 15.631).

Paullinia meliifolia A. Juss., Ann. Mus. Natl. Hist. Nat. 4: 347. 1804

Woody climbers; stem grayish-brown or greenish-brown, 5–6-furrowed when young, sub-cylindrical when mature, hirsute, glabrescent to glabrous, with a single vascular cylinder in cross section; stipules 0.8–1.8 cm long, leafy, falcate, cuneiform; petiole unwinged, canaliculate; rachis winged. Leaves biternate or pinnately 11–13-foliolate, basal leaflets trifoliolate; leaflets 2.1–11 × 1–4.9 cm, lanceolate, sub-chartaceous, apex acuminate to cuspidate, margin serrate-dentate, subrevolute, adaxial surface puberulous on the midvein and abaxial surface pubescent, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 1.5–12 cm long, puberulous; bracts triangular. Flowers zygomorphic, 6–7.5 mm; sepals 5; petal 4, crest of posterior petal appendage emarginate; lobes nectariferous 4, posterior ovoid, anterior orbicular, reduced; stamens 2–2.5 mm long, puberulous fillets, surrounding a pistilode, staminodes 1–2 mm long, surrounding a gynoecium, ovary ca. 1.5 mm long, trigonous-ovoid, puberulous at the angles. Capsules 1.5–1.9 × 1.2–1.7 cm, winged, obovoid, subcoriaceous, glabrous, stipe 1–4.5 mm long, endocarp lanose; seed solitary, ovoid or ellipsoid; arilloid bilobate; embryo with cotyledons more-or-less straight (Figures 4M–R).

Paullinia meliifolia occurs in northeastern Argentina, the eastern region of Paraguay and in the Brazilian states of Espírito Santo, Mato Grosso do Sul, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina and São Paulo (Figures 2A, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In restinga, it occurs in beach thicket and ridge forest formations. Flowering occurs from October to December and in February, and fruiting from September to July. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: young stem 5–6-costate or 5–6-furrowed, mature stem sub-cylindrical, stipules leafy, falcate cuneiform; leaves biternate or 11–13-foliolulate; capsules 3-winged, seed solitary.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Arraial do Cabo, Reserva Ecológica Estadual de Massambaba, próximo a lagoa salgada, 26.X.1993, fr., *G.V. Somner s.n* (RB 313040); Mun. Cabo Frio, Restinga de Cabo Frio, 26.X.1968, fl., *D. Sucre 3964* (RB); idem, 7. VI. 1968, fr., *D. Sucre, 3138* (RB); Mun. Mangaratiba, 16.II.2001, fr., *L.F.T. Menezes & M.C. Souza 792* (RBR); Mun. Niterói, Itaipuaçu, 15.X.1991, fr., *V.F. Ferreira 3943* (GUA); Mun. Rio das Ostras, Restinga da Praia Virgem, 14.XII.1999, fl. e fr., *H.N. Braga, 722* (RB); Mun. Rio de Janeiro, Restinga da Tijuca, 4.IV.1943, fr., *O.X.B. Machado s.n* (RB 75365); Mun. Saquarema, Reserva Ecológica Estadual de Jacarepiá, 12.II.1992 fl., *D. Araujo & C. Farney 9583* (GUA).

Paullinia micrantha Cambess., A. St.-Hil., A. Juss. & Cambess., Fl. Bras. Merid. 1: 373. 1828

Woody climbers; stem yellowish brown, cylindrical, 5–6-striate, puberulous, with a single vascular cylinder in cross section. Leaves pinnate, 11–13 foliolate or biternate, with basal leaflets trifoliate; stipules 0.5–1 mm long, triangular; petiole unwinged, canaliculate; rachis bi-canaliculate to winged; leaflets 1–10 × 0.5–3 cm, sub-coriaceous, sub-rhomboidal, elliptic or ovate, apex acute, rarely acuminate, margin serrate-dentate, adaxial surface puberulous only on midvein, abaxial surface puberulous, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 3.5–10.5 cm long, indument yellow-pilose; bracts 1–1.5 mm long, triangular. Flowers zygomorphic, 3–3.5 mm; sepals 4; petals 4, crest of posterior petal appendage erose or emarginate; nectariferous lobes 4, posterior ovoid, anterior ovoid, reduced; stamens 1–2.5 mm long, tomentose fillets, surrounding a pistilode, staminodes 1.5–2.3 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ellipsoid, with glandular trichomes, and pubescent on the angles. Capsules 1.2–1.7 × 0.9–1 cm, obovate, winged, subcoriaceous, glabrous, stipe 1–5 mm long, endocarp tomentose on the valve margins; seeds 3 (1–2), trigonous-obovoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 5A–D).

Paullinia micrantha is endemic to Brazil, occurring in the states of Alagoas, Bahia, Espírito Santo, Minas Gerais, Paraíba, Paraná, Pernambuco, Rio de Janeiro, São Paulo and Sergipe (Figures 2A, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In restinga, it occurs in ridge forests. Fruiting occurs in September. The taxon has been evaluated based on the IUCN (2019) criteria as least concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: stem yellowish brown, cylindric, 5–6-striate, puberulous and capsules 3-winged.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Paraty, Tarituba, beira do mar, à direita do bar, 29/III/2005, st., *J.D. Urdampilheta & S. Obando 299* (UEC); Mun. Rio das Ostras, praia das Areias Negras, encosta do primeiro costão rochoso, na borda da estrada de barro, 24.IX.2008, fr., *M.S. Faria 133* (RB); Vassouras, 2-III-1940, fl., *H. Monteiro Filho 192* (RBR).

Paullinia pseudota Radlk., Vidensk. Meddel. Naturhist. Foren. Kjøbenhavn 1890: 242 (1891)

Woody climbers; stem dark brown, grayish-brown or reddish-brown, cylindrical, striate, with a single vascular cylinder in cross section; stipules 1–1.5 mm long, deltoid; petiole unwinged, canaliculate; rachis unwinged or bi-canaliculate. Leaves 5-foliolate, generally with 1 or 2 pairs of reduced extra basal leaflets (0.2–1 cm long); leaflets 3–9.3 × 0.9–3.4 cm, elliptic to lanceolate, sub-coriaceous, apex acute to acuminate, margin entire, revolute, both surface glabrous, with domatia, venation brochidodromous. Thyrse axillary and terminal, racemiform, 1.5–6.5 cm long, tomentose; bracts triangular. Flowers zygomorphic, 2.5–5 mm long; sepals 4, petals 4, crest of posterior petal appendage erose or emarginate; nectariferous lobes 4, posterior ovoid, anterior orbicular, reduced; stamens 1.5–2 mm long, puberulous fillets, surrounding a pistilode, staminodes 1.5–2 mm long, surrounding a gynoecium, ovary ca. 1 mm long, trigonous-ellipsoid, puberulous on the angles. Capsules 1.5–1.7 × 1.5–1.6 cm, obovate, winged, subcoriaceous, with inflected margins, glabrous, stipe 2–5 mm long, endocarp tomentose on the valve margins; seeds 3 (1–2), trigonous-ovoid; arilloid bilobate; embryo with curved and inner cotyledon biplicate (Figures 5E–I).

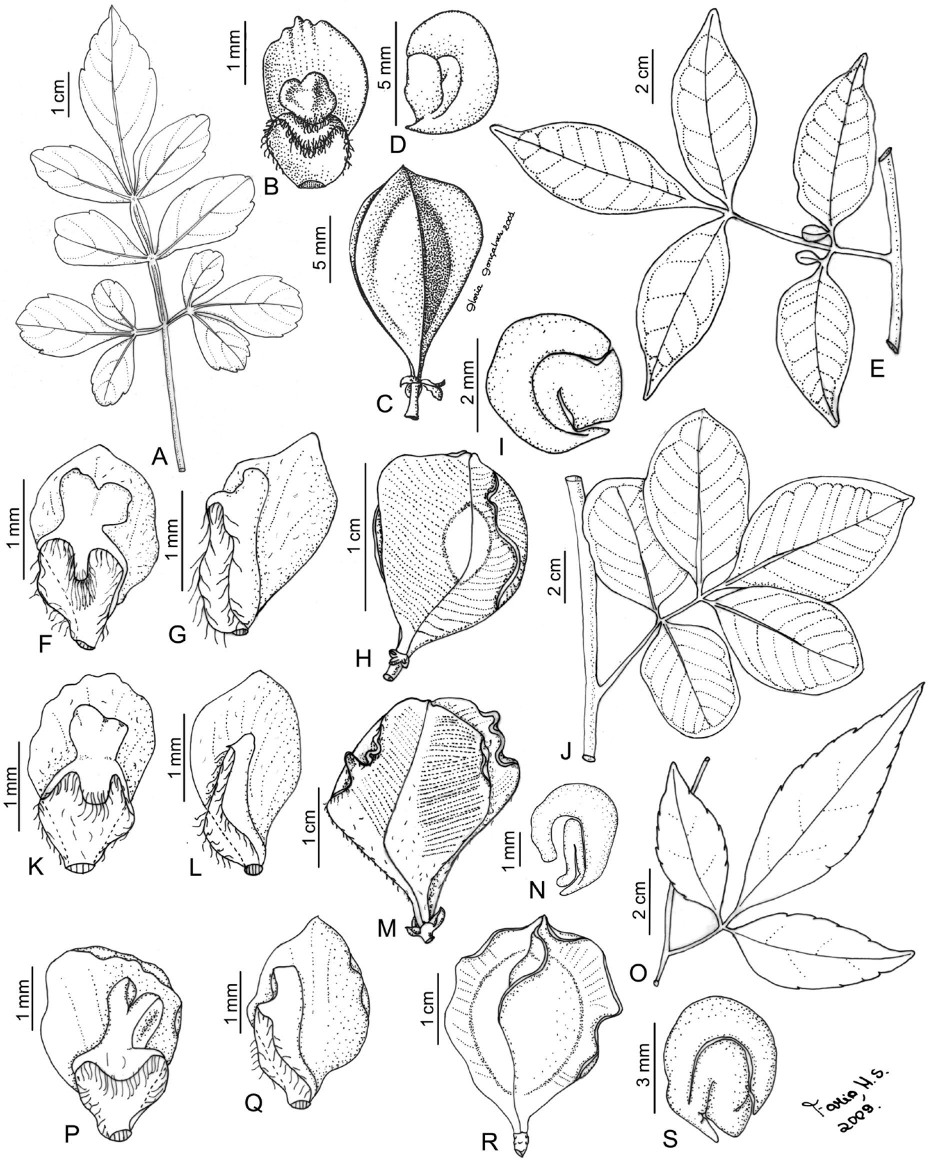

Figure 5. *Paullinia micranta* – A. biternate leaf; B. posterior petal; C. fruit; D: embryo. *P. pseudota* – E. 5-foliolate leaves; F. posterior petal; G. anterior petal; H. fruit; I. embryo. *P. revoluta* – J. 5-foliolate leaf; K. posterior petal; L. anterior petal; M. fruit; N. embryo. *P. ternata* – O. trifoliolate leave; P. posterior petal; Q. anterior petal; R. fruit; S. embryo (A–B: G.V. Somner 950, C–D: G.V. Somner 956; E: M.S. Faria et al. 88; F–G: C. Farney 2231; H–I: H. G. Dantas, 474; J–L: H.C. Lima et al. 2960; M–N: L. F. T. Menezes & Souza 188; O–Q: P.I.S. Braga 2221; R–S: C. Farney 2431. Illustrators A, E–S: M. S. Faria and B–D: G. Gonçalves).

Paullinia pseudota is endemic to Brazil, occurring in the states of Alagoas, Bahia, Ceará, Espírito Santo, Minas Gerais, Pará, Paraíba, Pernambuco, Rio de Janeiro, São Paulo and Sergipe (Figures 2A, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and savanna formations. In restinga, it occurs in dune thickets, beach thickets and ridge forests. Flowering from December to April and fruiting from December to June. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: stem cylindrical, striate, glabrous; leaves 5-foliolate, usually with one or two extra pairs of basal reduced leaflets, margin entire, venation brochidodromous, capsules winged, with margin inflected; seeds 3 (1–2).

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Angra dos Reis, Ilha Jipóia, Praia de Jurubaiba, 7.I.1990, bt., *A.M.S. da F.Vaz 701* (RB); Mun. Armação de Búzios, Praia da Gorda, 9.VI.2008, fr., *M.S. Faria et al. 88* (RB,RBR); idem, 15.II.2000, fl., *D. Fernandes & A. Oliveira 424* (RB); Mun. Arraial do Cabo, Reserva Ecológica Estadual de Massambaba, próximo à Lagoa Salgada, 21.II.1989, fl. e fr., *D. Araújo & N. Crud 8706* (GUA); Mun. Barra de São João, 20.III.1979, fl., *G. Martinelli et al. 5657* (RB); Mun. Cabo Frio, Vila do Sol, 1.IV.2008, fr., *M.S. Faria & L. Pederneiras 63* (RB); Mun. Casimiro de Abreu, Praia Brava, 28.V.1986, fr., *D. Araujo & N. Crud, 7500* (GUA); Mun. Macaé, entre Carapebus e Cabiunas, 13.III.2004, fr., E.J. Lucas 271 (RB); Mun. Rio das Ostras, Balneário das Garças, 18.IV.1999, fl., *H. do N. Braga 202* (RB); Mun. Rio de Janeiro, Restinga da Praia de Grumari, 21.V.2000, fr., *A. Oliveira & D. Fernandes 131* (RB); Mun. Mangaratiba, Restinga da Marambaia, 14.V.2002, fr., *G.V. Somner et al. 1016* (RBR); Mun. São João da Barra, Grussaí, 16.V.1989, fr., *D. Araujo 8833* (GUA); Mun. Saquarema, Reserva Ecológica de Jacarepiá, 6.VI.2007, fr., *M.S. Faria 14* (RB).

Paullinia revoluta Radlk. Monogr. *Paullinia*: 251. 1895

Woody climbers or erect shrubs; stem brown, subcylindrical, 5-costate, pubescent when young, glabrescent when mature, with a single vascular cylinder in cross section; stipules 1.5–2 mm long, deltoid; petiole unwinged, canaliculate; rachis unwinged, canaliculate or marginate. Leaves 5-foliolate or biternate; leaflets 2.6–9.1 × 1.5–5.8 cm, ovate, elliptic, subcoriaceous; apex acuminate, margin entire, revolute, both surfaces pubescent, or abaxial surface pubescent only on midveins, with domatia, venation brochidodromous. Thyrse axillary and terminal, racemiform, 1.5–8.1 cm long, pubescent; bracts triangular. Flowers zygomorphic, 6–7 mm long; sepals 4; petals 4, crest of posterior petal appendage erose; nectariferous lobes 4, posterior ovoid, anterior orbicular, reduced; stamens 5–3 mm long, puberulous fillets, surrounding a pistilode, staminodes 1.5–2.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ovoid, puberulous on the angles. Capsules 1.7–3.2 × 0.7–2.5 cm, obtriangular, winged, subcoriaceous, sericeous, stipe 1–3 mm long, endocarp tomentose on the valve margins; seeds 3 (1–2), trigonous-ovoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 5J–N).

Paullinia revoluta is endemic to Brazil, occurring in the states of Alagoas, Bahia, Espírito Santo, Minas Gerais, Paraná, Rio de Janeiro and Sergipe (Figures 2A, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest, seasonal semideciduous forest and caatinga formations. In restinga, it occurs in ridge forests. Fruiting occurs in July. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: leaflet number varying but generally 5-foliolate, rarely biternate, leaflets with entire revolute margins, capsules large 3-winged (1.7–3.2 × 0.7–2.5 cm), endocarp tomentose on valve margins; seeds 3 (1–2).

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Mangaratiba, restinga da praia da Marambaia, 13.VII.1998, fr. *L.F.T. Menezes & Souza 1*88 (RBR).

Paullinia ternata Radlk. Monogr. *Paullinia*: 317. 1895

Woody climbers; stem grayish, cylindrical, striate, glabrous, with a single vascular cylinder in cross section; stipules 4–4.5 cm long, linear-subulate; petiole unwinged, canaliculate. Leaves trifoliolate, deciduous in the flowering period; leaflets 3.5–9.2 × 1.3–2.9 cm, lanceolate to elliptic, sub-chartaceous, apex cuspidate, margin serrate-crenate, both surfaces glabrous, with domatia, venation mixed craspedodromous. Thyrse cauliflorous, fasciculate, 3.5–9.5 cm long, pubescent; bracts triangular. Flowers zygomorphic, ca. 5.5 mm long; sepals 5; petals 4, crest of posterior petal appendage emarginate; nectariferous lobes 4, posterior ovoid, anterior oblong, reduced; stamens 1.5–2 mm long, puberulous fillets, surrounding a pistilode, staminodes 1.5–2 mm long, surrounding a gynoecium; ovary ca. 1 mm long, trigonous-ellipsoid, pubescent. Capsules 2.6–3.1 × 1.7–2.5 cm, winged, obovate or suborbicular, subcoriaceous, pubescent, stipe ca. 2 mm long, endocarp tomentose on valves margins; seeds 3 (1–2), ellipsoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 5O–S).

Paullinia ternata is endemic to Brazil, occurring in Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo. It is found in the following plant formations: restinga (ridge forest), or in dense ombrophilous forests (Figures 2A, 3). Fruiting occurs from June to August. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: leaves trifoliolate, sub-chartaceous, margin slightly serrate-crenate, thyrses cauliflorous, fasciculate; endocarp tomentose on the valve margins; seeds 3 (1–2).

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, Estrada Cabo Frio-Búzios, 5.VI.1998, fr., *J.M.A. Braga 4860* (RB); Mun. Saquarema, R.E.E. Jacarepiá, Restinga de Ipitangas, 25.VI.1990, fr., *D. Araujo &. C. Farney 2431* (GUA, RB).

Paullinia trigonia Vell. Fl. Flum. 159, tab. 30. 1825; Icon. 30. 1829

Woody climbers or suberect shrubs; stem brown or reddish-brown, cylindrical, striate, pubescent, with a single vascular cylinder in cross section; stipules deltoid; petiole unwinged, canaliculate; rachis winged. Leaves generally biternate or rarely 11–13-foliolate, basal leaflet trifoliolate; leaflets 3.6–8.8 × 1.2–3.9 cm, sub-rhomboidal, elliptic, ovate, chartaceous, apex obtuse to acute, entire to serrate-dentate, margin revolute, both surfaces pubescent on veins, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 2–10.8 cm long, pubescent; bracts triangular. Flowers zygomorphic, 5–6.5 mm long; sepals 4; petals 4, crest of posterior petal appendage emarginate; nectariferous lobes 4, posterior oblong, anterior orbicular, reduced; stamens 1–2 mm long, pubescent fillets, surrounding a pistilode, staminodes 1–2 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ovoid, puberulous on the angles, and with glandular trichomes. Capsules 1.2–2.5 × 0.5–1 cm, elliptic or obovate, keeled or winged, subcoriaceous, glabrous, stipe 0.5–3 mm long, endocarp tomentose on valve margins; seeds 3 (1–2), trigonous-ovoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 6A–E).

Paullinia trigonia is endemic to Brazil, occurring in the states of Alagoas, Bahia, Espírito Santo, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, São Paulo and Sergipe (Figures 2B, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In the restinga, it occurs in seasonally flooded swamps and ridge forests. Flowering occurs in March and fruiting from February to June. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: stem reddish-brown, leaves generally biternate or rarely pinnately 11–13-foliolate; capsules keeled or winged; seeds 3 (1–2).

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Mangaratiba, Restinga da Marambaia, 11.VI.2004, fr., *L.F.T. Menezes et al. 1155* (RBR); idem, 26.VI.2004, fr., *Carvalho 1* (RBR); Mun. Niterói, Saco de São Francisco, 27.III.1938, fl., *M. Barreto 13004* (HB, R, RB); Mun. Rio de

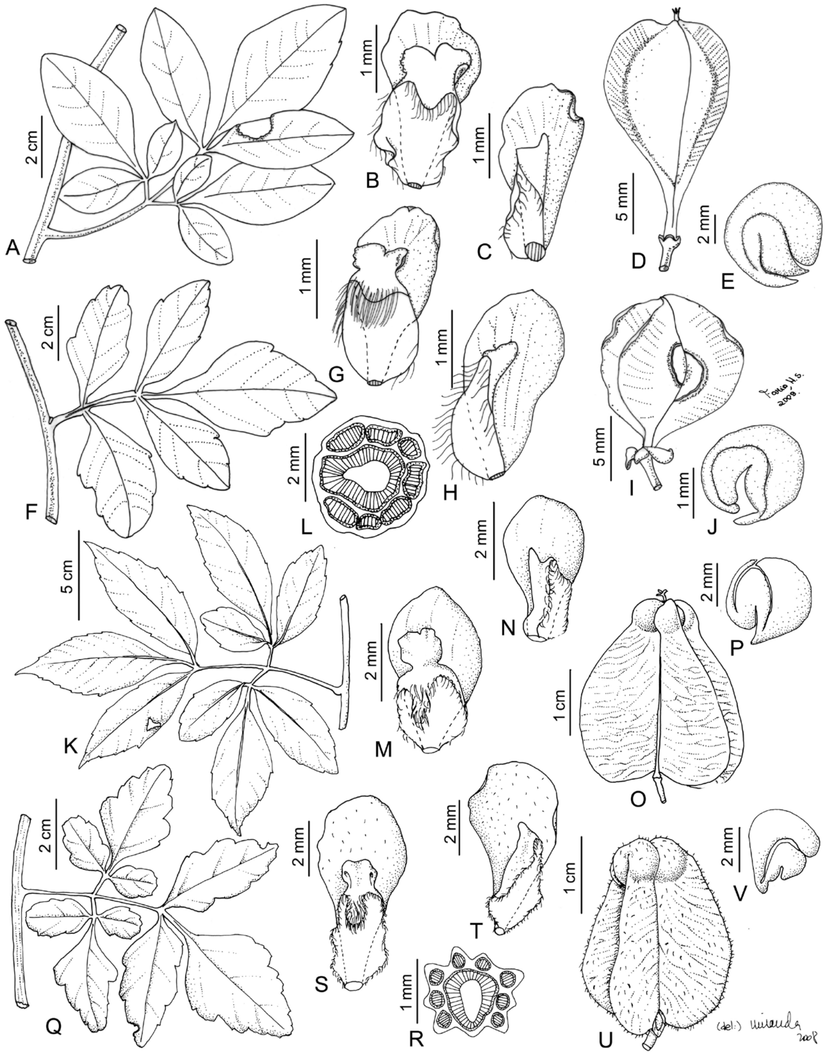

Figure 6. *Paullinia trigonia* – A. biternate leaf; B. posterior petal; C. anterior petal; D. fruit and E. embryo. *P. weinmanniifolia* – F. 5-foliolate leaf; G. posterior petal; H. anterior petal; I. fruit and J. embryo. *Serjania caracasana* – K. biternate leaf; L. cross-section of the stem; M. posterior petal; N. anterior petal; O. fruit; P. embryo. *S. clematidifolia* – Q. biternate leaf; R. cross-section of the stem; S. posterior petal; T. anterior petal; U. fruit and V. embryo. (A–C: C. Luchiari et al. 314; D–E: G. Martinelli et al. 11761; F–H: M.S. Faria & L. Pederneiras 65; I–J: M.G. Bovini & L. C. Giordano 775; K–N: M.S. Faria, 91; O–P: Mautone et al. 179; Q–T: A. Souza et al. 3384; U–V: D. Medeiros, 13. Illustrators A–J: M. S. Faria and K–V: C. Miranda).

Janeiro, Lagoa Marapendi, 10.IV.1972, fr., *J. Almeida 1442* (RB), Mun. Mangaratiba, Ilha da Marambaia, Praia da Gaeta, na floresta de cordão arenoso, 29.VII.2006, fr., *G.V. Somner et al. 1150* (RBR).

Paullinia weinmanniifolia Mart. Flora 20(2): Beibl. 91. 1837

Woody climbers, suberect or erect arching shrubs; stem brown, grayish-brown or grayish, cylindrical, striate, pubescent when young, glabrescent when mature, with a single vascular cylinder in cross section; stipules ca. 1 mm long, deltoid; petiole unwinged, canaliculate; rachis winged. Leaves frequently 5-foliolate or biternate, rarely trifoliolate; leaflets 2.5–7.5 × 1.2–3.4 cm, subrhomboidal, ovate or elliptic, subcoriaceous, apex obtuse to acute, margin repand-crenate, both surface with rare trichomes on midveins, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 1.3–7 cm long, pubescent; bracts triangular. Flowers zygomorphic, 4–5 mm; sepals 4; petals 4, crest of posterior petal appendage erose, emarginate or bifid; nectariferous lobes 4, posterior ovoid, anterior ovoid, reduced; stamens 1.5–2.5 mm long, puberulous fillets, surrounding a pistilode, staminodes 1–1.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ovoid, puberulous on the angles. Capsules 1.2–1.5 × 0.8–1.2 cm, winged, suborbicular, sub-coriaceous, glabrous, stipe 1–1.5 mm long, extra triangular appendage on the pericarp, endocarp tomentose on the valve margins; seeds 3 (1–2), trigonous-ellipsoid; arilloid bilobate; embryo with outer cotyledon curved and inner biplicate (Figures 1C, 6F–J).

Paullinia weinmanniifolia is endemic to Brazil, occurring in the states of Alagoas, Bahia, Espírito Santo, Maranhão, Pernambuco, Rio de Janeiro and Sergipe (Figures 2B, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In restinga, it occurs in ridge palmoid, non-flooded scrub, flooded scrub and dune thicket formations. Flowering occurs from March to June and November to December and fruiting from November to September. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Paullinia* by the following characters: leaves frequently 5-foliolate or biternate, rarely trifoliolate; capsules with extra triangular appendage on the pericarp; seeds 3 (1–2). In this species variation was observed in the number of leaflets in the same specimen. First, the terminal leaflet of the trifoliolate leaves divides and the leaf becomes 5-foliolate; then each basal leaflet divides and the leaf becomes biternate.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Araruama, Lagoa de Araruama, próximo a Enseada da Figueira, 5.V.1982, fl., *D. Araujo & R.F. de Oliveira 5052* (GUA); Mun. Arraial do Cabo, Praia do Foguete, 24.VIII.1987, fr., *D. Araujo & R.F. de Oliveira 7978* (GUA); Mun. São João da Barra, III.1939, fr., *A. Sampaio 8067* (R); Mun. Barra de São João, 20.III.1979, fl., *G. Martinelli 5656* (RB); Mun. Cabo Frio, Vila do Sol, 1.IV.2008, fl., *M.S. Faria & L. Pederneiras 64* (RB, RBR); Mun. Carapebus, PARNA Jurubatiba, 10.VI.2008, fr. *M.S. Faria et al. 93* (RB); Mun. Macaé, PARNA Jurubatiba, 12.VI.2007, fr., *M.S. Faria et al. 16* (RB, RBR); Mun. Maricá, Lagoa do Padre, 8.IX.1975, fr., *H.P. Bautista 165* (RB). Niterói, Ponta de Itaipu, 6.IX.1978, fr., *G. Martinelli 4903* (RB); Mun. Quissamã, PARNA Jurubatiba, 24.IX.2008, fr., *M.S. Faria et al. 129* (RB); Mun. Rio das Ostras, Restinga da Praia Virgem, 10.VI.2000, fr., *H. do N. Braga 1113* (RB); Mun. Rio de Janeiro, Restinga de Jacarepaguá, 7.V.1958, fl., *E. Pereira et al. 3708* (HB); Mun. São João da Barra, Atafona, 22.VII.1975, fr., *A.L. Peixoto 561* (RB); Mun. Saquarema, 5 km ao oeste do centro da cidade Sambaqui da Beirada, 7.VIII.1987, fr., *D. Araujo & A. Araujo 7925* (GUA).

Serjania caracasana (Jacq.) Willd., Sp. Pl. 2 (1): 465. 1799

Woody climbers; stem brown, sub-cylindrical, 7–10-costate with inconspicuous ribs, glabrous, in cross section composed of one large central vascular cylinder and eight smaller peripheral cylinders; stipules 1–1.5 mm long, triangular; petiole unwinged, canaliculate; rachis unwinged, bicanaliculate. Leaves biternate; leaflets 1.8–13.5 × 1–5 cm, lanceolate, ovate, chartaceous, apex acute to acuminate, margin serrate-dentate, adaxial surface with trichomes on midveins, abaxial surface glabrous, with domatia, venation semicraspedodromous. Thyrse axillary and terminal, racemiform, 2–12.5 cm long, puberulous; bracts triangular. Flowers zygomorphic, 7–9 mm long; sepals 5; petal 4, crest of posterior petal appendage erose; nectariferous lobes 4, posterior ovoid, anterior sub-elliptic reduced; stamens 2.5–4.5 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–2.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ovoid, puberulous. Schizocarps 2.5–2.9 × 2.4–2.9 cm, ovate-cordate, chartaceous, glabrous, seminiferous portion of inflated mericarp without dorsal crest, endocarp glabrous; seeds 1–3, subglobose, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 6K–P).

Serjania caracasana occurs in Argentina, Brazil, Bolivia, Colombia, Costa Rica, Cuba, Guatemala, Mexico, Paraguay, Peru and Venezuela. In Brazil, there are records for the following states: Amapá, Amazonas, Bahia, Ceará, Espírito Santo, Goiás, Mato Grosso do Sul, Mato Grosso, Minas Gerais, Pará, Paraíba, Paraná, Pernambuco, Piauí, Rio de Janeiro, Rondônia, Roraima, São Paulo and Tocantins (Figures 2B, 3). It is found in the following plant formations: restinga, dense ombrophilous forests, seasonal deciduous forests, seasonal semi-deciduous forests and savannas. In restinga, it occurs in seasonally flooded swamps and ridge forests. Flowering occurs from June to July and fruiting from June to October. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem composed of one large central cylinder and eight smaller peripheral cylinders in cross section, leaflets lanceolate, with serrate-dentate margins, fruit schizocarp glabrous, with seminiferous portion of mericarp inflated and without a dorsal crest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Angra dos Reis, Ilha Grande, Reserva Biológica Estadual da Praia do Sul, 13.VI.1984, fl., *D.S. Pedrosa & H.Q.B. Fernandes 1110* (GUA); Mun. Cabo Frio, Condomínio Florestinha, 9.VI.2008, fl., *M.S. Faria et al. 91* (RB); Mun. Macaé, a 4 km de Quissamã, restinga arbustiva, 5.VI.1979, fr., *D. Araujo & N. Crud 3101* (GUA); Mun. Mangaratiba, Ilha da Marambaia, praia da Armação, 24.IX.1991, fr., *G.V. Somner et al. 673* (RBR); Mun. Quissamã, Mata da Fazendinha, 28.X.1994, fr., *D. Araujo* 10147 (GUA); Mun. Rio de Janeiro, Restinga de Grumari, 29.VI.1972, fl., *J.A. Jesus 1680* (RB); idem, 4.VII.1973, fl., *J.A. Jesus 2406* (RB); idem, 1.VIII.1977, fr., *L. Moutane et al. 179* (RB); idem, 30.VI.1987, fl., *A. F. Vaz 455* (RB).

Serjania clematidifolia Cambess., in A. St.-Hil., A. Juss. & Cambess., Fl. Bras. Mer. 1: 361. 1828

Woody climbers; stem brown or dark brown, 9–10 costate, with conspicuous ribs, pubescent-tomentose, in cross section composed of one large central vascular cylinder and 8–9 smaller peripheral cylinders; stipules 0.5–1 mm long, ovate, petiole unwinged, canaliculate; rachis unwinged, bicanaliculate or marginate. Leaves biternate; leaflets 2.2–7.6 × 1.5–4 cm, rhomboidal to ovate, and elliptic, subchartaceous, apex acute, margin serrate-crenate, adaxial surface pubescent on midvein, abaxial surface pubescent, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 5.5–9.5 cm long, tomentose; bracts lanceolate. Flowers zygomorphic, 8–8.5 mm long; sepals 5; petals 4, crest of posterior petal appendage erose; nectariferous lobes 4, posterior orbicular, anterior orbicular, reduced; stamens 3.5–4.5 mm long, tomentose fillets, surrounding a pistilode, staminodes 1–1.5 mm long, surrounding a gynoecium; ovary ca. 3 mm long, trigonous-obovoid, tomentose. Schizocarps 2.5–2.7 × 2–2.2 cm, ovate-cordate, chartaceous, densely pubescent, seminiferous portion of mericarp globose, laterally concave, without dorsal crest, endocarp lanose; seeds 1–3, subglobose, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 6Q–V).

Serjania clematidifolia occurs in Bolivia and in Brazil in the following states: Amapá, Amazonas, Bahia, Espírito Santo, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraná, Rio de Janeiro, Rio Grande do Norte, Santa Catarina, São Paulo and Tocantins (Figures 2B, 3). It is found in the following plant formations: restinga, dense ombrophilous forests, seasonal deciduous forests, savannas and the Amazon dryland forest. In restinga, it occurs in ridge forests. Flowering occurs in October and December and fruiting from March to April and from July to November. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Serjania* by the following characteristics: 9–10 costate stem, with conspicuous ribs; leaflets with serrate-crenate margins; fruits with seminiferous portion of the mericarp globose, laterally concave and without a dorsal crest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Macaé, restinga próximo a lagoa de Cabiúnas, fl., 14.XII.1990, *A. Souza et al. 3384* (R); Mun. Mangaratiba, Restinga da Marambaia, Praia Grande, 23.VII.1991, fr., *G.V. Somner et al. 647* (RBR); Mun. Maricá, 25.VII.1988, fl. fr., *A. Souza et al. s.n.* (R); Mun. Niterói, São Gonçalo, Itaoca, Praia de São João, 31.VII.1994, fl., *D.C.P. Silva et al. 123* (GUA); Mun. Rio das Ostras, ARIE Itapebussus, 17.X.2007, fr., *M.S. Faria 36* (RB, RBR); Mun. Rio de Janeiro, Copacabana, s. d., fl. e fr., *C. Diogo s.n* (R); Mun. Saquarema, Reserva Ecológica Estadual de Jacarepiá, 27.IV.1996, fl., *A.Q. Lobão et al.139* (RB); idem, 26.VIII.1991, fl., *G.V. Somner & M.F. Freitas 653* (RB); Mun. Reserva Ecológica Estadual de Jacarepiá, 31.VII.1996, fl.,fr., *G.V. Somner et al. 800* (RBR); Mun. Sumaré, 17.VII.1968, fr., *D. Medeiros 13* (HB, RB).

Serjania communis Cambess., in A. St.-Hil., A. Juss. & Cambess., Fl. Bras. Mer. 1:362. 1828

Semi-woody climbers; stem greenish-brown, subcylindrical, obtusely triangular, with three major ribs, pubescent; in cross section composed of one central vascular cylinder and three smaller equidistant peripheral cylinders; stipules ca. 1 mm long, deltoid; petiole and rachis unwinged, bicanaliculate. Leaves biternate, leaflets 1.3–5.5 × 0.7–1.7 cm, ovate to lanceolate, sub-chartaceous, apex acute to acuminate; margin dentate-serrate, both surfaces pubescent, without domatia, venation semicraspedodromous. Thyrse axillary and terminal, racemiform, 2–15 cm long; bracts triangular. Flowers zygomorphic, 6.5–8.5 mm; sepals 4; petals 4, crest of posterior petal appendages erose or emarginate; nectariferous lobes 4, posterior ovoid to ellipsoid, anterior ellipsoid, reduced; stamens 3.5–4.5 mm long, pubescent fillets, surrounding a pistilode, staminodes 2.5–3 mm long, surrounding a gynoecium; ovary 1.5–2 mm long, trigonous-ovoid, pubescent. Schizocarps 2–2.6 × 2–2.1 cm, ovate-cordate, chartaceous, with pubescent wings; seminiferous portion of mericarp laterally flattened, pubescent, dorsal crest 2.5–3 mm wide, endocarp villose; seeds 1–3, elliptic-lenticular, lacking aril; embryo with sub-straight cotyledons (Figures 7A–F).

Serjania communis occurs in Colombia, Venezuela, Ecuador, Peru and Bolivia. In Brazil, it has been recorded in the states of Acre, Amazonas, Bahia, Ceará, Distrito Federal, Espírito Santo, Goiás, Mato Grosso do Sul, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, São Paulo and Sergipe (Figures 2B, 3). It is found in the following plant formations: restinga, dense ombrophilous forests, seasonal semi-deciduous forests, lowland forests and the savanna. In restinga, it occurs in ridge forests. Flowering occurs from April to August and fruiting from July to September. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: sub-cylindrical, obtusely triangular stem, with three major ribs, in cross section composed of one central cylinder and three smaller equidistant peripheral cylinders; fruits with seminiferous portion of mericarp laterally flattened, with a dorsal crest 2.5–3 mm wide; embryo with cotyledons sub-straight. The taxon's name refers to its wide distribution.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação dos Búzios, Restinga da Praia do Forno, 19.VIII.1998, fl., *D. Fernandes 34* (RB); Mun. Cabo Frio, Condomínio Florestinha, 9.VI.2008, fl., *M.S. Faria 92* (RB); Mun. Parati, APA Cairuçú, 14.VI.1994, fl., *M.G. Bovini & L.C. Giordano 495* (RB); Mun. Rio de Janeiro, Barra da Tijuca, 11.VII.1964, fr., *W. Hoehne 5738* (RB); Mun. Saquarema, Reserva Ecológica Estadual de Jacarepiá, Restinga de Ipitangas, 28.IX.1990, fr., *G.V. Somner 612 et al.* (RBR).

Serjania confertiflora Radlk., Consp. Sect. Sp. Serjan.: 4. 1874

Woody climbers; stem brown, 6-costate, with very prominent ribs, pubescent when young, glabrescent when mature, in cross section composed of one large central vascular cylinder and three smaller equidistant peripheral cylinders; stipules 0.5–1.5 mm long, triangular; petiole and rachis unwinged, canaliculate. Leaves biternate; leaflets 1.5–5.3 × 1.2–4.4 cm, ovate to lanceolate, chartaceous, apex acuminate, margin incised-dentate, with one pair of basal incisions, pubescent on the veins in both surfaces, with domatia, venation mixed craspedodromous. Thyrse axillary and terminal, racemiform, 1–3.5 cm long, pubescent; bracts triangular. Flowers zygomorphic, ca. 5.5 mm; sepals 5; petals 4, crest of posterior petal appendages erose or emarginate; nectariferous lobes 4, posterior ovoid, anterior ovoid, reduced; stamens 2–3 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–2.5 mm long, surrounding a gynoecium; ovary 1.5–2 mm long, trigonous-obovoid, puberulous. Schizocarps 1.8–2 × 1.9–2 cm, ovate-cordate, wings glabrous; seminiferous portion of mericarp inflated, glabrous; dorsal crest 1.5–4 mm wide, endocarp lanose; seeds 1–3, ellipsoid; without aril; embryo with outer cotyledon curved and inner biplicate (Figures 7G–L).

Serjania confertiflora occurs in Brazil, Bolivia, northern Paraguay and northwestern Argentina. In Brazil, it occurs in the states of Bahia, Espírito Santo, Goiás, Mato Grosso do Sul, Mato Grosso, Minas Gerais, Rio de Janeiro, São Paulo and Tocantins (Figures 2B, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and savanna formations. In restinga, it occurs in ridge forests. Flowering occurs in May and fruiting in June and August. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem 6-costate, with very prominent ribs, composed in cross section of one large central cylinder and three equidistant smaller peripheral cylinders; leaflets with dentate-incised margins, with a pair of basal incisions; thyrses with subverticillate cinccini, fruits with seminiferous portion of mericarp inflated, glabrous; dorsal crest 1.5–4 mm wide.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação dos Búzios, Praia de Tucuns, 28.V.2000, fl., *D. Fernandes & A. Oliveira 522* (RB); Mun. Cabo Frio, restinga entre a Praia de Focas e Praia de Fornos, 14.VIII.1986, fr., *P. Acevedo-Rodríguez 1451* (RB); Mun. Idem, Condomínio Florestinha, 11.VI.1998, fr., *L. Emygdio et al. 6235* (R).

Serjania corrugata Radlk., Consp. Sect. Sp. Serjan. 131. 1874

Woody climbers; stem brown and reddish-brown, 5-costate, puberulous, in cross section composed of one small central vascular cylinder and 5 radiate vascular cylinders, reddish glandular trichomes all over the plant; stipules ca. 0.5 mm long, ovate; petiole unwinged, canaliculate; rachis unwinged, bicanaliculate or marginate. Leaves biternate; leaflets 4.2–7.6 × 1–3.2 cm, lanceolate, sub-chartaceous, apex acuminate; margin entire, frequently with one tooth near base,

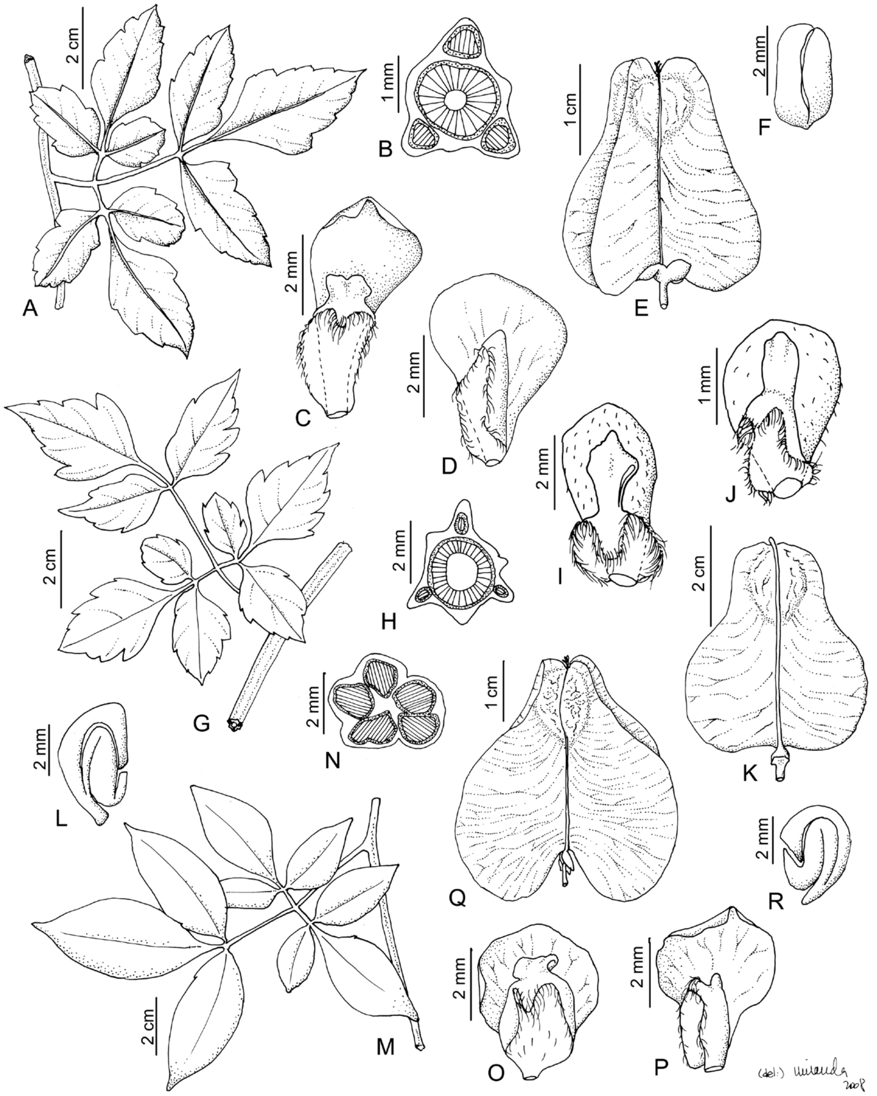

Figure 7. *Serjania communis* – A. biternate leaf; B. cross-section of the stem; C. posterior petal; D. anterior petal; E. fruit and F. embryo. *S. confertiflora* – G. biternate leaf; H. cross-section of the stem; I. posterior petal; J. anterior petal; K. fruit; L. embryo. *S. corrugata* – M. biternate leaf; N. cross-section of the stem; O. posterior petal; P. anterior petal; Q. fruit and R. embryo. (A–B: M.S. Faria, 92; C–D: M.G. Bovini & L.C. Giordano 495, E–F: W. Hoehne 5738; G–J: D. Fernandes & A. Oliveira 522; K–L: P. Acevedo-Rodríguez 1451; M–R: M–N: M.G. Bovini 506; O–P: A.P. Duarte 113; Q–R: M. S. Faria. Illustrator C. Miranda).

adaxial surface bright, puberulous on midvein and abaxial surface totally pubescent, with domatia, venation brochidodromous. Thyrse axillary and terminal, racemiform, 0.9–8.9 cm long, pubescent; bracts triangular. Flowers zygomorphic, 6–7 mm long; sepals 5; petals 4, crest of posterior petal appendages erose; nectariferous lobes 4, posterior ovate, anterior suborbicular, reduced; stamens 4–5 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–3 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-obovoid, pubescent. Schizocarps 3.3–3.7 × 2.6–3 cm, large ovate-cordate, chartaceous, frequently with reddish-puberulent wings when young; seminiferous portion of mericarp inflated, puberulent; dorsal crest ca. 4 mm wide; endocarp lanose; seeds 1–3, obovoid; without aril; embryo with outer cotyledon curved and inner biplicate (Figures 7M–R).

Serjania corrugata is endemic to Brazil, occurring in the states of Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro and Rio Grande do Norte (Figures 2B, 3). It is found in the following plant formations: restinga and dense ombrophilous forest formations. In restinga, it occurs in non-flooded scrubs. Flowering occurs from January to May and fruiting in January, April, and May and from July to September. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem in cross section with one small central vascular cylinder and 5 radiate vascular cylinders; leaves odoriferous when dry; leaflets shiny on adaxial surface, margin entire, frequently with one tooth near the base; reddish glandular trichomes all over the plant; fruits frequently reddish, large, with dorsal crest ca. 4 mm.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação dos Búzios, Praia Rasa, 15.I.1979, fl. e fr., *G. Martinelli 563* (RB); Mun. Cabo Frio, Praia das Dunas, 3.IV.2008, fr., *M.S. Faria & L. Pederneiras 79* (RB); Mun. Maricá, na estrada voltando para Maricá, 14.IV.1988, fl. e fr., *R. Marquette 127* (RB); Mun. Niterói, Restinga de Piratininga, 11.I.1891, fr., *Schwacke s.n.* (R); Mun. Rio de Janeiro, restinga de Jacarepaguá, Pedra de Itauna, lado oeste, 25.V.1973, fr., *D.S.D. Araújo 191* (RB).

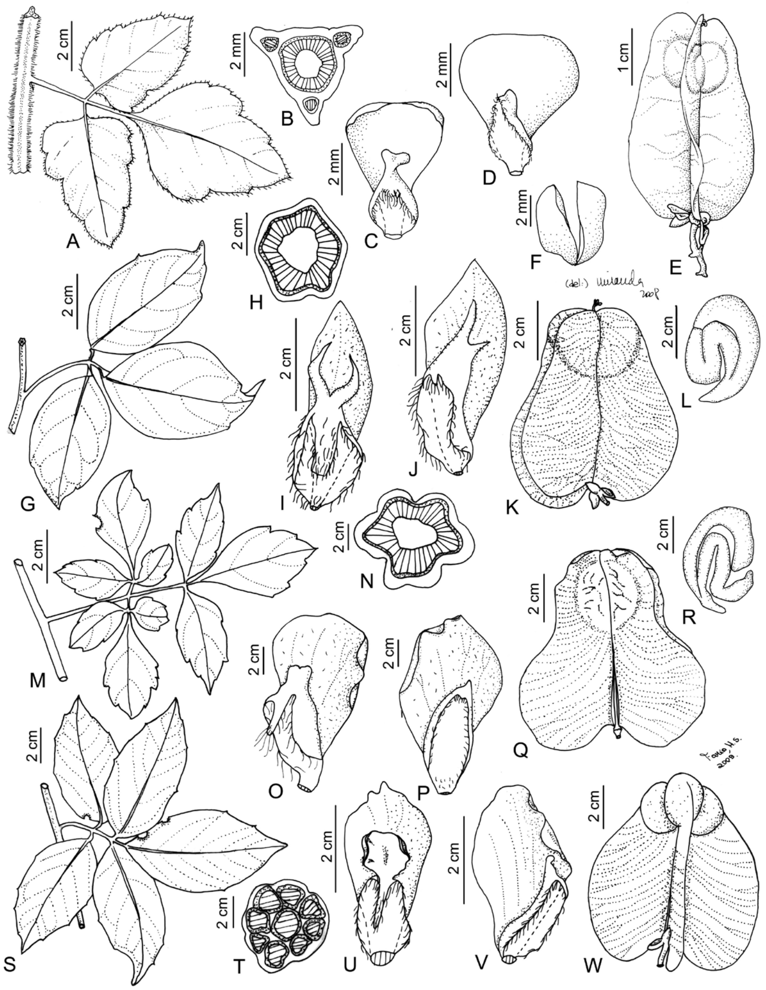

Figure 8. *Serjania cuspidata* – A. trifoliolate leave; B. cross-section of the stem; C. posterior petal; D. anterior petal; E. fruit and F. embryo. *S. dentata* – G. trifoliolate leave; H. cross-section of the stem; I. posterior petal; J. anterior petal; K. fruit; L. embryo. *S. eucardia* – M. biternate leaf; N. cross-section of the stem; O. posterior petal; P. anterior petal; Q. fruit; R. embryo. *S. fluminensis* – S. 5-foliolate leaf; T. cross-section of the stem; U. posterior petal; V. anterior petal and W. fruit. (A–E: M.S. Faria et al. 29; F–I: J. Fontella 2892; J–K: M.F. Freitas 35; L–M: O. Hoehne 5983; N–O: W. Hoehne 5961; P–Q: J. Almeida 1461; R–S, W: M.S. Faria et al. 84; T–V: G.V. Somner 756. Illustrators A–F: C. Miranda and G–W: M. S. Faria).

Serjania cuspidata Cambess. in St. Hil., Juss. & Cambess. Fl. Bras. Mer. 1:356. 1824

Semi-woody climbers; stem reddish brown, triangular (with prominent ferruginous-hirsute angles), hollow, in cross section composed of a large central vascular cylinder and three smaller equidistant, peripheral cylinders; stipules 4–4.5 mm long, linear; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 2.7–6 × 2.2–6 cm, ovate-subrhomboidal or ovate, sub-chartaceous, apex acuminate or cuspidate, margin serrate-dentate, both surfaces densely pubescent, venation mixed craspedodromous. Thyrse axillary, racemiform, 4–17 cm long, pubescent; bracts linear. Flowers zygomorphic, 0.9–1.2 mm long; sepals 4; petals 4, crest of posterior petal appendages erose or emarginate; nectariferous lobes 4, posterior ovate, anterior reduced; stamens 3–5 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–3.5 mm long, surrounding a gynoecium; ovary 1.5–2 mm long, trigonous-obovoid, pubescent. Schizocarps 2–3.7 × 1.5–2.6 cm, ovate-cordate, chartaceous, pubescent; seminiferous portion of mericarp laterally flattened, endocarp glabrous; dorsal crest 1–2 mm wide; seeds 1–3, lenticular; without aril; embryo with sub-straight cotyledons (Figures 8A–F).

Serjania cuspidata is endemic to Brazil, occurring in the states of Bahia, Minas Gerais, Rio de Janeiro and São Paulo (Figures 2C, 3). It is found in the following plant formations: restinga and dense ombrophilous forests. In restinga, it occurs in non-flooded scrub, dune thicket and ridge forest formations. Flowering occurs from January to June and from August to November and fruiting from January to May and from July to December. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, this species differs from other *Serjania* by the following characteristics: triangular stem, with ferruginous-hirsute trichomes on the angles; leaves trifoliolate; large fruits, with seminiferous portion of the mericarp laterally flattened, dorsal crest 1–2 mm wide; embryo with sub-straight cotyledons.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Angra dos Reis, Ilha Grande, Reserva Biológica Estadual da Praia do Sul, na Praia do Sul, 16.V.1984, fl. e fr., *D. Araujo 6284* (GUA); Mun. Araruama, APA de Massambaba, 4.III.2008, fl., *M.S. Faria et al. 58* (RB); Mun. Cabo Frio, Peró, Condomínio Acqua, 3.IV.2008, fl. e fr., *M.S. Faria et al. 78* (RB); Mun. Macaé, Restinga de Cabiúnas, próximo ao Canal Macaé-Campos, 5.V.1981, fl., *D. Araujo & N. Crud 4397* (GUA); Mun. Mangaratiba, Ilha da Marambaia, restinga da Praia Grande, 14.V.2002, fr., *G.V. Somner et al. 1017* (RBR); Mun. Maricá, Barra de Maricá, 28.XI.1988, fr., *A. Souza & H. Pereira 2557* (R); Mun. Niterói, São Gonçalo. Itaoca, Praia de São João, 13.III.1994, fl., *J.P.P. Carauta et al. s.n* (GUA 41771); Mun. Parati, Praia de São Gonçalo, 10.VII.2008, fr., *M.S. Faria et al. 111* (RB); Mun. Rio das Ostras, Área de Relevante Interesse Ecológico Itapebussus (ARIE), 15.X.2007, fl. e fr., *M.S. Faria et al.* 29 (RB); idem, 15.X.2007, fr., *M.S. Faria et al.* 30 (RB); Mun. Rio de Janeiro, Restinga da Tijuca, 8.X.1946, fr., *A. Edmundo 364* (RB); Mun. Saquarema, R.E.E. de Jacarepiá, 10.IX.1995, fl., fr., *A.Q. Lobão 42* (RB).

Serjania dentata (Vell.) Radlk., Consp. Sect. Sp. Serjan. 144. 1874

Woody climbers; stem brown, 5-angled, hollow, geniculate, glabrous, with a single vascular cylinder in cross section; stipules 0.5–1.5 mm long, triangular; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 2.9–10.3 × 1.3–6.4 cm, ovate to elliptic, chartaceous, when dried conduplicate, apex acute to acuminate, margin repand-dentate, without yellowish cartilaginous line, revolute, both surface glabrous, without domatia, venation semicraspedodromous. Thyrse axillary and terminal, racemiform, 1.6–12.5 cm long, pubescent; bracts deltoid. Flowers zygomorphic, 6–8 mm long; sepals 5; petals 4, posterior petal appendages with bicorniculate crest; nectariferous lobes 4, crest of posterior petals appendage corniculiform, anterior ovoid, reduced; stamens 2.5–4 mm long, pubescent fillets, surrounding a pistilode, staminodes 1.5–2.5 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-ovoid, pubescent. Schizocarps 2.5–3.4 × 2.7–3 cm, ovate-cordate, chartaceous; glabrous; seminiferous portion of mericarp inflated; dorsal crest 1–2 mm wide, endocarp glabrous; seeds 1–3, trigonous-ellipsoid; without aril; embryo with outer cotyledon curved and inner biplicate (Figures 8G–L).

Serjania dentata is endemic to Brazil, occurring in the states of Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo (Figures 2C, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal deciduous forest formations. In restinga, it occurs in non-flooded scrub, flooded scrub, dune thickets and ridge forests. Flowering occurs from January to June and from September to November and fruiting from July to September and in November. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem 5-angled, hollow, geniculate; leaves trifoliolate, with repand-dentate margin, when dried the leaflets are conduplicate; crest of posterior petal appendages bicorniculate; fruits with seminiferous portion of mericarp inflated; dorsal crest 1–2 mm wide.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Angra dos Reis, Ilha Grande, Reserva Biológica Estadual da Praia do Sul, Praia do Sul, 6.II.1996, fl., *D. Araujo, 10396* (GUA); Mun. Cabo Frio, entre Lagoa Mirim e praia de Massambaba, 28.III.1978, fl. e fr., *G. Martinelli 4120* (RB); Mun. Casimiro de Abreu, restinga entre Barra de S. João e Rio das Ostras, 21.III.1979, fl. e fr., *P.P. Jouvin 429* (RB); Mun. Macaé, restinga, 30.I.1997, fl. e fr., *V. Capello 45* (HB, R); Mun. Mangaratiba, Restinga da Marambaia, Campo de provas do exército Km 2, estrada ao lado do Porto Velho do Marinha, 26.VII.2003, fr., *G.V. Somner 1103* (RB, RBR); Mun. Maricá, Restinga da Barra de Maricá, 29.III.1989, fl., *M.F. Freitas et al. 35* (RB); Mun. Parati, Praia de São Gonçalo, 10.VII.2008, fr., *M.S. Faria 110* (RB); Mun. Rio das Ostras, Restinga da Praia Virgem, 11.I.2001, fr., *H. do N. Braga 1812* (RB); Mun. Niterói, Jacuné, na orla da estrada, restinga a 2 km da praia de Jacuné, 10.VIII.1986, fr., *P. Acevedo-Rodríguez 1415* (RB); Mun. Rio de Janeiro, Restinga da Tijuca, 9.IV.1946, fl., *O.X. de B. Machado s.n* (RB 75358); Mun. Saquarema, Reserva Ecológica Estadual de Jacarepiá, 22.I.1993, fl., *J. Fontella 2892* (RB).

Serjania eucardia Radlk., Consp. Sect. Sp. Serjan. 121. 1875

Woody climbers; stem dark brown, 5–6-costate, crenate-sinuous, hollow, velutinous-pubescent, with glandular trichomes, in cross section with a single vascular cylinder; stipules 1–2.5 mm long, deltoid; petiole unwinged, canaliculate, rachis unwinged, bi-canaliculate. Leaves biternate; leaflets 1.6–12.5 × 0.9–8.2 cm, large-rhomboidal, ovate, sub-chartaceous, apex acuminate to cuspidate, subserrate-dentate margin; both surfaces densely velutinous-pubescent, venation semicraspedodromous. Thyrse axillary and terminal, racemiform, 2.2–9 cm long, pubescent; bracts triangular. Flowers zygomorphic, 9–12 mm long; sepals 5; petals 4, crest of posterior petal appendages emarginate; nectariferous lobes 4, posterior orbicular, anterior orbicular, reduced; stamens 2.5–4.5 mm long, pubescent fillets, surrounding a pistilode, staminodes 3–4.5 mm long, surrounding a gynoecium; ovary 4–4.5 mm long, trigonous-obovoid, with ferruginous-glandular trichomes. Schizocarps 3.8–5 × 3.6–4.5 cm, ovate-cordate, subcoriaceous, wings puberulous; seminiferous portion of mericarp inflated, puberulous; dorsal crest 2–5 mm wide, endocarp villose; seeds 1–3, obovoid; without aril; embryo with outer cotyledon curved and inner biplicate (Figures 8M–R).

Serjania eucardia is endemic to Rio de Janeiro (Figures 2C, 3), occurring in restinga and dense ombrophilous forests. In restinga, it is found in non-flooded scrub, dune thickets and ridge forests. Flowering occurs from January to April and in December and fruiting in January, February, from April to June and in August and October. This species is evaluated here by its conservation status as endangered (EN), emphasizing its restricted distribution. Its extent of occurrence (EOO) is approximately 1000 km² (B1 <5000 km²), and is found exclusively in the restinga of Rio de Janeiro, environments that have been continuously degraded (B2b (ii,iii)).

In this study, the species differs from other *Serjania* by the following characteristics: stem 5–6 costate, velutinous, composed of only a single vascular cylinder in cross section; leaflets large-rhomboidal, densely pubescent-velutinous on both surfaces; large fruits, with inflated seminiferous portion; dorsal crest 2–5 mm wide.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Cabo Frio, Ponta do Gabriel ao nível do mar, 17.IV.1952, fr., *L.B. Smith et al. 6660* (R); Mun. Niterói, Jaconé, restinga na orla da estrada, 2 Km de praia de Jaconé, 10.VIII.1986, fr., *P. Acevedo-Rodríguez 1418* (RB); Mun. Macaé, na estrada para Lagoa Comprida, 27.IV.1982, fr., *D. Araújo & N. Crud 4983* (GUA); Mun. Mangaratiba, Restinga da Marambaia, entrada por Barra de Guaratiba, 28.I.2005, fl. e fr., *G.V. Somner 1172* (RB); Mun. Maricá, Bambuí, 3.III.1976, fl., *R.F. de Oliveira 161* (GUA); Mun. Rio de Janeiro, ca. 6 Km do Canal de Sernambetiba, 20.I.1970, fl., *J. Fontella et al. 416* (RB); idem, restinga da Barra da Tijuca, 30.XII.1964, fl., *W. Hoehne 5961* (RB); idem, Lagoa Marapendi, estrada do Autódromo, 10.IV.1972, fr., *J. Almeida 1461* (RB); Mun. Saquarema, Restinga de Jaconé, 30.V.1978, fr., *H.C. de Lima 559* (RB).

Serjania fluminensis Acev.-Rodr., Brittonia 39(3) 348. 1987

Woody climbers; stem brown, sub-cylindrical, 8-costate, pubescent, in cross section composed of one central vascular cylinder and 8–10 smaller peripheral cylinders; stipules ca. 0.5 mm long, triangular; petiole unwinged, canaliculate; rachis unwinged, bicanaliculate. Leaves 5-foliolate, leaflets 4.4–14 × 2–5.9 cm, elliptic, ovate, chartaceous, apex cuspidate, margin entire or repand-dentate, subrevolute, both surfaces glabrous, without domatia, venation semicraspedodromous. Thyrse axillary and terminal, 5.8–8.8 cm long, pubescent; bracts triangular. Flowers zygomorphic, 9–10 mm long; sepals 5; petals 4, crest of posterior petal appendages erose; nectariferous lobes 4, posterior ovoid, anterior ovoid, reduced; stamens 2.5–5 mm long, tomentose fillets, surrounding a pistilode, staminodes 2.5–3.5 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-obovoid, pubescent and with glandular trichomes. Schizocarps 2.7–4.7 × 2.4–4.4 cm, ovate-cordate, sub-coriaceous, wings glabrous, seminiferous portion of mericarp globose, without dorsal crest, endocarp lanose; seeds 1–3, obovoid; without aril; embryo not observed (Figures 8S–W).

Serjania fluminensis is endemic to the northern coast of Rio de Janeiro state, occurring in ridge forests of restinga (Figures 2C, 3). This species is infrequent in Rio de Janeiro's restinga and further collections are needed to better establish the details of its phenology. Flowering is recorded from May to June and fruiting in August, October, February, and from May to June. According to Somner et al. (2018), this species is evaluated by its conservation status as endangered (EN). In this study, we established that *S. fluminensis* has an extent of occurrence (EOO) of approximately 1500 km² (B1 <5000 km²), and is found exclusively in the restinga of Rio de Janeiro, whence there are only a few records. This habitat has suffered loss in quality caused by tourism and real estate development (B2a ≤5 and b (i,ii,iii,iv)).

In this study, the species differs from other *Serjania* by showing the following characteristics: stem composed in cross section of one vascular central cylinder and 8–10 smaller peripheral cylinders, leaves 5-foliolate, leaflets large and fruits with globose seminiferous portion, without a dorsal crest. The description of the flowers is presented here for the first time.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, restinga da Praia da Gorda, 15.II.2000, fr., *D. Fernandes & A. Oliveira 423* (RB); Mun. Cabo Frio, APA Pau-Brasil, 9.VI.2008, fr., *M.S. Faria et al. 84* (RB); Mun. Rio das Ostras, Restinga de Balneário das Garças, 1.V.1999, fl. e fr., *R.N. Damasceno 952* (RB); Mun. Saquarema, Restinga da Massambaba, 10.VIII.1986, fr., *P. Acevedo-Rodríguez & C. Farney 1424* (R, RB); idem, Reserva Ecológica Estadual de Jacarepiá, Restinga de Ipitangas, 24.V.1988, fr., *C. Farney & L.S. Sarayba 2133* (HB, RB); idem, 14.V.1993, fl. e fr., *G.V. Somner 756* (RBR); idem, 29.X.1991, fr., *G.V. Somner et al. 704* (RBR).

Serjania ichthyoctona Radlk., Serj. Monogr.: 230. 1875

Woody climbers; stem dark brown, triangular, 3-costate, ribs conspicuous, glabrous, in cross section composed of one large central vascular cylinder and three prominent smaller peripheral cylinders; stipules ca. 0.5 mm long, triangular, canaliculate; petiole unwinged, canaliculate; rachis unwinged, bicanaliculate. Leaves biternate, leaflets 1.9–10 × 1–4.9 cm, elliptic to lanceolate, coriaceous, both surface glabrous, apex acute, margin entire, revolute, without domatia, venation brochidodromous. Thyrse axillary and terminal, racemiform, 2–10.9 cm long, tomentose; bracts deltoid. Flowers zygomorphic, 5.5–7.5 mm long; sepals 5; petals 4, crest of posterior petals appendage bicorniculate; lobes 4, posterior ovoid, anterior ovoid, reduced; stamens 2.5–3.5 mm long, pubescent fillets, surrounding a pistilode, staminodes 2–2.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-obovoid, pubescent. Schizocarps 2.7–2.8 × 2.1–2.3 cm, chartaceous, pubescent; seminiferous portion of mericarp globose, without a dorsal crest, endocarp glabrous; seeds 1–3, globose; without aril; embryo with sub-straight cotyledons (Figures 9A–F).

Serjania ichthyoctona is endemic to Brazil, occurring in the states of Bahia, Espírito Santo, Pernambuco and Rio de Janeiro (Figures 2C, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest, seasonal deciduous forest and seasonal semideciduous forest formations. In restinga, it occurs in non-flooded scrub, flooded scrub and ridge forests. Flowering occurs in January and April, from June to September and fruiting from July to October. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem triangular, 3-costate, with conspicuous ribs, composed in cross section of one large central vascular cylinder and three prominent smaller peripheral cylinders; leaves biternate, coriaceous, leaflets with entire margins; fruits with seminiferous portion of mericarp globose, without crest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Cabo Frio, APA Bacia do Rio São João/Mico-leão-dourado, Parque Ecológico do Mico Leão Dourado, 14.VIII.2003, fl., *D. Fernandes 752* (RB); Mun. Casimiro de Abreu, estrada do Rio Dourado, hacia Rio das Ostras, 14.VIII.1986, fl., *P. Acevedo-Rodríguez et al. 1441* (RB, RBR); Mun. Macaé, Fazenda Jurubatiba, na mata de restinga, 17.IX.1986, fl., *D. Araujo & M.C.A. Pereira 7562* (GUA); Mun. Mangaratiba, Restinga da Marambaia, 31.VII.1997, fl., G.*V. Somner & M.S. Ferrucci 831* (RBR); Mun. Rio de Janeiro, Restinga da Tijuca, 22.VIII.1945, fl., *J.G. Kuhlmann 6267* (RB); Mun. Saquarema, Restinga de Ipitangas, 20.X.1988, fr., *C. Farney 2177* (HB, RB).

Serjania littoralis Somner & Ferrucci, Ann. Bot. Fennici 46: 479. 2009

Semi-woody climbers; stem light brown or dark brown, cylindrical, 6-striate, puberulous when young, glabrescent when mature, not hollow, geniculate, with orange glandular trichomes; in cross section with a single vascular cylinder; stipules ca. 0.5–1 mm long, triangular; petiole unwinged, canaliculate. Leaves trifoliolate, leaflets 2.4–7.5 × 1.2–3.4 cm, elliptic, chartaceous, conduplicate, apex acuminate-mucronate, margin entire, sometimes with 1–2 glandular teeth in the basal third, subrevolute, wavy, with yellowish cartilaginous line, both surfaces glabrous, without domatia, venation brochidodromous. Thyrse axillary or terminal, subspiciform, 1.3–2.8 cm long, pubescent; bracts triangular. Flowers zygomorphic, ca. 6.5 mm long; sepals 5, petals 4, crest of posterior petal appendages bicorniculate; posterior nectariferous lobes ovoid, anterior orbicular; stamens 2–3.5 mm long, puberulous fillets,

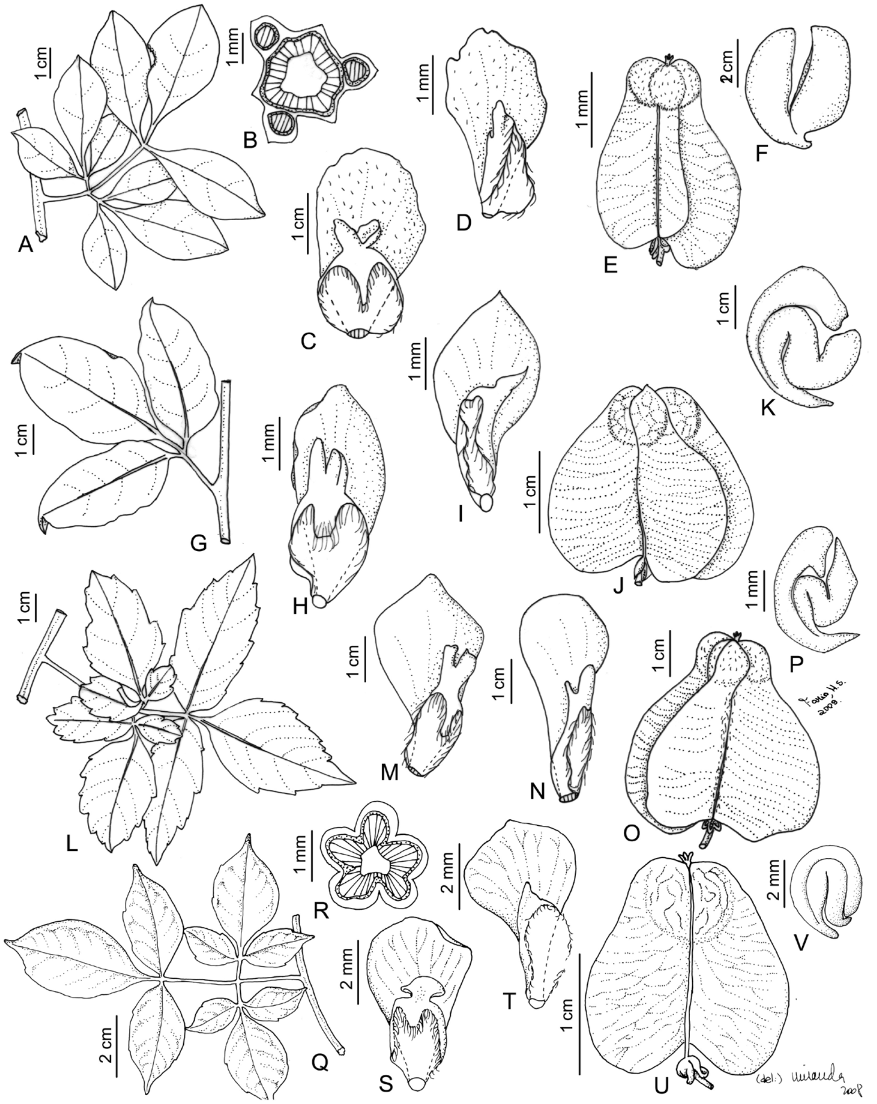

Figure 9. *Serjania ichthyoctona* – A. biternate leaf; B. cross-section of the stem; C. posterior petal; D. anterior petal; E. fruit; F. embryo. *S. littoralis* – G. trifoliolate leave; H. posterior petal; I. anterior petal; J. fruit; K. embryo. *S. pernambucensis* – L. biternate leaf; M. posterior petal; N. anterior petal; O. fruit; P. embryo. *S. salzmanniana* – Q. biternate leaf; R. cross-section of the stem; S. posterior petal; T. anterior petal; U. fruit; V. embryo. (A–B: D. Sucre 5874; C–D: D. Fernandes 752; E–F: V.L.G. Klein, 1038; G: M. S. Faria 90; H–I: M. S. Faria 82; J–K: D. Araujo 10309; L–P: M. Vianna F. et al. 347; Q–R: M. S. Faria 123; S–T: C. Farney, U–V: M. S. Faria 124. Illustrators A–P: M. S. Faria and Q–V: C. Miranda).

surrounding a pistilode, staminodes 1.5–2.5 mm long, surrounding a gynoecium; ovary ca. 2.5 mm long, trigonous-obovoid, with glandular trichomes. Schizocarps 1.4–2.4 × 1.3–2.5 cm, chartaceous, glabrous, seminiferous portion of mericarp inflated, dorsal crest 1–1.5 mm wide, endocarp glabrous; seeds 1–3, subglobose, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 9G–K).

Serjania littoralis is endemic to the northern coast of Rio de Janeiro state, occurring in ridge forests of restinga (Figures 2C, 3). However, there are records of collections on rocky stretches of the shore, a type of habitat described by Veloso *et al*. (1991) as "*pontal rochoso*", which influence on the origin of the restingas. Flowering occurs from May to June and fruiting from June to August. According to Somner et al. (2018), the conservation status of this species is evaluated as endangered (EN). In this study, we established that *S. littoralis* has an extent of occurrence (EOO) of approximately 1200 km² (B1 <5000 km²), and is found exclusively in the restinga of Rio de Janeiro, where there are few records of its occurrence. This habitat has suffered loss of quality caused from tourism and real estate development (B2a ≤5 and b(i,ii,iii,iv)).

In this study, the species differs from other *Serjania* by the following characteristics: stem 6-striate, with orange glandular trichomes, and a single vascular cylinder in cross section; leaves trifoliolate, leaflets with margins entire, subrevolute, wavy, with a yellow cartilaginous line; crest of posterior petal appendagea bicorniculate; fruits with seminiferous portion of mericarp inflated, and dorsal crest 1–1.5 mm wide.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, Praia da Gorda, 9.VI.2008, fr., *M.S. Faria 90* (RB); restinga da praia de José Gonçalves, 25.VI.1999, fr., *D. Fernández 236* (RB, RBR); Mun. Cabo Frio, APA Pau-Brasil, 9.VI.2008, fl., *M.S. Faria 82*

(RB); estrada antiga para Búzios, próximo Centrinho, 28.VI.1995, fl., *D. Araujo 10309* (GUA).

Serjania pernambucensis Radlk., in Martius, Fl. Bras. 13 (3): 332. 1892

Woody climbers; stem dark brown, 5–6-sulcate, densely ferruginous-tomentose, with a single vascular cylinder in cross section; stipules 1.5–2 mm long, ovate-triangular; petiole and rachis unwinged, canaliculate. Leaves biternate, leaflets 6.5–8.5 × 4.8–5.1 cm, ovate, coriaceous, apex acute, margin serrate-dentate, ferruginous-pubescent on both sides, abaxial surface more densely pubescent, with glandular trichomes, venation craspedodromous. Thyrse axillary and terminal, racemiform, 1.2–3.1 cm long, dense ferruginous-tomentose; bracts triangular. Flowers zygomorphic, 6–7.5 mm long; sepals 5; petals 4, crest of posterior petal appendages erose or emarginate; nectariferous lobes 4, posterior orbicular, anterior ovoid; stamens 3–3.5 mm lomg, puberulous fillets, surrounding a pistilode, staminodes 2–2.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-obovoid, densely ferruginous-tomentose. Schizocarps 2.3–2.5 × 2–2.2 cm, pubescent close to the septum, seminiferous portion of mericarp globose, ferruginous-tomentose, without dorsal crest, endocarp lanose; seeds 1–3, obovate, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 9L–P).

Serjania pernambucensis is endemic to Brazil, occurring in Bahia, Minas Gerais, Pernambuco and Rio de Janeiro (Figures 2C, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest, seasonal semideciduous forest and savanna formations. This species is rare in Rio de Janeiro and is found on the northern coast of the state, occurring in ridge forests of restinga. Flowering occurs in March and May, and fruiting in March and from May to June. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: indument densely ferruginous-tomentose throughout the plant; leaves biternate, with unwinged petiole and rachis; fruits with seminiferous portion of the mericarp globose, without a dorsal crest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, Estrada do condomínio Vila Verde, 30.V.2004, fl. e fr., *M. Vianna Filho et al. 347* (GUA); Mun. Macaé, Bairro dos Cavalheiros, estrada de acesso ao vale encantado, 16.V.2009, fl., *R.D. Ribeiro 1111* (RB); Mun. Rio das Ostras, Praia Virgem, rua João Persegueiro do Amaral, paralelo à praia, 05.V. 2016, fl., *G.V. Somner et al.* (RBR).

Serjania salzmanniana Schltd., Linnaea 18: 46. 1844

Woody climbers; stem dark brown, 5-costate, crenate-lobate, hollow, pubescent, with a single vascular cylinder in cross section; stipules ca. 1 mm long, triangular; petiole unwinged, canaliculate; rachis bicanaliculate or marginate. Leaves biternate, rarely 5-foliolate, bullate; leaflets 2.6–8.5 × 1.5–4.5 cm, rhomboidal to ovate or elliptic, chartaceous, apex acuminate-mucronate, margin serrate-dentate, adaxial surface puberulous on midvein, abaxial surface glabrous, without domatia, venation semicraspedodromous. Thyrse axillary and terminal, racemiform, 2.2–7 cm long, tomentose; bracts triangular. Flowers zygomorphic, ca. 9 mm long; sepals 5; petals 4, crest of posterior petal appendages erose; nectariferous lobes 4, posterior ovoid, anterior orbicular, reduced; stamens 2.5–4 mm long, puberulous fillets, surrounding a pistilode, staminodes 2.5–4 mm long, surrounding a gynoecium; ovary ca. 3 mm long, trigonous-obovoid, pubescent and with glandular trichomes. Schizocarps 1.7–2.8 × 1.5–2 cm, ovate-cordate, chartaceous, glabrous, dorsal crest 2–4 mm wide, seminiferous portion of mericarp inflated, endocarp lanose; seeds 1–3, obovoid, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 9Q–V).

Serjania salzmanniana is endemic to Brazil, occurring in the states of Alagoas, Bahia, Ceará, Espírito Santo, Goiás, Maranhão, Pará, Paraíba, Pernambuco, Rio de Janeiro, Rio Grande do Norte and Sergipe (Figures 2C, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest, seasonal semideciduous forest and savanna formations. In restinga, it occurs in scrub dunes, seasonally flooded scrub, seasonally flooded swamps and ridge forests. The species is very frequent in non-flooded scrub in Carapebus restinga. Flowering occurs from February to March and in December, and fruiting from February to June, from August to September and in December. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem crenate-lobate, with a single vascular cylinder in cross section; leaves biternate or 5-foliolate, bullate; fruits with seminiferous portion of mericarp inflated and dorsal crest 2–4 mm wide.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Carapebus, PARNA Jurubatiba, 10.VI.2008, fr., *M.S. Faria et al. 98* (RB, RBR); Mun. Casimiro de Abreu, no loteamento Praia Ouro Verde, Restinga de “Ericaceae”, 27.VI.1983, fr., *D. Araujo 5641* (GUA); Mun. Macaé, entre a Lagoa Cabiúnas e a faixa de tubulação da Petrobras, 25.III.1998, fr., *D. Araujo 10644* (GUA); Mun. Paquetá, Praia da Moreninha, 17.V.2008, fr., *J. Figueira s.n* (RBR 30699); Mun. Saquarema, Jaconé, 29.III.2000, fl., *C. Farney 4015* (RB).

Serjania tenuis Radlk., Consp. Sect. Sp. Serjan. 98. 1874

Woody vine; stem brown or greenish brown, 3–5-costate, obtusely-triangular, with three prominent ribs, puberulous when young, glabrous when mature, in cross section composed of a single central vascular cylinder and three smaller peripheral cylinders; stipules ca. 1 mm long, deltoid; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 4.9–9.5 × 1.9–4.1 cm, lanceolate to ovate, sub-chartaceous, apex acuminate, mucronate, margin with four small teeth, or rarely entire, adaxial surface glabrous and abaxial surface pilose on the midvein, without domatia, venation mixed craspedodromous. Thyrse axillary, racemiform, 3.5–16.5 cm long, pubescent; bracts triangular. Flowers zygomorphic, 7–9 mm long; sepals 4; petals 4, crest of posterior petal appendages emarginate; nectariferous lobes 4, posterior lobes ovoid, anterior ovoid, reduced; stamens 2.5–4 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–3.5 mm long, surrounding a gynoecium; ovary ca. 3.5 mm long, trigonous-obovoid, pubescent. Schizocarps 2.5–2.6 × 2.3–2.4 cm, ovate-cordate, chartaceous, glabrous; seminiferous portion of mericarp laterally flattened; dorsal crest 1–2 mm long, endocarp lanose; seeds 1–3, lenticular, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 10A–E).

Serjania tenuis is endemic to Rio de Janeiro, occurring in restinga (in ridge forests) and dense ombrophilous forests (Figures 2D, 3). Flowering occurs in March and from May to June and fruiting in March and May. According to Somner et al. (2018),

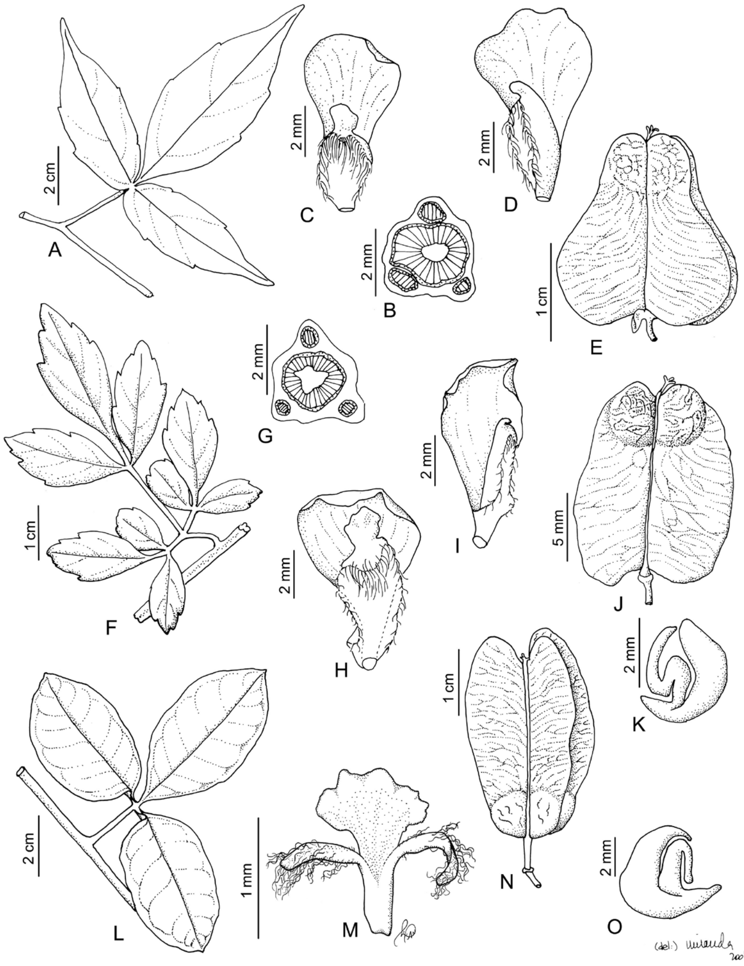

Figure 10. *Serjania tenuis* – A. trifoliolate leave; B. cross section of the stem; C. posterior petal; D. anterior petal; E. fruit. *S. thoracoides* – F. biternate leaf; G. cross section of the stem; H. posterior petal; I. anterior petal; J. fruit; K. embryo. *Thinouia restingae* – L. trifoliolate leave; M. petal; N. fruit; O. embryo. (A–B: D. Sucre 4968; C–E: M. S. Faria 74; F, G, J–K: P. Acevedo-Rodríguez et al. 1452; H–I: D. Sucre 3925; L–M: M.G. Bovini 1925; N–O: M.G. Bovini & J.M.A. Braga 170. Illustrator A–L, N–O: C. Miranda and M: L. A. Brito).

the conservation status of this species is evaluated as vulnerable (VU), and it suffers from habitat degradation due to human action in Atlantic Forest (B2b(iii)). In this study, we established that the species has an extent of occurrence (EOO) of approximately 14000 km² (B1 >20000 km²).

In this study, the species differs from other *Serjania* by the following characteristics: stem 3–5-costate, obtusely-triangular, with three prominent ribs, in cross section composed of one central vascular cylinder and three smaller peripheral cylinders; leaflet margins with four small teeth, or rarely entire; fruits with seminiferous portion of mericarp laterally flattened.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Cabo Frio, Caminho para Praia do Peró, 3.III.2008, fl., *M.S. Faria et al. 73* (RB); idem, 3.III.2008, fr., *M.S. Faria 74* (RB); Mun. Rio de Janeiro, Restinga de Grumari, 8.III.1935, fl., *C.V. Freire 591* (R).

Serjania thoracoides Radlk., Consp. Sect. Sp. Serjan. 170. 1874

Woody climbers; stem dark brown, triangular, 3-costate, ribs conspicuous, rarely pubescent, in cross section composed of one large central cylinder and three smaller peripheral cylinders; stipules 1–1.5 mm long, triangular; petiole unwinged, canaliculate, rachis unwinged, bicanaliculate. Leaves biternate; leaflets 2–3.2 × 0.8–1.5 cm, rhomboidal to elliptic; chartaceous, apex acuminate-mucronate, margin serrate-dentate, adaxial surface pubescent on midvein and abaxial surface puberulous, without domatia, venation craspedodromous. Thyrse axillary and terminal, racemiform, 0.8–2.3 long, pubescent; bracts deltoid. Flowers zygomorphic, 5.5–6.5 mm long; sepals 5; petals 4, crest of posterior petal appendages erose; nectariferous lobes 4, posterior nectariferous lobes ovoid, anterior ellipsoid, reduced; stamens 2.5–3 mm long, puberulous fillets, surrounding a pistilode, staminodes 2–2.5 mm long, surrounding a gynoecium; ovary ca. 1 mm long, trigonous-obovoid, pubescent. Schizocarps 1.5–1.7 × 1–1.6 cm, chartaceous, glabrous; seminiferous portion of mericarp globose, without crest; endocarp lanose; seeds 1–3, globose, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 10F–K).

Serjania thoracoides is endemic to southeastern Brazil and occurs in Espírito Santo, Minas Gerais and Rio de Janeiro (Figures 2D, 3). It is found in restinga and dense ombrophilous forest formations. In restinga, it occurs in dune thickets. Flowering occurs in January, from May to June and from August to October and fruiting from August to October. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Serjania* by the following characteristics: stem triangular, 3-costate, ribs conspicuous, in cross section composed of one large central vascular cylinder and three smaller peripheral cylinders; fruits small, with seminiferous portion of mericarp globose and without a crest.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, Restinga da praia do Forno, 19.VIII.1998, fl., *D. Fernandes et al. 34* (R); Mun. Cabo Frio, restinga entre a Praia das Focas e a Praia do Forno, 14.VIII.1986, fr., *P. Acevedo-Rodríguez 1452* (RB).

Thinouia mucronata Radlk., Sitzungsber. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. München 8: 282. 1878

Thinouia repanda Radlk. in Engl. & Prantl, Nat. Pflanzenfam. 3(5): 308. 1895.

Woody climbers; stem grayish brown, slightly costate when young, cylindrical when mature, glabrescent or glabrous, in cross section with a single vascular cylinder; stipules 0.5–1 mm long, triangular; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 3–8.8 × 1–5.1 cm, ovate-rhomboidal or ovate, chartaceous, apex acute or obtuse-mucronate, margin subentire, with 1–2(-3–4) teeth reduced to inconspicuous gland, glabrous or puberulous on both surfaces, domatia, venation craspedodromous. Thyrse axillary, umbelliform, 0.8–1.7 cm long, pubescent; bracts ovoid. Flowers actinomorphic, 2.5–4 mm long; sepals 5; petals 5, spathulate, with divergent bifid appendages, never bifurcated; nectariferous disk annular; stamens 2.2–4 mm long, villose fillets, surrounding a pistilode, staminodes 1.5–1.7 mm long, surrounding a gynoecium; ovary ca. 1.2 mm long, trigonous-ovoid, villose. Schizocarps 3.5–3.9 × 1.9–2.5 cm, obcordiform, chartaceous, glabrous; stipe 0.6–0.8 cm long, endocarp villose; seeds 1–3, trigonous-ellipsoid, without aril; embryo with outer cotyledon curved and inner biplicate (Figures 11A–C).

Thinouia mucronata occurs in Argentina, Brazil, Bolivia and Paraguay. In Brazil, there are records in the following states: Bahia, Espírito Santo, Mato Grosso do Sul, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina and São Paulo (Figures 2D, 3). This species is uncommon in the restinga of Rio de Janeiro, with only one occurrence record. It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest, seasonal semideciduous forest and gallery forest formations. In restinga, it occurs in ridge forests and dune thickets. Fruiting occurs in April and June. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Thinouia* by the following characteristics: stem with a single vascular cylinder in cross section; leaflets chartaceous, with sub-entire margins, with one or two, rarely three to four teeth reduced to inconspicuous gland, venation craspedodromous; corolla spathulate, with divergent bifid appendages; fruits obcordiform, glabrous.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Cabo Frio, Estação Radiogonométrica de Campos Novos, 2 Distrito, Estrada do Anel Viário, 12.VI.2009, fr., *G.V. Somner & M. Faria 1354* (RBR).

Thinouia restingae Ferrucci & Somner, Brittonia 60(4): 371. 2008

Woody climbers; stem grayish brown, sub-cylindrical, 5–6 costate, glabrous, in cross section composed of one central vascular cylinder and three peripheral cylinders; stipules 1–2.5 mm long, triangular, petiole unwinged, canaliculate. Leaves trifoliolate, leaflets elliptic to lanceolate, 2.3–5.8 × 1–3 cm; sub-coriaceous, apex acute-mucronate, margin entire, both surfaces glabrous, without domatia, venation brochidodromous. Thyrse axillary, umbelliform, 1–1.5 cm long, pubescent; bracts triangular. Flowers actinomorphic, 5–6 mm long; sepals 5; petals 5, petals spathulate, with divergent bifid appendages, sometimes bifurcated; nectariferous disk annular; stamens 2.5–4 mm long, villose fillets, surrounding a pistilode, staminodes ca. 1.5 mm long, surrounding a gynoecium; ovary ca. 1.5 mm long, trigonous-ovoid, pubescent on the angles. Schizocarps 2.8–3.4 × 1.7–1.9 cm, obcordiform, chartaceous, glabrous; endocarp villose; seeds 1–3, obovoid; without aril; embryo with outer cotyledon curved and inner biplicate (Figures 10L–O).

Thinouia restingae is endemic to Brazil, occurring in the states of Bahia, Espírito Santo and Rio de Janeiro (Figures 2D, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In restinga, it occurs in dune thickets and ridge forests. Flowering occurs in October and December and fruiting in January, May, July, August and October. This species is evaluated here by its conservation status as vulnerable (VU). Although its extent of occurrence (EOO) is below 20000 km² (B1) and records are still scarce and scattered, the species is concentrated especially in restinga of Rio de Janeiro State, environments that have suffered intense human degradation. A few isolated specimens were recorded in Bahia and Espírito Santo in the Atlantic Forest (B2 < 2000 km²; B2a ≤10 and b(i, iii,iv)).

In this study, the species differs from other *Thinouia* by the following characteristics: stem sub-cylindrical, 5–6 costate, glabrous, in cross section composed of one central vascular cylinder and three peripheral cylinders; leaflets subcoriaceous, with entire margins, both sides glabrous; venation brochidodromous, petals with divergent bifid appendages, sometimes bifurcated.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Armação de Búzios, Praia da Gorda, 16.XII.1998, fl. *D. Fernandes 195* (RBR); Mun. Macaé, condomínio Mar do Norte, 18.VII.1993, fr., *M.G. Bovini & J.M.A. Braga 170* (RB); Mun. Saquarema, Restinga de Ipitangas, 30.X.1983, fl., *C. Farney 2173* (RB); Mun. Rio das Ostras, restinga do Mar do Norte, 18.12.2000, fl., *M.G. Bovini 1925* (RB).

Urvillea glabra Cambess., Fl. Bras. Merid. 1: 353, tab. 74. 1828

Subwoody climbers; stem light brown, subcylindrical, 5–6-costate, inconspicuous ribs, geniculate, glabrous, with a single vascular cylinder in cross section; stipules ca. 0.5 mm long, triangular; petiole unwinged, canaliculate. Leaves trifoliolate; leaflet 1.2–7.6 × 1.3–3.4 cm, ovate, sub-chartaceous, apex acute, margin serrate-dentate, with 2 or 4 pairs of teeth close to apex, venation prominent, both sides glabrous, abaxially with laticiferous utricles, with domatia, venation mixed craspedodromous. Thyrse axillary, sub-spiciform, 1–5.2 cm long,

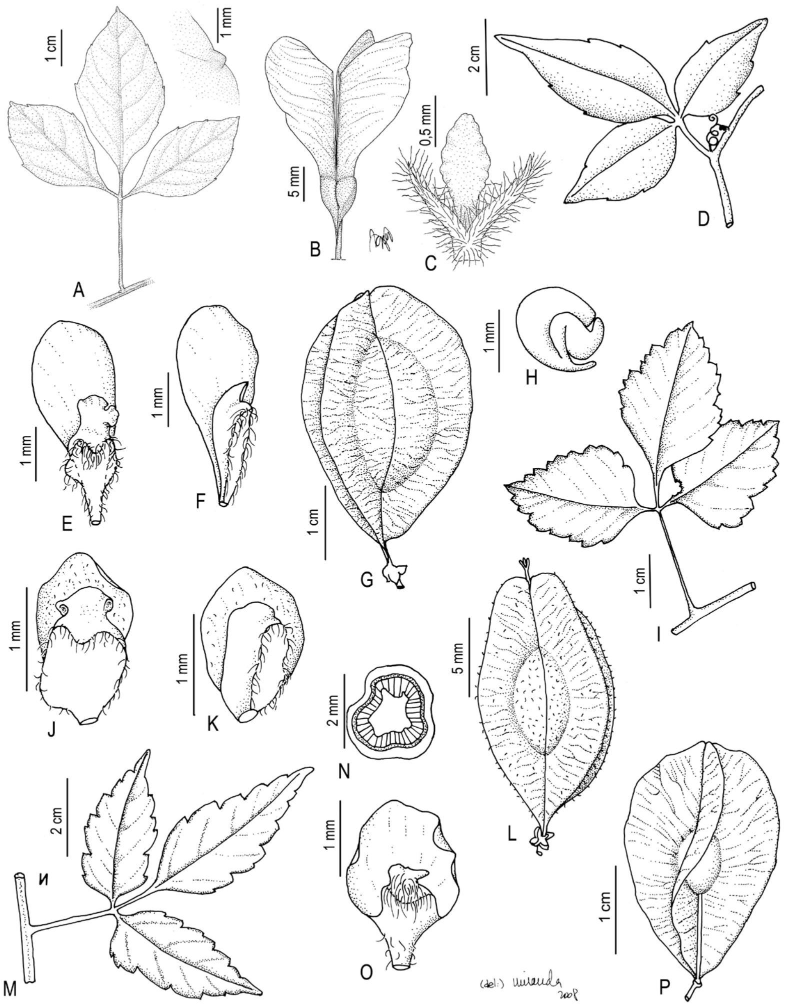

Figure 11. *Thinouia mucronata* – A. trifoliolate leave; B. fruit; C. petal. *Urvillea glabra* – D. trifoliolate leave; E. posterior petal; F. anterior petal; G. fruit; H. embryo. *U. rufescens* – I. trifoliolate leave; J. posterior petal; K. anterior petal; L. fruit. *U. stipitata* – M. trifoliolate leave; N. cross section of the stem; O. petal; P. fruit. (A, C: L. B. Salmazi s.n.; B: F. Chagas-Silva 1501; D–F: M. S. Faria et al. 41; G–H: H.P. Bautista 334; I–J: M.C. Gaglianone et al. 148; K: M. S. Faria 34; L–M: R. Andreata et al. 668; N: R.C. Forzza et al. 2729; O: A. Oliveira & D. Fernandes 139. Illustrators A–C: I. H. F. Azevedo and D–P: C. Miranda).

puberulous; bracts triangular. Flowers zygomorphic, 4.5–6.5 mm; sepals 5; petals 4, crest of posterior petal appendages biauriculiform; posterior nectariferous lobes orbicular, anterior elliptic; stamens 2.5–3 mm long, puberulous fillets, surrounding a pistilode, staminodes 1–1.5 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-ellipsoid, pubescent. Capsules 3–5.5 × 2.2–2.7 cm, three-winged, obovate or oblong, sub-chartaceous, glabrous, with inflated locules; endocarp puberulous; seeds 1–3, subglobose; aril semicircular; embryo with outer cotyledon curved and inner biplicate (Figures 11D–H).

Urvillea glabra is endemic to Brazil, occurring in Espírito Santo, Rio de Janeiro and São Paulo, in sandy coastal plain and dense ombrophilous forest formations (Figures 2D, 3). In restinga, it occurs in non-flooded scrubs and ridge forests. Flowering occurs from April to June and fruiting in May and from July to September. According to Valente et al. (2013), this species is evaluated by its conservation status as Vulnerable (VU). Although it has an extent of occurrence (EOO) of approximately 6300 km² (B1 <20000 km²), records are still scarce and scattered, the species is concentrated especially in restinga in Rio de Janeiro State, and with a few isolated records in Espírito Santo and São Paulo, environments that have suffered intense human degradation (B2 < 2000 km²; B2a ≤10 and b(i, iii,iv)).

In this study, the species differs from other *Urvillea* by the following characteristics: stem geniculate, glabrous; leaves sub-chartaceous; leaflets glabrous on both sides, abaxially with laticiferous utricles; margin serrate-dentate, with 2 or 3 pairs of teeth close to the apex; capsules obovate or oblong, measuring 3 to 5.5 cm long, glabrous.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Cabo Frio, APA Pau-Brasil, 9.VI.2008, fl., *M.S. Faria 81* (RB); idem, *M.S. Faria 83* (RB); Mun. Paraty, caminho a Paratimirim, 23º15.54´, 44º39,37´W, 27-IX-2005, *Urdampilleta & Obando 293* (CTES, UEC); Mun. Rio de Janeiro, Restinga de Grumari, 16.VIII.1986, fr., *P. Acevedo-Rodríguez et al. 1461* (RB); idem, 30.V.1972, fl., *J.A. Jesus 1596* (RB); Mun. Saquarema, Reserva Ecológica Estadual de Jacarepiá, 22-VII-1993, *Araujo 9870* (CTES).

Urvillea rufescens Cambess. Cambess., Fl. Bras. Merid. 1: 354. 1828

Woody climbers; subcylindrical, stem reddish brown, 5-costate, not geniculate, pubescent, in cross section with a single vascular cylinder; stipules triangular, ca. 0.5 mm long; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 1–4.7 × 0.4–2.2 cm, ovate, sub-coriaceous, apex obtuse or acuminate, mucronate, margin crenate-dentate, adaxial surface dark-brown, glabrous or sub-glabrous, midvein pubescent with orange glandular trichomes, venation sunken, abaxial surface greenish-brown, pubescent, densely so on veins, without laticiferous utricles, without domatia, venation craspedodromous. Thyrse axillary, sub-spiciform, 2.8–9 cm long, pubescent; bracts triangular. Flowers zygomorphic, ca. 2.5 mm; sepals 5, petals 4, crest of posterior petal appendages emarginate; posterior nectariferous lobes ovoid, anterior ovoid or elliptic; stamens 1.5–3 mm long, puberulous fillets, surrounding a pistilode, staminodes 1–1.5 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-ellipsoid, densely tomentose. Capsules 1.8–2.2 × 0.9–1.6 cm, three-winged, elliptic, sub-chartaceous, puberulous, locules inflated, pubescent only on the central portion, endocarp glabrous, puberulous at junction of septum walls; seeds 1–3, ovoid; aril cordiform; embryo with outer cotyledon curved and inner biplicate (Figures 11I–L).

Urvillea rufescens is endemic to Brazil, occurring in Bahia, Espírito Santo, Minas Gerais, Pernambuco, Rio de Janeiro and São Paulo states (Figures 2D, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and seasonal semideciduous forest formations. In restinga, it occurs in dune thickets, seasonally flooded forests and ridge forests. Flowering and fruiting occur from June to October. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Urvillea* by the following characteristics: stem pubescent, not geniculate; leaflets sub-coriaceous, with crenate-dentate margin, adaxial surface glabrous or subglabrous, pubescent on the midvein with orange glandular trichomes, abaxial surface without utricle, pubescent; capsules elliptic, measuring 1.8 to 2.2 cm long, puberulous.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Mun. Araruama, Praia do Hospício, 5.VIII.1987, fl., *A.M.S. da F. Vaz 463* (RB); Mun. Cabo Frio, Distrito de Tamoios, Estação Rádio Marinha Campo Novos, 2.X.2003, fl., *G.S.Z., Rezende 111* (RB); Mun. Casimiro de Abreu, Estrada de terra bacia São Pedro da Aldeia, 14.VIII.1986, fl., fr., *P. Acevedo-Rodríguez 1443* (RB). Maricá, 2.VI.1988, fr., *A. Souza et al. 2232* (R); Mun. Rio das Ostras, ARIE de Itapebussus, 17.X.2007, fr., *M.S. Faria 34* (RB); Mun. Rio de Janeiro, Restinga de Grumari, 14.VIII.1968, fl., *D. Sucre 3500* (RB); Mun. São João da Barra, Restinga de Iquipari, 5.IX.2003, fl. e fr., *M.C. Gaglianone 148* (RB); Mun. Saquarema, Restinga de Massambaba, 10.VIII.1986, fl., *P. Acevedo-Rodríguez* 1423 (RB). Idem, Restinga de Ipitangas, Reserva Ecológica Estadual de Jacarepia, 29.X.1991, fr., *G.V. Somner et al.* 710 (CTES).

Urvillea stipitata Radlk., Sitzungsber. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. München 8: 264. 1878

Woody climbers; stem reddish brown or grayish brown, subcylindrical, 5-costate, puberulous when young, glabrous when mature, in cross section with a single vascular cylinder; stipules 2–3 mm long, falcate or subulate; petiole unwinged, canaliculate. Leaves trifoliolate; leaflets 2–11 × 1.3–4.4 cm, ovate to ovate-lanceolate, sub-chartaceous, apex acute or acuminate, mucronate, margin incise-dentate, with 1 or 2 pairs of proximal incisions not exceeding one third of semi-blade; adaxial surface dark-brown, glabrous or subglabrous, except the puberulous veins, venation prominent, abaxial surface light-brown, with laticiferous utricle, totally pubescent or with puberulous veins; venation craspedodromous; with domatia. Thyrse axillary, racemiform, 1–7 cm long, tomentose; bracts falcate. Flowers zygomorphic, 5–6 mm long; sepals 5; petals 4, crest of posterior petal appendages biauriculiform; posterior nectariferous lobes suborbicular, anterior elliptic; stamens 2–3 mm long, pubescent fillets, surrounding a pistilode, staminodes 1.–2.5 mm long, surrounding a gynoecium; ovary ca. 2 mm long, trigonous-ellipsoid, pubescent or with glandular trichomes. Capsules 2.3–2.8 × 1.4–2.8 cm, three-winged, elliptic or obovate, locules flattened laterally, sub-chartaceous, pubescent, endocarp puberulous; seeds 1, trigonous-ovoid; aril not cordiform; embryo with outer cotyledon curved and inner biplicate (Figures 11M–P).

Urvillea stipitata is endemic to Brazil, occurring in Alagoas, Bahia, Minas Gerais, Pará, Paraíba, Pernambuco, Rio de Janeiro and Rio Grande do Norte (Figures 2D, 3). It is found in the following plant formations: sandy coastal plain, dense ombrophilous forest and savanna formations. In restinga, it occurs in dune thickets and ridge forests. Flowering occurs in February and April and fruiting from April to July and in November. The taxon has been evaluated based on the IUCN (2019) criteria as Least Concern (LC).

In this study, the species differs from other *Urvillea* by the following characteristics: stem puberulous when young, glabrous when mature, not geniculate; leaflet margins incise-dentate, with 1 or 2 pairs of proximal incisions not exceeding one third of semi-blade; abaxial surface with laticiferous utricle; capsules elliptic or obovate, pubescent.

Selected materials: **BRAZIL**. RIO DE JANEIRO: Rio das Ostras, Praia da Virgem, 4.XI.2002, fr., *H. do N. Braga 4028* (R); Mun. Rio de Janeiro, Restinga Grumari, 30.VI.1987, fr., *A.M.S. da F. Vaz 456* (RB); idem 21.V.2000, fr., *A. Oliveira & D. Fernandes 139* (RB); idem, 10.V.1985, fr., *Araújo et al. 6851* (CTES).

Discussion

The genera with the highest number of species in the restinga were *Serjania* (15 spp.) and *Paullinia* (9 spp.), thus corroborating the data obtained by Araujo (2000) in her floristic and phytosociological analysis of Rio de Janeiro state's restinga. The restingas of Rio de Janeiro have a large number of Paullinieae, which comprise about 65% of the total of Sapindaceae (46) in this ecosystem (Sapindaceae in Flora e Funga do Brasil 2022).

Among the 30 species studied here, around 13% are exclusively of sandy coastal plain formations, approximately 85% are also found in dense ombrophilous forests, and almost 50% also occur in seasonal semi-deciduous forests (Table 2). The high number of restinga species occurring in dense ombrophilous forest areas corroborates studies on the origin of restinga vegetation, indicating that there was a colonization of the restingas by species from adjacent forest regions, after sea level regression events that occurred in the Pleistocene (Cerqueira 2000).

Similarly, Rizzini (1979) stated that the flora of restinga must have originated from Atlantic Forest vegetation, and because this region has such a recent holocene origin, still has much influence of the Atlantic Forest and few endemic species typical of this restinga.

The richest sandy coastal plain was Cabo Frio (19 species), which is already a region known for its concentration of a large number of endemic species (Lacerda et al. 1993, Araujo 1997). A large number of Paullinieae species were found in degraded areas, which was expected since many gaps in the ridge forest were observed, thus allowing the abundance of these climbing plants (Engel et al. 1998, Lima et al. 1997). The occurrence of endemic species of the sandy coastal plains (*P. coriacea*, *S. eucardia*, *S. fluminensis* and *S. littoralis*) should be highlighted in future management of these habitats with the aim of conserving these species.

In this study we observed a large number of species in the ridge forests (27 species), which are characterized by their sharp changes in topographic elevation and tall canopy trees. These phytophysiognomic characteristics are favorable for the development of plants with a climbing habit. Although vines are important elements of the biota as a source of food for the fauna, many projects for the recovery of degraded areas implement methods that remove the climber plants to favor the growth of trees and shrubs (Rozza et al. 2007, Viani et al. 2015). In our study, we present native and threatened lianas of the restingas, and this information will be important in future forest management projects in these regions.

During the field expeditions, countless buildings under construction and fires were observed in the sandy coastal plains visited, besides sand removal. Some species of *Paullinia* and *Serjania* have records of use by the population for human food, manufacture of handicrafts and medicines (Guarim Neto et al. 2000). Taking into account this information on traditional uses, the processes of degradation occurring in the ecosystem and the values of richness/endemism of the species, it is important to emphasize the need to raise awareness among local people, so that these areas can be preserved.

Among the 30 species studied, seven were classified as threatened of extinction, while the remaining species do not face a significant risk for extinction, being classified as Least Concern. We classified *P. coriacea* and *T. restingae* as Vulnerable and *S. eucardia* as Endangered, for the first time. We are currently developing a work in collaboration with the CNCFlora Group to formalize the new classification of these three species, which will soon be published. Four other species, *Serjania fluminensis*, *S. littoralis*, *S. tenuis* and *U. glabra*, were extracted from the “Livro vermelho da flora do Brasil” (Valente et al. 2013) and the “Livro vermelho da flora endêmica do Estado do Rio de Janeiro” (Somner et al. 2018). It is suggested that future conservation projects should be undertaken for these eight threatened species studied here.

Although we focused on the species found in the sandy coastal plains of Rio de Janeiro, many species have a wider distribution in South America or are widely distributed on the Atlantic coast, with few cases restricted to Rio de Janeiro. From the analysis of the total geographic distribution of the species (Figure 2) and using the ten patterns defined by Araujo (2000) for the species of Rio de Janeiro’s sandy coastal plains, their distribution was classified as: Southeastern Atlantic Coast (*P. coriacea, P. ferruginea, S. eucardia, S. fluminensis, S. littoralis, S. tenuis* and *U. glabra*), Neotropical (*C. corindum* and *S. caracasana*), Broad Atlantic Coast (*P. micrantha, P. pseudota, P. revoluta., P. ternata, P. trigonia, P. weinmanniifolia, S. corrugata, S. cuspidata, S. dentata, S. ichthyoctona* and *T. mucronata*), Amazon-Atlantic Coast (*S. communis*), Eastern-Southern Brazil (*P. meliifolia, S clematidifolia, S. confertiflora, S. pernambuscensis, S. thoracoides* and *U. rufescens*), Northern Amazon-Atlantic Coast (*S. salzmanniana* and *U. stipitata*) and Pleistocene Arch (*T. mucronata*).

The sandy coastal plains are an ecosystem that has suffered from deforestation in addition to the constant threat by human occupation and degradation by tourism (Maciel 1990). Because of this, it is important to develop floristic and phytosociological studies to obtain knowledge of the plant species that occur in these sandy coastal plains areas in order to propose public conservation policies (Chaves et al. 2013). This study has also highlighted species that need further attention in conservation projects because of their endemic status, and provides taxonomic resources to facilitate the accurate identification of these species in future studies.

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Author Contributions

Mônica dos Santos Faria: Participated in data collection, contributed with data analysis and interpretation, made critical revisions and added intellectual content and contributed to manuscript preparation.

Nilda Marquete Ferreira da Silva: Participated in data collection, made a substantial contribution to the concept and design of the study, made critical revisions and added intellectual content.

Lilian de Andrade Brito: Contributed with data analysis and interpretation, made critical revisions added intellectual content and contributed to manuscript preparation.

Genise Vieira Somner: Made a substantial contribution to the concept and design of the study, participated in data collection, made critical revisions, added intellectual content and contributed to manuscript preparation.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to the publication of this manuscript.

Data Availability

The following online material is available for this article: Numerical list of species and list of all the studied exsiccatae (https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.3ESAAB).

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The midday sun reveals what the waters hide: *Podocnemis unifilis* Troschel, 1848 (Testudines, Podocnemididae), another exotic species in the Pantanal of Mato Grosso state

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Abstract: The process of exotic species introduction is recognized as one of the greatest threats to the ecology and economy of the planet, due to changes in interactions in native biological communities. In this sense, reporting bioinvasions is the first step to understanding its introduction process and creating strategies to mitigate possible socio-environmental damages. Here we report the first records of *Podocnemis unifilis* introduced in the Northern Pantanal, Mato Grosso, Brazil. We obtained the species' first records occasionally during 2014 and 2015. In the following years from 2016 to 2019, we carried out systematic observations through nautical incursions on the Paraguay River, between the Sepotuba River mouth and the Taiamã Ecological Station (TES). We also included third part records, when it was possible to prove the species identification and registration sites. *Podocnemis unifilis* adults, hatchling and nests were recorded at different points along the Paraguay River. Our results indicate that *P. unifilis* was introduced close to the urban nucleus of Cáceres about 30 years ago. Currently, it has an established population, recording nests and hatchling for years in a row. A particular one is its occurrence at the TES, an important natural fish nursery and refuge for the wetland fauna. Thus, continuous monitoring is suggested from *P.unifilis*, since the Pantanal's environment with several different aquatic environments, offers favorable conditions for the species population increase in the Northern Pantanal.

Keywords: *Chelonian distribution; Conservation Unit; Floodplain; Invasive fauna; Tracajá.*

O sol do meio-dia revela o que as águas escondem: *Podocnemis unifilis* Troschel, 1848 (Testudines, Podocnemididae), outra espécie exótica no Pantanal mato-grossense

Resumo: O processo de introdução de espécies exóticas é reconhecido como uma das maiores ameaças à ecologia e economia do planeta, devido às mudanças nas interações em comunidades biológicas nativas. Nesse sentido, relatar as bioinvasões é o primeiro passo para entender seu processo de implantação e criar estratégias para mitigar possíveis danos socioambientais. Aqui relatamos os primeiros registros de *P. unifilis* introduzidos no Pantanal Norte, Mato Grosso, Brasil. Obtivemos os primeiros registros das espécies ocasionalmente durante 2014 e 2015. Nos anos seguintes, de 2016 a 2019, realizamos observações sistemáticas por meio de incursões náuticas no rio Paraguai, entre a foz do rio Sepotuba e a Estação Ecológica Taiamã (TES). Incluímos também registros de terceiros, quando foi possível comprovar os locais de identificação e registro das espécies. Adultos de *Podcnemis unifilis*, filhotes e ninhos foram registrados em diferentes pontos ao longo do rio Paraguai. Nossos resultados indicam que *P. unifilis* foi introduzido próximo ao núcleo urbano de Cáceres há cerca de 30 anos. Atualmente, ela tem uma população estabelecida, registrando ninhos e filhotes por anos consecutivos. Uma em particular é a sua ocorrência no TES, importante viveiro natural de peixes e refúgio da fauna pantaneira. Assim, sugere-se o monitoramento contínuo de *P.unifilis*, uma vez que o ambiente do Pantanal com diversos ambientes aquáticos distintos, oferece condições favoráveis para o aumento da população da espécie no Pantanal Norte.

Palavras-chave: *Distribuição de quelônios; Unidade de Conservação; Várzea; Fauna invasora; Tracajá.*

Introduction

The process of exotic species introduction is recognized as one of the greatest threats to the ecology of species and the economy of the planet (Gisp 2005, Doherty et al. 2016). Its impacts, in a given environment, can vary in different degrees of severity, which has led researchers to seek to understand the relationship dynamics of invasive species with the native biological community of the invaded areas (Crystal-Ornelas & Lockwood 2020). From a harmful perspective to biodiversity, it concerns the interactions change of the of native biological communities, such as competition, predation, parasitism, changes in the food web, hybridization, which can lead to changes in the community structure and even local extinctions (Mack et al. 2000, Simberloff & Rejmáne 2011, Doherty et al. 2016, Frehse et al. 2016).

Reviewing publications on biological invasions in Brazil, Frehse et al. (2016) describe the introduction of 980 animal species in the country and point out that almost a third of these were intentionally introduced for some economic purpose. Regarding vertebrates, the occurrence of 137 invasive species in Brazil is reported, which represents about two percent of the non-marine vertebrate fauna, registered for the country (Rocha et al. 2011). Have also to consider the existence of internal bioinvasions, that is, environments occupations by national species, but not native to that environment.

Despite the increasing number of studies, aquatic bioinvasion systems are still little reported in Latin America (Pysek et al. 2008). In Brazil, from the end of the last century, scientific research on bioinvasion in aquatic systems has been intensified, increasing the introduced exotic species registration (Sousa et al. 2009). However, available data on aquatic bioinvasions are still sparse and restricted to certain species or regions (Sousa et al. 2009), which results in concern about the biodiversity of Brazilian aquatic systems.

The Pantanal biome is no exception to the occurrence of exotic species, since after human occupation, non-native plants and animals were introduced, either intentionally or accidentally, altering the natural ecological communities (Alho et al. 2011). This biome has the largest continuous wetland on the planet, with approximately 140,000 km², distributed along the Paraguay River basin (Harris et al. 2005). The main Pantanal characteristic is its alternation of habitats between flooded and dry periods, causing the lateral overflow of rivers and lakes (Alho 2008). These characteristics mainly favor the establishment of aquatic or semi-aquatic species. This biome is still poorly studied and has only two federal conservation units in the territory, the Taiamã Ecological Station (TES) and the Pantanal National Park. Therefore, the occurrence of an invasive species in these protected areas in the Pantanal is worrying, and the introduction and species reproduction in a conservation unit area is prohibited by Federal Law Nº. 9985/00 Art. 31 (Sampaio & Schmidt 2013).

Several taxonomic groups have the potential for bioinvasion including reptiles (Gisp 2005). Among reptiles, turtles are an important invasive fauna, because many species of this group are capable to adapt to a wide variety of environments and are easily established in different aquatic environments (Gisp 2005). Currently, Brazil has records of invasive turtle species, including introductions from other countries or even native species in non-native environments, as is the case with *Trachemys scripta,* an United States native species that was introduced in Brazil and today can be found for example in the central-west, northeast and south regions of the country (see Vieira & Costa 2006, Leão et al. 2011, Tortato et al. 2014, Ferreira et al. 2016). *Trachemys dorbigni*, whose original distribution is Uruguay, Northeast Argentina and the central southern portion of Rio Grande do Sul, Brazil, was recently registered as introduced of Santa Catarina and São Paulo states (see Santos et al. 2009, Tortato et al. 2014). *Trachemys scripta* and *T. dorbigni* are species officially listed as invasive in Santa Catarina state (Consema 2010). *Podocnemis expansa* and *P. unifilis* are originally described for the Orinoco, Amazonas and Araguaia-Tocantins river basins, (Vogt 2008, Santos & Blamires 2012; van Dijk et al. 2014, Cantarelli et al. 2014), however, both species have already been found in Pernambuco state (Santos et al. 2016, Souza et al. 2019) and *P. unifilis* also in Mato Grosso do Sul state (Ferreira et al. 2016, Caramaschi 2020). These are some works that demonstrate the invasive potential of the Chelonians, including species native to Brazil introduced outside their natural origin areas.

Podocnemis unifilis, popularly known as "tracajá", is one of the most widely distributed species of the genus *Podocnemis* (see Ferrara et al. 2017). It has high plasticity, occupying a wide variety of aquatic habitats, such as large rivers, lakes, meandering lakes, swamps, marshes, white, black or clear water rivers (Vogt 2008). Females of this species can reach a little more than 50 cm in length with an approximate weight of 12 kg and can spawn in several places, such as beaches and river banks (Vogt 2008). Their nests can be dug either in the sand, in the clay or a mixture of soil with plant remains (Vogt 2008, Ferrara et al. 2017). A female can spawn 15 to 30 eggs (Ferrara et al. 2017), and the offspring born after a period of 48 to 89 days (Vogt 2008, MMA 2016).

The species *P. unifilis* occurs naturally in the Amazon, Oniroco and Araguaia-Tocantins basins, covering Brazil, Colombia, Venezuela, Peru, Equator, Bolivia, Guyana, French Guiana and Suriname (Vogt 2008, Schneider et al. 2012, Rhodin et al. 2017, Ferrara et al. 2017). However, in none of Testudines' assessments, (Vogt et al. 2015, Ferrara et al. 2017, Rhodin et al. 2017) or studies with reptiles in the Northern Pantanal (see Strüssmann et al. 2011, ICMBIO 2017) reports the species *P. unifilis* or any congener to this portion of the Pantanal. Furthermore, the records of the introduction of *P. unifilis* in the Paraguay River in the state of Mato Grosso do Sul are punctual and the structure of the population species is still unknown to the Pantanal.

Thus, the present work aims to report the first records populations of *P. unifilis* for the Northern Pantanal, Mato Grosso state, Brazil, considering a case of introduction and presenting the species first records at the Taiamã Ecological Station (TES), one of two federal conservation areas in the Pantanal biome.

Material and Methods

1. *Species identification*

To identify the specimes we used it as a base taxonomic key of Amazonian chelonians (Ferrara 2017). Voucher specimens deposited in the herpetological collection of the Limnology, Biodiversity, Ethnobiology of Pantanal Research Center (CELBE), of the State University of Mato Grosso (UNEMAT) were also used to identify the species. We carried out morphological characteristics analyzes of adult specimens, hatchling turtles and eggs, found in the Paraguay River. We also got the help of Dr. Richard C. Vogt, a researcher with extensive experience in South American turtles, who confirmed the identification of the specimens through pictures.

2. *Study area*

The study area comprises a stretch of the Paraguay River of approximately 440 km long, located between the confluence of the Sepotuda and Paraguay rivers (15° 55'26.51" S and 57° 39'8.69" W), and approximately 15 km to the downstream of the Taiamã Ecological Station (17° 1'37.07" S 57° 22'38.77" W) (Figure 1). Within this stretch, the largest beach found is "Furo do touro" (16° 11'02.87" S and 57° 46'55" W), approximately 25 km, downstream from the Cáceres-MT city center. The "Furo do touro" beach is formed by white sand, with an approximate 400 m length × 105 m wide, parallel to the Paraguay River, which forms between the months of July and November with the water level reduction, in the dry season. This region constitutes the Upper Course of the Paraguay River and is described as Pantanal of Cáceres (Silva and Abdon 1998, Leandro & Souza 2012) consisting of the beginning of the Pantanal floodplain.

According to Alvares et al. (2014), the region's climate is of the Aw type (wet and dry tropical, or of savanna climate). The average annual precipitation is 1,330 mm with temperatures ranging from 10ºC in June to 38ºC in December (Resende et al. 1994). The vegetation in this area diverges, with the transition area between the Cerrado and the Amazon Forest biomes in its upstream portion (Silva-Júnior et al. 2019). In its intermediate portion, between the urban centre of Cáceres and further downstream, in TES the vegetation is characterized by typical tree formations of riparian forest, with trees belonging to the Cerrado biome or the semideciduous forest and covered fields composed of grasses, both seasonally flooded (ICMBIO 2017).

3. *Taiamã Ecological Station (TES)*

TES is located in the Mato Grosso state, in its northern portion, within the limits of the municipality of Cáceres, between the meridians W 57º 24' and W 45° 40' and parallels S 16° 48' and W 16° 58' (ICMBIO 2017). It has a total area of 11,555 ha strongly influenced by the marked seasonality of the Paraguay River hydrological regime, which leads to the structuring of a wide variety of aquatic environments such as permanent, temporary lagoons, meandering lagoons and small channels that connect lakes and river (ICMBIO 2017). TES has an important role in protecting the Pantanal biodiversity, as it is one of the few areas, institutionally, protected within the Pantanal. The station presents a series of measures that provide for the control of the impact of invasive alien species on the biological diversity of native species. However, until now *P. unifilis*

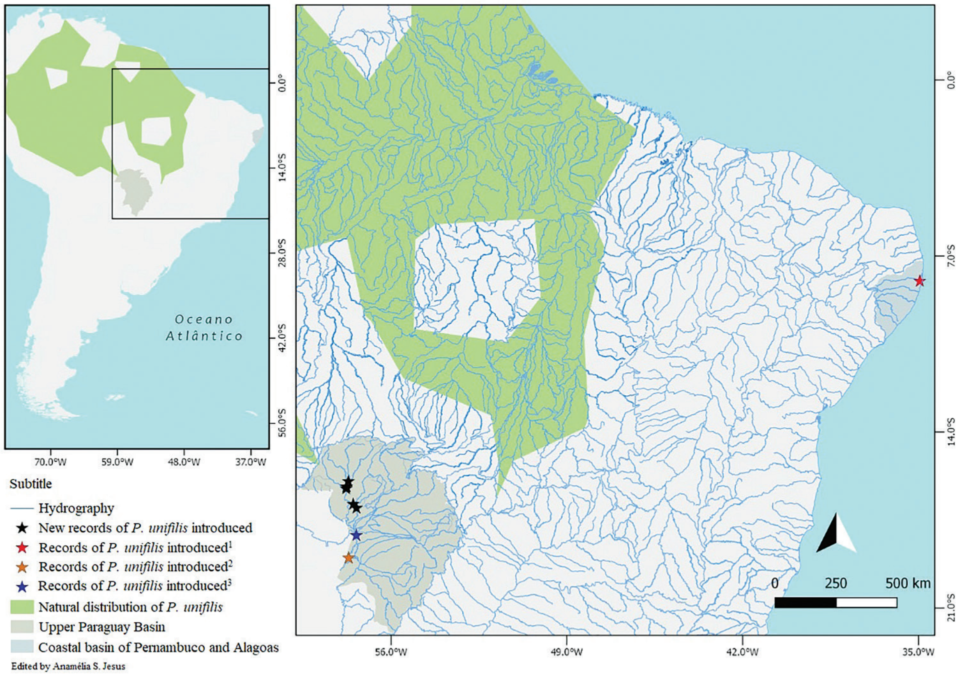

Figure 1. Distribution map of *P. unifilis*. Green polygon represents the species natural distribution as compiled by data from Ferrara et al. (2017); Red star corresponds to Santos et al. (2016); The orange star corresponds to Ferreira et al. (2016); The blue star corresponds to Caramaschi (2020); and the black stars corresponds to the new records of *P. unifilis* in the Paraguay River, Northern Pantanal, Mato Grosso state, Brazil.

is not one of the invasive species for the Northern Pantanal region and occurs in TES (ICMBIO 2017).

4. *Field data collection*

The *P. unifilis* species' first records in the Paraguay River occurred occasionally, during sport fishing activity, carried out by the researchers in the years 2014 and 2015. During the following years, from 2016 to 2019, systematic observations were made through nautical incursions courses along the Paraguay River, in the studied stretch. The incursions were carried out during the drought period between July and November. Sampling took place using the direct observation method when the specimens were found lounging on beaches. This method consists of counting animals that are exposed to the sun on logs or the river banks and lakes. This strategy has been used successfully by authors such as Pluto and Bellis (1986), Conway-Gómez (2007) and Segurado and Figueiredo (2007).

We also include records made on occasional or opportunistic collections, which occurred during the conduct of other research or fishing activity by professional fishermen and/or amateurs. These records were confirmed utilizing photos and the location of the visualization. Subsequently, these points were located on maps and the geographic coordinate was obtained.

We collected some hatchling that were found dead after birth. The collected animals were deposited in the herpetological collection at Centro de Pesquisa em Limnologia, Biodiversidade, Etnobiologia do Pantanal (CELBE), of State University of Mato Grosso (UNEMAT), (permanent license from Sistema of Autorização and Informações on Biodiversidade – SISBIO – número 8849-1).

We also carried out a historical bibliographic review in scientific articles and relief maps, observing the main natural barriers that separate the watersheds with the natural occurrence of *P. unifilis* and the Paraguay river basin, to verify a possible natural migration of the species. Finally, we analyzed historical records related to the municipality of Cáceres. Through historical documents, historians, official websites such as the city hall website, International Fishing Festival (Festival Internacional de Pesca esportiva – FIPe) and the Institute of National Artistic Historical Patrimony (Instituto of Patrimônio Histórico Artístico Nacional – IPHAN). We also obtained information from fishermen from pioneer families in the city of Cáceres.

Results

1. *Records*

In October 2014, seven nests of *P. unifilis* were observed, with eggs already hatched (Figure 2a, b and c), and 18 hatchling turtles on the "Furo do touro" beach (Figure 3).

In September 2015, 22 adult individuals were sighted near the confluence of the Sepotuba River with the Paraguay River. In October 2017, two young specimens of *P. unifilis* were accidentally collected from fishing nets, while researchers from the State University of Mato Grosso collected fish in a bay downstream from the beach "Furo do touro", these animals were collected and deposited in the herpetology collection at the CELBE (CELBE-Q-0001; CELBE-Q-0002). At the end of August 2019, we registered four nests, with about 26 eggs each, on a beach 2 km upstream of the "Furo do touro" beach. In October 2019, the largest number of nests was observed, where we observed traces of 85 nests with eggs already hatched on the "Furo do touro" beach. In that same month, we recorded an adult specimen of *P. unifilis* looming on a dirt and clay beach downstream from TES. Besides, between 2016 and 2019, adult and young specimens were regularly observed in bays and on beaches along the "Furo do touro" beach and the mouth of the Sepotuba river, along the course of the Paraguay river, (Figure 4). In November 2019, two specimens were recorded lounging on a beach within the perimeters of TES. Four nests were also recorded, which indicates that the species is established and reproducing within the conservation unit.

2. *Historical surveys*

According to information from residents, the specimens were introduced into the Paraguay River in the 1970s, released near the

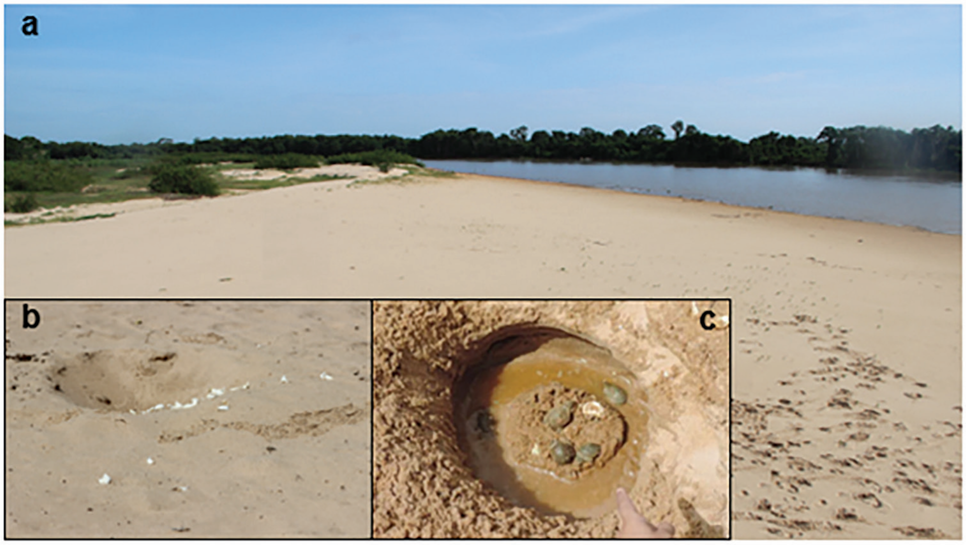

Figure 2. (a) "Furo do Touro" beach, on the Paraguay River, in the Pantanal of Cáceres, Mato Grosso state; (b and c) Traces and nest of *P. unifilis*, found on the "Furo do touro" beach in October 2014.

Photographs by Dionei J. Silva.

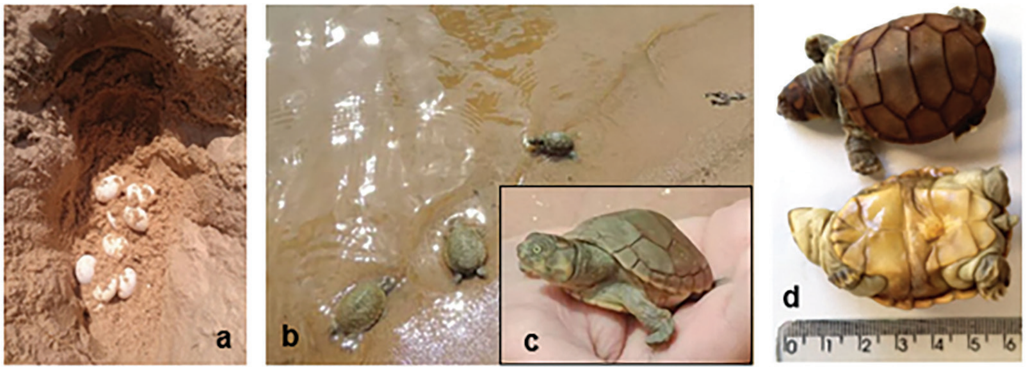

Figure 3. (a) Nest with eggs, (b, c) Live baby *P. unifilis* e (d) dead baby turtles of *P. unifilis* on "Furo do touro" beach, in the Pantanal of Cáceres, Mato Grosso state, Brazil. Photographs by Amabilen Furlan; Claumir For Review Only Muniz and Dionei Silva.

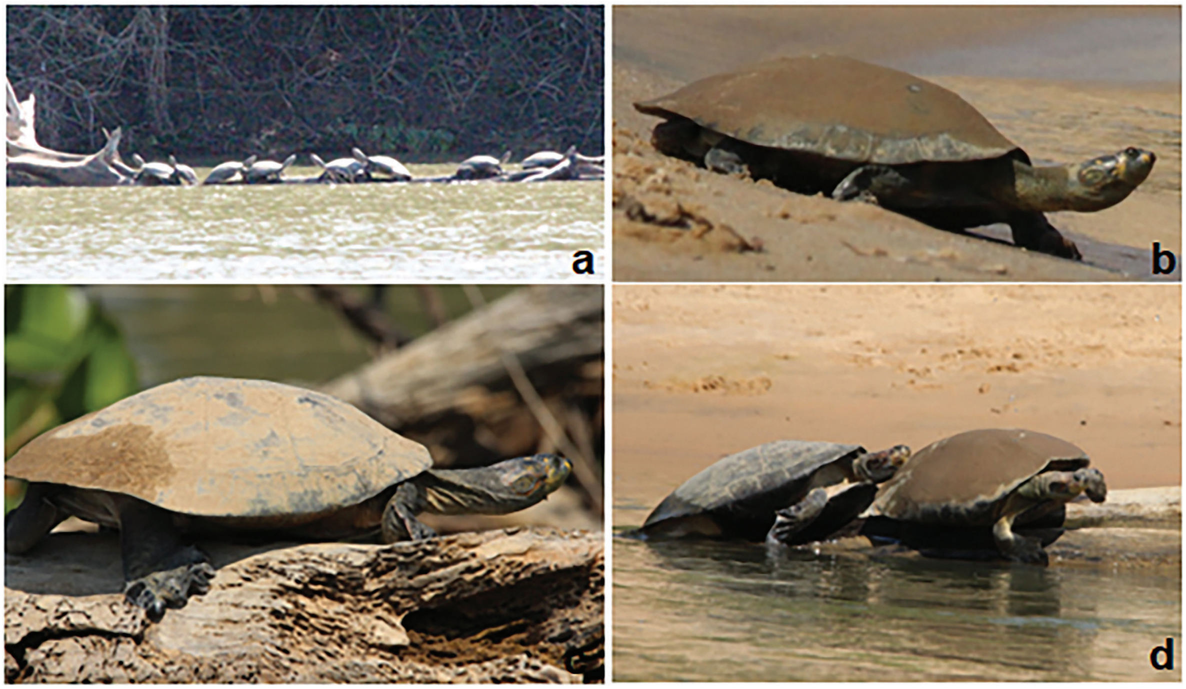

Figure 4. (a–d) Records of specimens of *P. unifilis*, young and adult on logs and beaches along the study area in the Pantanal de Cáceres, Mato Grosso, Brazil. Photographs by Claumir Muniz and Dionei J. Silva.

urban center of the municipality of Cáceres. The first specimens were reportedly brought from the Amazonas state by the Fanaia family patriarch (family report). These animals remained close to the urban nucleus, where there are reports from residents that around 1985 some specimens were recaptured and placed in a fountain, located in the Major João Carlos square, where they remained for years (residents' report).

Discussion

1. *Migration hypothesis*

The hypothesis of *P. unifilis* specimens migration to this portion of the Paraguay River from the Guaporé River, which belongs to the Amazon basin where the species presence is recorded (Vogt 2008, Schneider et al. 2012, Rhodin et al. 2017, Ferrara et al. 2017), is initially discarded. The possibility is unlikely considering that there is no direct connection between the Paraguay and Guaporé rivers and that the distance between them, at the nearest record point, is approximately 160 km.

Due to the residual plateaus, it is not considered that the Paraguay River basin is connected to the Guaporé River basin (MMA 2006). However, the Upper Paraguay-Guaporé depressions are indirectly connected by a slightly sloping segment, where the distance between the Guaporé River and the Upper Jauru River basins is approximately 5 km (Ross 1985), where Jauru River is an important tributary of the Paraguay River.

By the aforementioned connection, a remote possibility of transposing the species from the Guaporé basin to the Paraguay River basin could be considered, however, there are no species occurrence records in these regions (Vogt 2008, Schneider et al. 2012, Ferrara et al.

2017, Rhodin et al. 2017). Likewise, there are no records of any floods that have established water contact between the two basins. Another point that rules out natural migration is the fact that our *P. unifilis* records in the Paraguay River are concentrated close to the urban nucleus of the municipality of Cáceres and the record closest points of *P. unifilis* in the Guaporé River (Ferrara et al. 2017) are about 425 km away from our records (see Figure 1). Migration from another basin is also ruled out, since the closest occurrence point of *P. unifilis*, in our records, besides the Guaporé River, is in the Araguaia River, in locations that are about 650 km from this portion of the Paraguay River.

2. *Introduction hypothesis*

The municipality of Cáceres was formed from a small village named Vila Maria do Paraguay, founded in 1778, in the Pantanal of the Mato Grosso state (IPHAN 2020). At the end of the 19th century, Cáceres played a prominent role in the state economy mainly because of its location, on the banks of the Paraguay River, whereby many means of transport, exported and imported varied commodities (Pinho 2013). However, with improvements in the construction of the road network, especially with the construction of the "Marechal Rondon" bridge over the Paraguay River in the 1950s (Almeida 2014) connecting Cáceres to the western region of the state and part of the northern region of Brazil (Silva et al. 2007), made it possible to increase land transport to the city. Subsequently, the construction of the bus terminal in the center of Cáceres, as well as the improvement of the old airport called "Manoel Cuiabano" (Almeida 2014) provided Cáceres with a greater flow of people and objects.

So, considering that: (1) the majority of *P. unifilis* nest and adult records in the Northern Pantanal, are close to the urban center of Cáceres and; (2) taking into account the fact that tracajás return to the same nesting sites and feeding lakes (Andrade et al. 2015), and; (3) distance and geographical barriers in its area of occurrence and; (4) the historical reports of residents, it is palpable to assume that *P. unifilis* was introduced close to the urban center of Cáceres, in the recent past.

This hypothesis is reinforced by the fact that in conversations with fishermen and riverside dwellers and residents, we did not obtain reports of turtle registration before the 1950s. The recent introduction is also reinforced by studies with the distribution of turtles (Van Dikj et al. 2014, Vogt et al. 2015, Ferrara et al. 2017, Rhodin et al. 2017), and studies with herpetofauna in the Pantanal (Strüssmann et al. 2011, ICMBIO 2017) there is no indication of the species for the Northern Pantanal so far. This may be related to the fact that the species took several years to reach a population size in which individuals could be noticed by the population.

3. *Podocnemis unifilis in the Taiamã Ecological Station*

After the species records in November 2019, we no longer obtained records of it within the ecological station. However, taking into account its high displacement capacity (IBAMA 2016), and our species records both downstream and upstream of the ecological station, it is reasonable to assume that *P. unifilis* occurs, even in low density, in the Paraguay River in the entire extension of the Taiamã Ecological Station. The fact that the species is reproducing inside the conservation unit is worrying, as it is an area intended for the reproduction and conservation of typical Pantanal species. The presence of an invasive species can directly generate competition with native species within the conservation unit, such as the aquatic Testudines *Acanthochelys macrocephala* and *Phrynops geoffroanus* and the pacu fish *Piaractus mesopotamicus*, which has a diet similar to *P. unifilis* and finds an important natural nursery in Taiamã (ICMBIO 2017).

4. *Introduction problem*

Chelonians have been used as an important food source by traditional Amazonian peoples for hundreds of years (Vogt 1994, Eisemberg et al. 2019, Stanford et al. 2020). Turtle and eggs consumption is part of the Amazon culture (Andrade et al. 2015). These explorations have aimed not only at sustainable consumption of turtles but also at illegal trade in large urban centers (Fachín-Terán 1999, Fachín-Terán et al. 2000, Stanford et al. 2020) leading to super exploration. This is one of the main factors that make turtles be considered one of the most threatened animal groups on the planet (Vogt 2008, IBAMA 2016, Ferrara et al. 2017, Stanford et al. 2020).

In this new introduction area of *P. unifilis* in the Northern Pantanal, the consumption of tracajás and their eggs is not cultural, therefore, there is a tendency for the population to grow higher than those recorded in native habitats. Also, species' natural characteristics, such as high longevity and displacement capacity (IBAMA 2016), and its reproductive capacity, laying 15 to 30 eggs per year (Ferrara et al. 2017), favor the population increase. The favoring of the establishment and population increase of *P. unifilis* in the studied region is also due to the Pantanal environmental characteristics, which has several aquatic habitats suited to the characteristics of the species. In this way, areas of the Pantanal may allow good adaptation of this species in the northern portion of the Pantanal. In addition, its ability to move is also a cause for concern, as a recent record of *P. unifilis* for the Serra do Amolar region, Paraguay river basin (Caramaschi 2020), might be the result of migration of this population described here, given that this record is located about 120 km downstream of the points at the Taiamã Ecological Station.

Thus, the occurrence of *P. unifilis* in the Pantanal brings ecological concerns since, in most cases, exotic species constitute threats to biodiversity, as they can modify the structure of the local community, changing the habitat and restructuring the community through new interspecific interactions (CrystalOrnelas & Lockwood 2020, Frehse et al. 2016). In this way, it can cause extinctions of native species (Cadi and Joly 2004, Alho & Gonçalves 2005, Alho 2008, Alho et al. 2011, Garcia-Diaz et al. 2015).

Although the results of an introduction are difficult to predict, the most predictable consequences are competition with closely related species (Frehse et al. 2016). In studies with the introduction of turtles, Cadi & Joly (2003) observed that *Emys orbicularis* ended up changing its thermoregulation habits, giving the best places for sunbathing to the species *Trachemys scripta elegans*, which is an introduced species. Finally, Cadi and Joly (2004) observed that the introduction of *T. s. elegans* caused weight loss and high mortality in the populations of *E. orbicularis*. Extensions of results like these can be aggravated for the Pantanal, as the Testudines constitute one of the most poorly sampled groups in this biome (Strüssmann et al. 2011) and there are still many doubts and disagreements about the distribution of aquatic Testudines in the Pantanal. However, when considering the different approaches to invasive species (Frehse et al. 2016), it is reasonable to predict that *P. unifilis* can cause direct competition with species of aquatic Testudines occurring in the Pantanal biome such as *Acanthochelys macrocephala* and *Phrynops geoffroanus*. Since with the introduction of *P. unifilis* there was a densification of individuals, competing for food and spawning grounds, since, for example, the diet of *P. unifilis* and *P. geoffroanus* are similar and we have already recorded *P. unifilis* and *P. geoffroanus* in a radius of 1 meter on a beach of the Paraguay River (personal communication), thus suggesting that *P. unifilis* can compete with native species in the wetland.

Several invasive species are registered in the Pantanal, such as the "Porco do mato" *Sus scrofa* (Linnaeus, 1758), the golden mussel *Limnoperna fortunei* (Dunker 1857), the "tucunaré", Amazonian fish, *Cichla* cf. *ocellaris* Bloch and Schneider 1801, the "tambaqui from the Amazon", *Colossoma macropomum* Cuvier, 1816, in addition to the various domesticated animals and grasses (Alho et al. 2011). *Podocnemis unifilis* starts to constitute the first exotic chelonian known to the Pantanal, whose ecological interactions may cause effects that are quickly visible to the biodiversity of the Pantanal. However, many of them will only be observed in the long term, which requires continuous monitoring of this species in the region.

Our records are the first of this kind for the Northern Pantanal, including Taiamã Ecological Station. We found that the species was introduced in this region of the Pantanal in the recent past and is currently established since it has been reproducing in the place for several years. The typical environment structure with large rivers, where forests are flooded during the flood season, the presence of large meanders, lakes and white sand beaches during the dry season are characteristics of suitable habitats for the species, ensuring conditions of the permanent establishment in the region.

If the presence of the species *Podocnemis unifilis* in this area of the Pantanal constitutes, in fact, an impact factor on the structure of the local communities, the registration of the species and its reproduction at the Taiamã Ecological Station, which is considered a nursery for several species of fish, is worrying. These facts point to the necessity for proposing research and studies seeking to understand how *P. unifilis* is structured in the Pantanal, seeking to understand its ecological aspects, such as reproduction, main predators, competition with native species and reproduction. Local monitoring programs are also essential to detect the evolution of the species' occupation and distribution and to avoid possible damages.

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Author Contributions

Odair Diogo da Silva: Substantial contribution to the concept and design of the study, contribution to the analysis and interpretation of data, contribution to the preparation of the manuscript, contribution to the critical review, adding intellectual content.

Joselaine Souto Hall Silva: Contribution to the critical review by adding intellectual content.

Vancleber Divino Silva-Alves: Contribution to critical review, adding intellectual content.

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Eder Correa Fermiano: Contribution to the preparation of the manuscript.

Claumir César Muniz: Contribution to data collection, contribution to critical review adding intellectual content.

Áurea Regina Alves Ignácio: Contribution to the preparation of the manuscript.

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Paulo César Vênere: Contribution to the analysis and interpretation of data.

Manoel dos Santos Filho: Contribution to data collection, contribution to critical review adding intellectual content.

Dionei José da Silva: Substantial contribution to the concept and design of the study, contribution to the analysis and interpretation of data, contribution to the preparation of the manuscript, contribution to the critical review, adding intellectual content.

Conflicts of Interest

We have no conflicts of interest between the authors.

Ethics

The authors affirm that they followed all ethical criteria regarding the preparation of this manuscript.

Data Availability

We understand the importance of the topic and agree to deposit information in appropriate places.

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Taxonomic Review

Fish species of the Paraiba River estuary, northeastern Brazil

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Abstract: The Paraiba River estuary is the largest and most important estuary of Paraiba state, northeastern Brazil. It is under intense environmental degradation by the surrounding human population, and possibly several fish species are at risk in this habitat. Scientific sampling of the ichthyofauna started in the late 1970's and proceeded until recently. We present a list of fish species captured in this estuary, based on voucher specimens housed at the Federal University of Paraiba collection. Four orders of Chondrichthyes and 26 orders of Osteichthyes were identified. A total of 187 fish species, including eight species of Chondrichthyes and 179 Osteichthyes, with 123 genera and 57 families were identified. Perciformes dominated in terms of richness (32 species), followed by Acanthuriformes and Clupeiformes. Comparing estuaries along the Brazilian northeastern coast and considering our large time sampling span, a higher richness would be expected. According to the IUCN Red List, *Urotrygon microphthalmum* is considered Critically Endangered and more seven species are classified as Vulnerable: *Rhizoprionodon porosus, Rhinoptera bonasus, Megalops atlanticus, Epinephelus itajara, Hyporthodus niveatus, Lutjanus cyanopterus,* and *Cynoscion acoupa*. Three of these species also appear in the same category in the threatened Brazilian list, all of which have declining population trends. Concerning the Elasmobranchii, *Carcharhinus porosus* is listed as Critically Endangered in our country and globally. This inventory organizes and broadens knowledge on the fish community that occurs in this important ecosystem, with inferences about life habits, ecological guilds and conservation status of the fish species.

Keywords: *richness, life habits, ecological guilds, conservation status, estuarine ecosystem.*

Espécies de peixes do estuário do Rio Paraíba, nordeste do Brasil

Resumo: O estuário do Rio Paraíba, maior e mais importante do estado da Paraíba, nordeste do Brasil, sofre intensa degradação ambiental pela população humana no seu entorno, e possivelmente várias espécies de peixes estão ameaçadas neste habitat. Nós apresentamos uma lista de espécies de peixes capturadas neste estuário, com base em espécimes tombados na coleção da Universidade Federal da Paraíba. Quatro ordens de Chondrichthyes e 26 ordens de Osteichthyes foram identificadas. Um total de 187 espécies de peixes foi registrado, incluindo oito espécies de Chondrichthyes e 179 Osteichthyes, com 123 gêneros e 57 famílias. Em relação à riqueza, Perciformes dominou com 32 espécies, seguido por Acanthuriformes e Clupeiformes. Comparando estuários ao longo do nordeste brasileiro e considerando nosso longo período de amostragens, seria esperada uma riqueza maior. De acordo com a lista vermelha da IUCN, *Urotrygon microphthalmum* é tida como Criticamente Ameaçada e mais sete espécies são classificadas como Vulnerável: *Rhizoprionodon porosus, Rhinoptera bonasus, Megalops atlanticus, Epinephelus itajara, Hyporthodus niveatus, Lutjanus cyanopterus* e *Cynoscion acoupa*. Três dessas espécies também aparecem na mesma categoria na lista brasileira de espécies ameaçadas, tendo todas elas, suas populações em declínio. Em relação aos Elasmobranchii, *Carcharhinus porosus* é listada como Criticamente Ameaçada em nosso país e globalmente. Esse inventário abrange e organiza o conhecimento acerca da comunidade de peixes que ocorre nesse importante ecossistema, com inferências sobre hábitos de vida, guildas ecológicas e status de conservação das espécies de peixes.

Palavras-chave: *riqueza, hábitos de vida, guildas ecológicas, conservação, ecossistema estuarino.*

Introduction

Estuaries have been considered an important ecological system due to the abundance of resources, representing spawning, development, recruitment, and connectivity areas for many species. They provide a rich habitat for the development of various organisms, including fish species. They are important to the proper functioning of the coastal aquatic environment by contributing available biomass in the food chain and they also provide important food resources for human consumption and source of income, mainly for the artisanal fishing community (Martins & Vendel 2014, Mérigot et al. 2017).

Estuaries throughout the world, especially in the tropics, have experienced high degrees of anthropic pressure. Similarly, estuarine fish species are often impacted by urban and industry effluents and agricultural activities (McLusky & Elliott 2004, Barletta et al. 2010), mainly juveniles, that use this environment as shelter and nursery grounds (Blaber et al. 2000).

Estuarine ichthyofauna exhibits considerable variation in terms of morphology and biology and its species inhabit or migrate among marine, estuarine, and freshwater environments (Elliott et al. 2007). The knowledge on the taxonomy and ecology of the species that occur in the estuarine system is essential (Mérigot et al. 2017), because it provides information about local diversity, and represents an important tool in the management and conservation of both species and ecosystem (González-Acosta et al. 2018).

The Paraiba River estuary is the largest and most important estuary of Paraiba state (Dominguez et al. 2016). Initial studies on the composition of the ichthyofauna of this estuary were conducted within the scope of the Estuary Project, developed between 1978 and 1980 with funds from FINEP. A total of 106 species were reported in this work, including also those collected in reef environments adjacent to the estuary mouth (Rosa 1980a). Another research project in fish ecology, funded by Science Without Borders/CAPES between 2012–2015 represented a major sampling effort of the fish assemblages along the salinity gradient of two estuaries in Paraiba, but no separate species list was provided for each one (Dolbeth et al. 2016).

Nonetheless, published results on the local fish taxonomic composition are partial and outdated (Rosa 1980b, Dolbeth et al. 2016). Therefore, we aimed in the present study to provide a first and comprehensive list of the fish species recorded in the Paraiba River estuary, Paraiba, Brazil, based on vouchers housed at the fish collection of the Universidade Federal da Paraiba (UFPB), collected along the entire estuary extension. Although sampling effort was highly irregular over time, as well as the use of different fishing gear in sampling, the results provide important insights on the changes in the fish community composition that occurred over 40 years.

Material and Methods

1. *Study area*

The Paraiba River estuary (34º47'07" to 34º55'37" S and 06º56'58" to 07º08'18" W) has a length of approximately 22 km and a width of 2.2 km at the mouth (Figure 1). The estuarine system itself has 3,012 ha and covers the municipalities of Santa Rita, Bayeux, João Pessoa, Lucena, and Cabedelo (Teixeira et al. 2020) and drains a fluvial-marine plain formed by the Paraiba River and its major tributaries: Sanhauá, Paroeira, Mandacaru, Tibiri, Tambiá, Ribeira, and Guia. The depth in the main channel is 3.0 m, except near the harbor, where frequent dredging maintains a depth of 11.0 m (Alves et al. 2016, Dolbeth et al. 2016). Along the estuary, small sandbanks are observed during low tide. The southern margin of the estuary mouth harbors a large rocky breakwater, which provides habitat for several reef fish species. Samples were collected mostly at the Paraiba main channel and at the Sanhauá and Mandacaru tributaries. Fishes from the adjacent marine environment to the south of the estuary in the Cabedelo municipality were not included in the checklist. On the other hand, fishes on the adjacent marine environment at the Lucena municipality, which borders

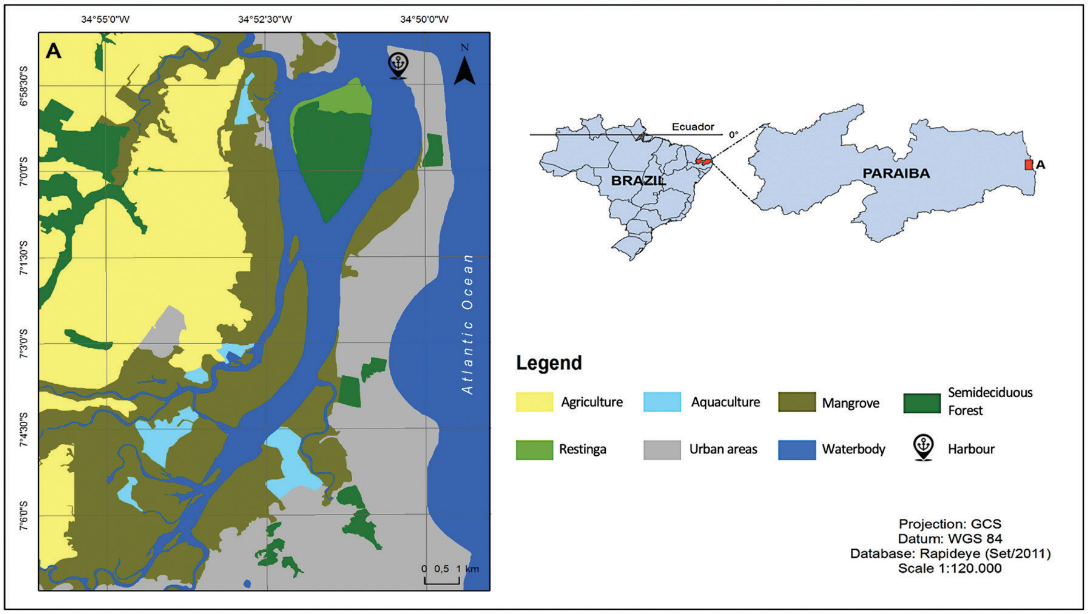

Figure 1. Paraiba River estuary, Paraiba, Brazil.

the northern margin of the estuary, were considered in the checklist, due to great influence of the estuarine waters in this environment and the northern direction of the coastal drift current.

The Paraiba River basin drains a semi-arid region formed by the Caatinga biome and a thin coastal strip covered by Atlantic Forest remains and narrow strips of mangroves (Alves et al. 2016, Teixeira et al. 2020). Regarding land use and cover, this region is dominated by agriculture (14618 ± 582 ha), urban (9414 ± 470 ha), and mangrove (7842 ± 264 ha) (Teixeira et al. 2020). In fact, the Paraiba River estuary is surrounded by a large territory of urban areas with plus than one million inhabitants, shrimp aquaculture areas, and extensive sugar cane plantations that have almost completely replaced the original rain forest (Santana et al. 2018).

These economic activities together with the impact of urban wastewater, have been leading to an intense environmental degradation of the estuary. Recent studies have shown a higher degree of human disturbance in the Paraiba River estuary, such as a higher nutrient enrichment, microplastic pollution, and revealed a high activity of a cellular detoxification by fishes, which indicates a high concentration of pollutants in the water of the Paraiba River estuary (Alves et al. 2016, Dolbeth et al. 2016, de Moura et al. 2016, Santos et al. 2017, Vendel et al. 2017, David et al. 2018, Macêdo et al. 2019).

2. *Fish data*

The species listed in the Table 1 were identified following Figueiredo & Menezes (1978, 1980, 2000), Menezes & Figueiredo (1980, 1985), Britski et al. (1984), Allen (1985), Harrison (2002), Marceniuk (2005), Marceniuk & Menezes (2007), McBride et al. (2010), Lucena & Soares (2016), Marceniuk et al. (2017, 2019b, 2020), Chao et al. (2021). The fish species nomenclature followed Fricke et al. (2022) and the taxonomic order according to Nelson et al. (2016), except for Triportheidae and Labridae. The examined specimens are from the fish collection of the Federal University of Paraiba (UFPB); for more details see the 895 voucher numbers to listed species in Supplementary Material (Table A.1). The richest taxa were plotted using Prism 9.2.0 (Graphpad Software, CA).

The species were grouped into the following ecological guilds (modified from Elliott et al. 2007): R = resident: species that complete their whole life cycle within the estuarine environment; M = marine migrants: species that remain in the estuary for a trophic or reproductive ecophase; Om = Occasional marine and Of = Occasional freshwater, whose presence in the estuary is irregular. This classification includes data from literature about migration, life cycle, frequency by which the species occur in estuaries or personal observations. The same was applied

Table 1. List of fish species sampled in the Paraiba River estuary, the conservation status follows last-known IUCN's assessment (2022), their ecological guild, and life habit. Asterisk **(*)** corresponds to species with data based on direct personal observations and plus **(+)** represents exotic species. **Ecological guild**: (R) Resident, (M) Marine migrant, (Om) Marine occasional, (Of) Freshwater occasional. **Life habit**: (E) Estuarine, (Sb) Soft bottom, (R) Reef, (Wc) Water column, (P) Pelagic, (PB) Benthopelagic, (B) Benthic. **Ref**: references to ecological guild, life habits and previous citations in the Paraiba River estuary.

Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
CHONDRICHTHYES CARCHARHINIFORMES **Carcharhinidae**				
Carcharhinus porosus (Ranzani, 1839)	CR	Om	PB	1
Rhizoprionodon porosus (Poey, 1861)	VU	Om	PB	1
TORPEDINIFORMES				
Narcinidae				
Narcine brasiliensis (Olfers, 1831)	NT	Om	B	1,8
PRISTIFORMES				
Rhinobatidae				
Pseudobatos percellens (Walbaum, 1792)	EN	Om	B	1
MYLIOBATIFORMES				
Dasyatidae				
Hypanus guttatus (Bloch & Schneider, 1801)	NT	Om	R	1,8
Hypanus marianae (Gomes, Rosa & Gadig, 2000)	EN	Om	R	1,5
Urotrygonidae				
Urotrygon microphthalmum (Delsman, 1941)	CR	Om	B	1
Myliobatidae				
Rhinoptera bonasus (Mitchill, 1815)	VU	Om	B	1
OSTEICHTHYES ELOPIFORMES **Elopidae**				
Elops smithi (McBride et al., 2010)	DD	Om	P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Megalopidae				
Megalops atlanticus (Valenciennes, 1847)	VU	Om	E, R, Wc, P	8
ALBULIFORMES				
Albulidae				
Albula vulpes (Linnaeus, 1758)	NT	Om	E, R, PB	2,8
ANGUILLIFORMES				
Muraenidae				
Gymnothorax funebris (Ranzani, 1839)	LC	Om	E, R, B	2
Gymnothorax moringa (Cuvier, 1829)	LC	Om	E, R, B	2
Gymnothorax ocellatus (Agassiz, 1831)	LC	Om	E, Sb, B	2,8
Ophichthidae				
Myrichthys ocellatus (Lesueur, 1825)	LC	Om	B	2
Myrophis punctatus (Lütken, 1852)	LC	Of	PB	4
Ophichthus cylindroideus (Ranzani, 1839)	LC	Om	E, Sb, PB	2
CLUPEIFORMES				
Pristigasteridae				
Chirocentrodon bleekerianus (Poey, 1867)	LC	Om	E, Wc, P	2,8
Odontognathus mucronatus (Lacépède, 1800)	LC	Om	E,Wc, P	2
Pellona harroweri (Fowler, 1917)	LC	Om	E, Wc, P	2
Engraulidae				
Anchoa januaria (Steindachner, 1879)	LC	Om	E, R, Wc, P	2,8
Anchoa lyolepis (Evermann & Marsh, 1900)	LC	R	E, R, Wc, P	2
Anchoa marini (Hildebrand, 1943)	LC	Om	E, R, Wc, P	8*
Anchoa spinifer (Valenciennes, 1848)	LC	Om	E, R, Wc, P	8,*
Anchoa tricolor (Spix & Agassiz, 1829)	LC	Om	E, R, Wc, P	*
Anchovia clupeoides (Swainson, 1839)	LC	R	E, R, Wc, P	2,8
Anchovia surinamensis (Bleeker, 1865)	LC	R	E, R, Wc, P	2
Anchoviella lepidentostole (Fowler, 1911)	LC	R	E, R, Wc, P	2
Cetengraulis edentulus (Cuvier, 1829)	LC	R	E, R, Wc, P	2,8
Lycengraulis grossidens (Agassiz, 1829)	LC	R	E, R, Wc, P	2,8
Clupeidae				
Harengula clupeola (Cuvier, 1829)	LC	R	E, R, Wc, P	2
Lile piquitinga (Schreiner & Miranda Ribeiro, 1903)	LC	R	E, R, Wc, P	*
Opisthonema oglinum (Lesueur, 1818)	LC	R	E, R, Wc, P	2,8
Rhinosardinia cf. *bahiensis* (Steindachner, 1879)	LC	R	E, Wc, P	2
Sardinella brasiliensis (Steindachner, 1879)	DD	R	E, R, Wc, P	2
CHARACIFORMES				
Curimatidae				
Steindachnerina notonota (Miranda Ribeiro, 1937)	–	Of	WC, P	*
Characidae				
Psalidodon fasciatus (Cuvier, 1819)	LC	Of	Wc, P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Triportheidae				
Triportheus guentheri (Garman, 1890)	–	Of	Wc, P	*
SILURIFORMES				
Ariidae				
Aspistor luniscutis (Valenciennes, 1840)	–	R	E, Sb, PB	2,7
Bagre filamentosus (Swainson, 1839)	–	M	E, Sb, PB	8,*
Cathorops agassizii (Eigenmann & Eigenmann, 1888)	–	R	E, B	2,7
Cathorops spixii (Agassiz, 1829)	–	R	E, Sb, PB	2,7
Notarius parmocassis (Valenciennes, 1840)	–	R	E, Sb, PB	*
Sciades herzbergii (Bloch, 1794)	LC	R	E, Sb, PB	2,7,8
Sciades proops (Valenciennes, 1840)	–	R	E, Sb, PB	2,7,8
AULOPIFORMES				
Synodontidae				
Synodus foetens (Linnaeus, 1766)	LC	M	E, Sb, R, PB	2,8
Synodus synodus (Linnaeus, 1758)	LC	M	R, B	2
BATRACHOIDIFORMES				
Batrachoididae				
Porichthys kymosemeum (Gilbert, 1968)	–	Om	E, Sb, R, B	2,8
Thalassophryne nattereri (Steindachner, 1876)	LC	Om	E, Sb, R, B	2
GOBIIFORMES				
Eleotridae				
Dormitator maculatus (Bloch, 1792)	LC	Om	E, B	2,8
Eleotris pisonis (Gmelin, 1789)	LC	Om	E, B	2
Erotelis smaragdus (Valenciennes, 1837)	LC	R	E, B	4,8
Guavina guavina (Valenciennes, 1837)	LC	Om	E, B	2,8
Gobiidae				
Bathygobius soporator (Valenciennes, 1837)	LC	Om	E, R, B	2,8
Ctenogobius boleosoma (Jordan & Gilbert, 1882)	LC	Om	E, R, B	2
Ctenogobius shufeldti (Jordan & Eigenmann, 1887)	LC	Om	E, R, B	2
Ctenogobius smaragdus (Valenciennes, 1837)	LC	Om	E, R, B	2,8
Ctenogobius stigmaticus (Poey, 1860)	LC	Om	E, R, B	2,8
Gobioides broussonnetii (Lacépède, 1800)	LC	Om	E, B	2,8
Gobionellus oceanicus (Pallas, 1770)	LC	Om	E, B	2,8
Gobionellus stomatus (Starks, 1913)	–	Om	E, B	8,*
Microgobius meeki (Evermann & Marsh, 1899)	LC	Om	E, B	2
MUGILIFORMES				
Mugilidae				
Mugil brevirostris (Miranda Ribeiro, 1915)	–	M	E, R, Wc, P	2
Mugil curema (Valenciennes, 1836)	LC	M	E, R, Wc, P	2,8
Mugil curvidens (Valenciennes, 1836)	–	M	E, R, Wc, P	2
Mugil liza (Valenciennes, 1836)	DD	M	E, R, Wc, P	2
CICHLIFORMES				
Cichlidae				
Oreochromis niloticus (Linnaeus, 1758) +	LC	Of	Wc, P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
ATHERINIFORMES				
Atherinopsidae				
Atherinella blackburni (Schultz, 1949)	LC	Om	R, Wc, P	*
Atherinella brasiliensis (Quoy & Gaimard, 1825)	LC	R	E, R, Wc, P	2
BELONIFORMES				
Hemiramphidae				
Hemiramphus brasiliensis (Linnaeus, 1758)	LC	R	E, R, Wc, P	2,8
Hyporhamphus roberti (Valenciennes, 1847)	LC	R	E, R, Wc, P	2
Hyporhamphus unifasciatus (Ranzani, 1841)	LC	R	E, R, Wc, P	2,8
Belonidae				
Strongylura marina (Walbaum, 1792)	LC	R	E, R, Wc, P	2
Strongylura timucu (Walbaum, 1792)	LC	R	E, R, Wc, P	2,8
CYPRINODONTIFORMES				
Poeciliidae				
Poecilia reticulata (Peters, 1859**)** +	LC	Of	Wc, P	*
Poecilia vivipara (Bloch & Schneider, 1801)	–	Of	Wc, P	*
CARANGIFORMES				
Echeneidae				
Echeneis naucrates (Linnaeus, 1758)	LC	M	R, Wc, P	2,8
Carangidae				
Caranx bartholomaei (Cuvier, 1833)	LC	M	E, R, Wc, P	2
Caranx hippos (Linnaeus, 1766)	LC	M	E, R, Wc, P	2
Caranx latus (Agassiz, 1831)	LC	M	E, R, Wc, P	2,8
Chloroscombrus chrysurus (Linnaeus, 1766)	LC	M	E, Wc, P	2
Oligoplites palometa (Cuvier, 1833)	LC	M	E, Wc, P	2
Oligoplites saliens (Bloch, 1793)	LC	M	E, R, Wc, P	2
Oligoplites saurus (Bloch & Schneider, 1801)	LC	M	E, R, Wc, P	2,8
Selar crumenophthalmus (Bloch, 1793)	LC	M	R, Wc, P	2
Selene setapinnis (Mitchill, 1815)	LC	M	E, R, Wc, P	2
Selene vomer (Linnaeus, 1758)	LC	M	E, R, Wc, P	2,8
Trachinotus falcatus (Linnaeus, 1758)	LC	M	E, R, Wc, P	2
Trachinotus goodei (Jordan & Evermann, 1896)	LC	M	E, R, Wc, P	2
ISTIOPHORIFORMES				
Sphyraenidae				
Sphyraena barracuda (Edwards, 1771)	LC	Om	E, R, Wc, P	2,8
PLEURONECTIFORMES				
Paralichthyidae				
Citharichthys macrops (Dresel, 1885)	LC	Om	E, Sb, R, B	2
Citharichthys cf. *arenaceus* (Evermann & Marsh, 1900)	LC	R	E, Sb, R, B	2
Citharichthys spilopterus (Günther, 1862)	LC	R	E, Sb, R, B	2,8
Etropus crossotus (Jordan & Gilbert, 1882)	LC	R	E, Sb, R, B	2
Paralichthys brasiliensis (Ranzani, 1842)	LC	Om	E, Sb, R, B	2
Syacium micrurum (Ranzani, 1842)	LC	Om	E, Sb, R, B	2

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Bothidae				
Bothus ocellatus (Agassiz, 1831)	LC	Om	Sb, R, B	2,8
Achiridae				
Achirus achirus (Linnaeus, 1758)	LC	Om	E, Sb, B	2,8
Achirus declivis (Chabanaud, 1940)	LC	Om	E, Sb, B	2
Achirus lineatus (Linnaeus, 1758)	LC	R	E, Sb, B	2
Trinectes microphthalmus (Chabanaud, 1928)	LC	R	E, Sb, B	2
Trinectes paulistanus (Miranda Ribeiro, 1915)	LC	M	E, Sb, B	2
Cynoglossidae				
Symphurus plagusia (Bloch & Schneider, 1801)	LC	M	E, Sb, B	2,8
Symphurus tessellatus (Quoy & Gaimard, 1824)	LC	M	E, Sb, R, B	2
SYNGNATHIFORMES				
Syngnathidae				
Bryx dunckeri (Metzelaar, 1919)	LC	M	R, B	2
Cosmocampus elucens (Poey, 1868)	LC	M	R	*
Hippocampus reidi (Ginsburg, 1933)	NT	M	E, R, B	2
Microphis lineatus (Kaup, 1856)	–	M	E, PB	2
Syngnathus pelagicus (Linnaeus, 1758)	LC	M	E, P	2
Fistulariidae				
Fistularia petimba (Lacépède, 1803)	LC	Om	E, R, Wc, P, PB	2
Fistularia tabacaria (Linnaeus, 1758)	LC	M	E, R, Wc, P	8
Dactylopteridae				
Dactylopterus volitans (Linnaeus, 1758)	LC	Om	E, Sb, R, B	2,8
SCOMBRIFORMES				
Trichiuridae				
Trichiurus lepturus (Linnaeus, 1758)	LC	Om	E, Sb, R, Wc, P, PB, B	2,8
Scombridae				
Scomberomorus brasiliensis (Collette, Russo & Zavala–Camin, 1978)	LC	M	R, Wc, P	2
LABRIFORMES				
Labridae				
Nicholsina usta (Valenciennes, 1840)	LC	Om	Sb, R, PB	2
Sparisoma radians (Valenciennes, 1840)	LC	Om	R, PB	2
PERCIFORMES				
Centropomidae				
Centropomus ensiferus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus parallelus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus pectinatus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus undecimalis (Bloch, 1792)	LC	Om	E, Sb, R, PB	2,8
Gerreidae				
Diapterus auratus (Ranzani, 1842)	LC	R	E, Sb, R, PB	2,8
Diapterus rhombeus (Cuvier, 1829)	LC	R	E, Sb, R, PB	2
Eucinostomus argenteus (Baird & Girard, 1855)	LC	R	E, Sb, R, PB	2,8

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Eucinostomus gula (Quoy & Gaimard, 1824)	LC	R	E, Sb, R, PB	2,8
Eucinostomus melanopterus (Bleeker, 1863)	LC	R	E, Sb, R, PB	2,8
Eugerres brasilianus (Cuvier, 1830)	LC	R	E, Sb, R, PB	2
Mullidae				
Pseudupeneus maculatus (Bloch, 1793)	LC	M	Sb, R, PB	2,8
Kyphosidae				
Kyphosus sectatrix (Linnaeus, 1758)	LC	M	E, R, Wc, P	8
Serranidae				
Alphestes afer (Bloch, 1793)	LC	Om	E, Sb, R, PB	2,8
Diplectrum formosum (Linnaeus, 1766)	LC	Om	E, Sb, R, PB	2
Epinephelus itajara (Lichtenstein, 1822)	VU	Om	E, Sb, R, PB	2
Hyporthodus niveatus (Valenciennes, 1828)	VU	Om	Sb, R, PB	2
Rypticus randalli (Courtenay, 1967)	LC	M	E, Sb, R, PB	2,8
Haemulidae				
Conodon nobilis (Linnaeus, 1758)	LC	Om	E, R, PB	2
Genyatremus luteus (Bloch, 1790)	DD	Om	E, PB	1
Haemulon aurolineatum (Cuvier, 1830)	LC	M	R, PB	2
Haemulon plumieri (Lacépède, 1801)	LC	Om	Sb, R, PB	2
Haemulopsis corvinaeformis (Steindachner, 1868)	LC	M	E, Sb, R, PB	2,8
Orthopristis scapularis (Fowler, 1915)	–	M	E, Sb, R, PB	2
Pomadasys ramosus (Poey, 1860)	–	M	E, PB	2
Rhonciscus crocro (Cuvier, 1830)	DD	M	E, Sb, PB	2
Lutjanidae				
Lutjanus alexandrei (Moura & Lindeman, 2007)	–	M	E, Sb, R, PB	2
Lutjanus buccanella (Cuvier, 1828)	DD	M	Sb, R, PB	2
Lutjanus cyanopterus (Cuvier, 1828)	VU	M	E, Sb, R, PB	2
Lutjanus jocu (Bloch & Schneider, 1801)	DD	M	E, Sb, R, PB	2,8
Lutjanus synagris (Linnaeus, 1758)	NT	M	E, Sb, R, PB	2,8
Lutjanus vivanus (Cuvier, 1828)	LC	M	E, Sb, R, PB	2
Polynemidae				
Polydactylus virginicus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	2,8
SCORPAENIFORMES				
Scorpaenidae				
Scorpaena brasiliensis (Cuvier, 1829)	LC	Om	E, Sb, R, B	2
Scorpaena plumieri (Bloch, 1789)	LC	Om	E, Sb, R, B	2,8
Triglidae				
Prionotus punctatus (Bloch, 1793)	LC	M	E, Sb, R, B	2,8
MORONIFORMES				
Ephippidae				
Chaetodipterus faber (Broussonet, 1782)	LC	M	E, Sb, R, Wc, P, PB	2,8

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
ACANTHURIFORMES				
Sciaenidae				
Bairdiella goeldi (Marceniuk et al., 2019)	LC	M	E, PB	2,8
Cynoscion acoupa (Lacépède, 1801)	VU	M	E, Sb, PB	2
Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	LC	M	E, Sb, PB	6
Cynoscion leiarchus (Cuvier, 1830)	LC	M	E, Sb, PB	6,8
Cynoscion microlepidotus (Cuvier, 1830)	LC	M	E, Sb, PB	6
Cynoscion virescens (Cuvier, 1830)	LC	M	E, Sb, PB	6
Isopisthus parvipinnis (Cuvier, 1830)	LC	M	E, Sb, PB	6
Larimus breviceps (Cuvier, 1830)	LC	M	E, Sb, PB	6,8
Macrodon ancylodon (Bloch & Schneider, 1801)	LC	M	E, Sb, PB	6
Menticirrhus martinicensis (Cuvier, 1830)	–	M	E, Sb, PB	*
Menticirrhus cuiaranensis (Marceniuk et al., 2020)	–	M	E, Sb, PB	8,*
Micropogonias furnieri (Desmarest, 1823)	LC	M	E, Sb, PB	6
Nebris microps (Cuvier, 1830)	LC	M	E, Sb, PB	6
Odontoscion dentex (Cuvier, 1830)	LC	M	R, PB	2
Paralonchurus brasiliensis (Steindachner, 1875)	LC	M	E, Sb, PB	2
Stellifer brasiliensis (Schultz, 1945)	LC	M	E, Sb, PB	2
Stellifer collettei (Chao, Carvalho-Filho & Santos, 2021)	–	M	E, Sb, PB	*
Stellifer gomezi (Cervigón, 2011)	LC	Om	Sb, PB	*
Stellifer menezesi (Chao, Carvalho-Filho & Santos, 2021)	–	Om	Sb, PB	*
Stellifer musicki (Chao, Carvalho-Filho & Santos, 2021)	–	Om	Sb, PB	*
Stellifer naso (Jordan, 1889)	LC	M	E, Sb, PB	2,8
Stellifer punctatissimus (Meek & Hildebrand, 1925)	LC	Om	Sb, PB	8,*
Stellifer rastrifer (Jordan, 1889)	LC	M	E, Sb, PB	2
Stellifer stellifer (Bloch, 1790)	DD	M	E, Sb, PB	2
Umbrina coroides (Cuvier, 1830)	LC	M	E, Sb, R, PB	2,8
LOPHIIFORMES				
Antennariidae				
Antennarius striatus (Shaw, 1794)	LC	Om	E, Sb, R, B	2
Ogcocephalidae				
Ogcocephalus vespertilio (Linnaeus, 1758)	LC	Om	E, Sb, R, B	2,3,8
TETRAODONTIFORMES				
Tetraodontidae				
Colomesus psittacus (Bloch & Schneider, 1801)	LC	M	E, Sb, PB	2
Lagocephalus laevigatus (Linnaeus, 1766)	LC	M	E, R, Wc, P, PB	2,3
Sphoeroides greeleyi (Gilbert, 1900)	LC	R	E, Sb, R, PB	2,3
Sphoeroides spengleri (Bloch, 1785)	LC	Om	Sb, R, PB	2,3
Sphoeroides testudineus (Linnaeus, 1758)	LC	R	E, Sb, R, PB	2,3,8
Diodontidae				
Chilomycterus antillarum (Jordan & Rutter, 1897)	LC	M	Sb, R, PB	2
Chilomycterus spinosus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	2
Diodon holocanthus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	8

1 – Marceniuk et al. 2019; 2 – Marceniuk et al. 2021; 3 – Barbanti et al. 2013; 4 – Tubino et al. 2008; 5 – Gomes et al. 2000; 6 – Chao 2002; 7 – Dantas et al. 2010; 8 – Listed by Rosa 1980b; * Personal data; IUCN – International Union for Conservation of Nature; – unspecified data.

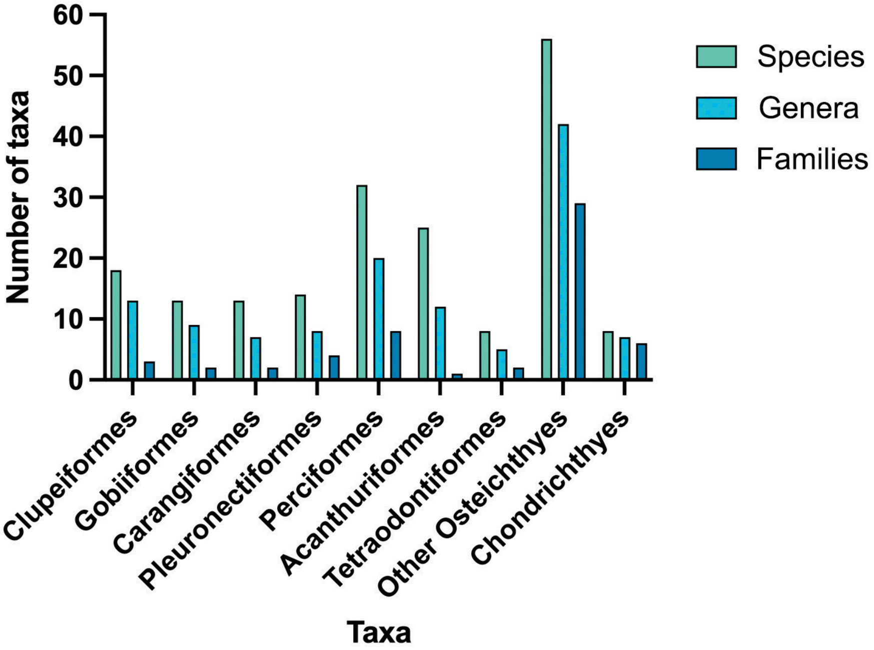

Figure 2. Number of families, genera, and species by higher taxonomic groups of Paraiba River estuary fish fauna, Paraiba, Brazil.

to the seven life habit's categories (estuarine, soft bottom, reef, water column, pelagic, benthopelagic, and benthic), due to the lack of previous studies for all species, for some the assignment to a guild, it was based on their distribution, size, and density in the literature (see Table 1).

Results

The checklist of fishes from Paraiba River estuary includes a total of 187 species, 123 genera, 57 families, 4 orders of Chondrichthyes, and 26 orders of Osteichthyes (Table 1). The class Osteichthyes was the most diverse comprising 95.7% of the total ichthyofauna caught (n = 179). Belonging to this class, Perciformes was the most representative order in terms of richness, with 32 species, followed by Acanthuriformes (n = 25), Clupeiformes (n = 18), and Pleuronectiformes (n = 14) (Figure 2). Among the families, Sciaenidae had the largest number of species (n = 25), followed by Carangidae (n = 12), Engraulidae (n = 10), Gobiidae (n = 9) and Haemulidae (n = 8), which altogether represent 34.2% of the richness in the estuary. The class Chondrichthyes represented only 4.3% of the total ichthyofauna caught (n = 8). All Chondrichthyes families but two were not represented by single species, as well as other 20 Osteichthyan families (Elopidae, Megalopidae, Albulidae, Curimatidae, Characidae, Triportheidae, Cichlidae, Echeneidae, Sphyraenidae, Bothidae, Dactylopteridae, Trichiuridae, Scombridae, Mullidae, Kyphosidae, Polynemidae, Triglidae, Ephippidae, Antennariidae, Ogcocephalidae). Out of the 187 species listed in this study, 128 are new records for the estuary, as only 59 were in a survey carried out 40 years ago in the Paraiba state (Table 1).

All listed species presented coastal habits, were classified by ecological guild, and life habit (Table 1). The resident fish fauna was represented by fewer species (n = 37 – 19.8%) as compared to marine and occasional marine ones (n = 73 and 70 species, respectively – 76.5% both), while the occasional freshwater ones were represented by only seven species (3.7%), two of them exotics (*Oreochromis niloticus* and *Poecilia reticulata*).

According to the International Union for Conservation of Nature Red List categories and criteria in IUCN, five species are classified as Near Threatened (*Narcine brasiliensis*, *Hypanus guttatus*, *Albula vulpes*, *Hippocampus reidi* and *Lutjanus synagris*), seven other species (*Rhizoprionodon porosus*, *Rhinoptera bonasus*, *Megalops atlanticus*, *Epinephelus itajara*, *Hyporthodus niveatus*, *Lutjanus cyanopterus* and *Cynoscion acoupa*) are classified as Vulnerable, two (*Carcharhinus porosus* and *Urotrygon microphthalmum*) are considered Critically Endangered. The other species listed herein are classified as Least Concern or Data Deficient.

Discussion

The fish richness reported herein for Paraiba River estuary (187 species) is greater than that reported for some northeastern estuaries by Reis-Filho et al. (2010) (124 species – Paraguaçu River, Todos os Santos bay, Bahia), Favero et al. (2019) (92 species – Maracaípe River, Ipojuca, Pernambuco), and Melo et al. (2021) (49 species – Timonha and Ubatuba Rivers, Ceará). This is because this study covers a longer sampling effort over time. About forty years ago, a preliminary survey of coastal marine fishes was carried out in Paraiba; 136 fish species were listed, including 59 species that occurred strictly in the Paraiba River estuary (Rosa 1980b). Several species were misidentified in that study or are currently considered as synonym, for instance *Hypanus marianae* was listed as *Dasyatis say* (Lesueur 1817), *Bagre filamentosus* was listed as *Bagre marinus* (Mitchill 1815), and *Diapterus auratus* was listed as *Diapterus olisthostomus* (Goode & Bean 1882).

An updated and more complete fish checklist was pending for this important estuarine system, therefore the taxonomic effort herein provides records of 187 fish species occurring in the largest estuary in Paraiba state, representing a reliable source of information to scientists, decision makers and the general public.

The predominance of the order Perciformes is a common pattern for estuarine fish inventories from Brazil (Carvalho Neta & Castro 2008, Reis-Filho et al. 2010, Lamas et al. 2016), and this is also the order of greatest richness among teleost fish (Menezes et al. 2007). Regarding the richest families, Sciaenidae, Engraulidae and Gobiidae are frequently reported from tropical estuaries and their species are very abundant in Northeast Brazil (Paiva et al. 2009, Reis-Filho et al. 2010, Martins & Vendel 2014, Dolbeth et al. 2016). In contrast, it seems that, within Brazilian estuaries, a higher biomass of Sciaenidae and Ariidae represents a general pattern, especially in those estuaries with higher mean annual rainfall and under influence of extensive river plume such as the Amazon (Vilar et al. 2013; Marceniuk et al. 2017).

The genus *Stellifer* with nine species was the richest genus in the Paraiba River estuary, followed by *Lutjanus* with six species, *Anchoa* and *Cynoscion* with five species each. This pattern was not identical in nearby estuaries, but little differences were observed regarding the most abundant genera. In the Barra de Camaratuba estuary, Paraiba, *Lutjanus* and *Centropomus* were the richest genera (Martins & Vendel 2014), whereas *Anchoa*, *Ctenogobius*, and *Oligoplites* were the richest in the Paraguaçu River estuary, Bahia (Reis-Filho et al. 2010). Despite this, all the richest genera from the nearby estuaries were also captured in the Paraiba River estuary with at least three species each.

The inventory presented here, includes six species from freshwater environments, three of which, *Psalidodon fasciatus*, *Triportheus guentheri* and *Steindachnerina notonota* were captured exceptionally in 2008 during an El Niño event, when the rains were more intense and freshwater species expanded their range into the estuary. *Oreochromis niloticus* and *Poecilia reticulata* were the only introduced exotic species, both known from freshwater origin. The occurrence of these invading species may be either related to their commercial potential, in terms of food for human consumption (*O. niloticus*) or the aquarium trade (*Poecilia* spp.). The introduction of these species may have resulted from fish farms along rivers that empty into the estuary (Leão et al. 2011) or the improper discard of specimens obtained through the ornamental fish trade, as documented for *Xiphophorus maculatus* (Günther 1866) in a tributary to the Paraiba River estuary, but not recorded herein (Magalhães & Jacobi 2010, Ramos et al. 2020). As it is established that alien species are one of the human-driven threats to biodiversity, the occurrence of two exotic species here leads us to reaffirm the importance of estuaries conservation (Vitousek et al. 1997, Bellard et al. 2016).

On the taxonomic uncertainties, *Citharichthys arenaceus* is a species that occurs in the Caribbean, from the Gulf of Mexico to Venezuela. Here in Brazil we have an undescribed species (misidentified as *C. arenaceus*) which is in the process of description (Rocha 2017), therefore considered in this study *Citharichthys* cf. *arenaceus*. Also, *Rhinosardinia* cf. *bahiensis* might not represent a single species; in the present study most specimens keyed out as *R. amazonica* based on counts of lateral line scales (Carvalho-Filho 1999) and a few specimens tentatively as *R. bahiensis*. We treated all as *Rhinosardinia* cf. *bahiensis*, but future studies should evaluate if such variation may correspond to a single species occurring from Venezuela to Northeastern Brazil.

The catfishes *Cathorops agassizii*, *C. spixii* and S*ciades herzbergii*, the toadfish *Thalassophryne nattereri*, are dangerous species, as already mentioned for this estuary (Macêdo et al. 2017). They are common species on the Brazilian coast (Haddad Jr et al. 2003, Haddad Jr 2003) and their registration herein is important due to the risks of injury caused by them in estuary areas (Haddad Jr 2016).

As expected, fishes that complete their life cycle in the estuarine environment represent few species with large numbers of individuals, which is a recurring pattern in estuarine ecosystems (Barletta et al. 2005, Paiva et al. 2009, Vendel et al. 2010, Vilar et al. 2011). In fact, this may be explained by the fact that resident species are typically euryhaline and tolerate the spatial and temporal fluctuations widely found in estuarine ecosystems (Elliott et al. 2007), especially salinity, which is considered the main factor influencing the distribution of fishes in estuaries (Barletta et al. 2005, Vilar et al. 2011).

It is well known that freshwater inflow is one of the main drivers to the estuarine diversity, in this region the high water consumption by damming, associated with a low freshwater input in the rainy season, might have an influence over nutrient cycling, fish guilds, and in the salinity itself into the estuary (Garcia et al. 2004, Possamai et al. 2018, Possamai et al. 2020), this favors marine species predominance as shown here. Moreover, the damming along the Paraiba river basin, generated by needs towards water consumption, by human, on agriculture, and on livestock (Teixeira et al. 2020) affect the maintenance of annual hydrological regime as a whole, which is characterized by rainy and dry seasons typical of the semiarid Paraiba state region.

Regarding the conservation status of the species listed here, three species classified as Vulnerable according to the IUCN (*M. atlanticus*, *H. niveatus*, *L. cyanopterus*) also appear in the same classification in the red book of the Brazilian fauna threatened of extinction and *E. itajara* as Critically Endangered, all of which have an indication of declining population trends (Lindeman et al. 2016a, Bertoncini et al. 2018, Lindeman et al. 2016b, Pollom et al. 2020). These species have population declines stemming from intense fishing activity in regions where they occur (MMA 2020). Regarding the Elasmobranchii, only *Carcharhinus porosus* is listed as Critically Endangered in Brazil (Pollom et al. 2020) and also globally, according to the last IUCN (2022) assessment. This species has not been captured again in the estuary or in other locations of Paraiba state since the 70's. Another species, *Porichthys kymosemeum*, not evaluated by the IUCN, also has not been captured in the estuary or in other locations of Paraiba since the early 1980's. This reinforces the importance of recording and monitoring the fish species occurrence over time.

Conclusions

This inventory of fish species from the Paraiba River estuary organizes and expands the knowledge about the fish community that occurs in this ecosystem, providing knowledge about richness, life habits, ecological guilds and conservation status of fish species, important data for the proper management of local species as ecological and economic resources.

Supplementary Material

The following online material is available for this article:

Table A.1 – Taxonomic list with voucher numbers of fish species collected in the Paraiba River estuary, deposited at the fish collection of Universidade Federal da Paraiba (UFPB). The fish species nomenclature followed Fricke et al. (2022), taxonomic order according to Nelson et al. (2016).

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Associate Editor

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Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Data Availability

The entire dataset supporting the results of this study was published in the article and in the section "Supplementary materials".

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Occurrence of potential wild hosts of *Echinococcus vogeli* in the forests of southwestern Brazilian Amazonia

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Abstract: The helminth *Echinococcus vogeli* Rausch & Bernstein, 1972 is a causative agent of Neotropical Echinococcosis, a chronic zoonotic disease which is endemic to the Neotropical region. This parasite is transmitted from bush dogs (*Speothos venaticus*) to their prey, which include lowland pacas (*Cuniculus paca*) and agoutis (*Dasyprocta* spp.). In Brazil, most human cases of Neotropical Echinococcosis have been recorded in the Amazonian states of Acre and Pará, although few data are available on the occurrence of the potential definitive or intermediate hosts of *E. vogeli* in the Amazon region. In the present study, we surveyed the forests surrounding 46 human communities located within and around of outside six sustainable-use protected areas in the southwestern Amazon basin of Brazil. The forests were surveyed using camera traps to determine the local presence of potential wild hosts of *E. vogeli*, and the exploitation of these hosts for game meat was evaluated through interviews with 136 subsistence hunters resident in the local communities. We recorded pacas, agoutis, and bush dogs, as well as domestic dogs (*Canis familiaris*), all potential reservoirs of Neotropical Echinococcosis, using the same habitats. We also confirmed the frequent consumption of paca and agouti meat by subsistence hunters and their families in the study communities. Our data contribute to the understanding of the occurrence of *E. vogeli* in Brazilian ecosystems.
Keywords: *Neotropical echinococcosis; subsistence hunting; Brazilian Amazonia; camera trap.*

Ocorrência de potenciais hospedeiros silvestres de *Echinococcus vogeli* nas florestas do sudoeste da Amazônia brasileira

Resumo: O helminto *Echinococcus vogeli* Rausch & Bernstein, 1972 é o agente causador da Equinococose Neotropical, uma doença zoonótica crônica e endêmica da região Neotropical. Este parasito é transmitido entre o cachorro-vinagre (*Speothos venaticus*) e suas presas, como pacas (*Cuniculus paca*) e cutias (*Dasyprocta* spp.). No Brasil, a maioria dos casos humanos de Equinococose Neotropical é registrada nos estados do Acre e Pará, embora existam poucos dados disponíveis sobre a ocorrência de potenciais hospedeiros definitivos e intermediários de *E. vogeli* na Amazônia. No presente estudo, foram investigadas áreas de floresta ao redor de 46 comunidades humanas localizadas no interior e entorno de seis unidades de conservação de uso sustentável no sudoeste da bacia amazônica brasileira e, por meio de armadilhas fotográficas, foram avaliadas as presenças de potenciais hospedeiros silvestres de *E. vogeli.* Adicionalmente, foram avaliados o padrão de consumo da carne dos hospedeiros silvestres por meio de entrevistas com 136 moradores dessas comunidades. Foram registradas pacas, cutias e cachorros-vinagre, bem como cães domésticos (*Canis familiaris*) utilizando os mesmos habitats, todos potenciais reservatórios da

Equinococose Neotropical. Além disto, confirmamos a alto consumo de paca e cutia nas comunidades. Os dados do presente trabalho contribuem para pesquisas em andamento sobre a presença dos potenciais reservatórios de *E. vogeli* em ambientes brasileiros.

Palavras-chave: *equinococose neotropical; caça de subsistência; Amazônia brasileira; armadilha fotográfica.*

Introduction

Infectious diseases with zoonotic potential are a research priority, given their potential impacts on public health, livestock, and wildlife conservation (Cleaveland et al. 2001). Worldwide, zoonotic diseases are the leading cause (61%) of human infections (Cunningham 2005), and 70% of emerging infectious diseases originate from wildlife, in particular mammals (Cleaveland et al. 2001, Thompson et al. 2009, Johnson et al. 2015). Many of the helminths that infect humans are zoonotic pathogens with wild and domestic animal hosts (Carmena & Cardona 2014, Gordon et al. 2016, Otranto & Deplazes 2019). Wild mammals, such as carnivores and rodents, may often host a considerable diversity of zoonotic helminths (Cleaveland et al. 2001, Han et al. 2016).

Echinococcosis is a helminthic zoonotic infection caused by the larval stage of the tapeworms of the genus *Echinococcus* Rudolphi, 1801, which have a worldwide distribution. This zoonotic disease is clinically important and considered the most prevalent of the zoonotic helminthiases, which causes serious human morbidity and death, affecting not only humans, but also livestock and wildlife, with implications for the conservation of wild mammal populations (Jenkins et al. 2005, Thompson et al. 2009, Gordon et al. 2016). Echinococcosis can be transmitted through a variety of domestic, synanthropic, and sylvatic cycles, with wild animals being considered a major source of infection in humans (Carmena & Cardona 2014). In a recent molecular study, Vuitton et al. (2020) validated four *Echinococcus* species of public health interest: *Echinococcus granulosus* (Batsch, 1786) *sensu lato (s.l.),* which causes cystic echinococcosis; *Echinococcus multilocularis* Leuckart, 1863, causing alveolar echinococcosis; and *Echinococcus vogeli* Rausch & Bernstein, 1972 and *Echinococcus oligarthra* Diesing, 1863, which cause neotropical echinococcosis. Only three of these species occur in Brazil (*E. granulosus, E. vogeli* and *E. oligarthra)*, however, only two are prevalent: *Echinococcus granulosus* which is found in southern Brazil and causes cystic echinococcosis, and *Echinococcus vogeli*, which occurs in northern Brazil, and causes neotropical echinococcosis (Siqueira et al. 2013) (Figure 1).

Echinococcus vogeli is endemic to the Neotropical region, where its definitive host is the bush dog (*Speothos venaticus* Lund, 1842), and the principal intermediate host is the lowland paca (*Cuniculus paca* Linnaeus, 1766), which is the preferred prey of bush dog (D'Alessandro et al. 1981, D'Alessandro 1997, D'Alessandro & Rausch 2008). Other wild animals are known to act as hosts of *E. vogeli* in Brazil, including the agouti (*Dasyprocta leporina* Linnaeus, 1758), and the nine-banded armadillo (*Dasypus novemcinctus* Linnaeus, 1758 (Santos et al. 2012, Almeida et al. 2013, Soares et al. 2014). In addition to the natural cycle of the parasite in these animals, *E. vogeli* may circulate in a partially synanthropic cycle, in particular, through the hunting and consumption of the meat of wild paca (an intermediate host of *E. vogeli*), and the introduction of domestic hunting dogs (*Canis familiaris*), which may feed on infected paca tissue (Eckert & Deplazes 2004, D'Alessandro & Rausch 2008).

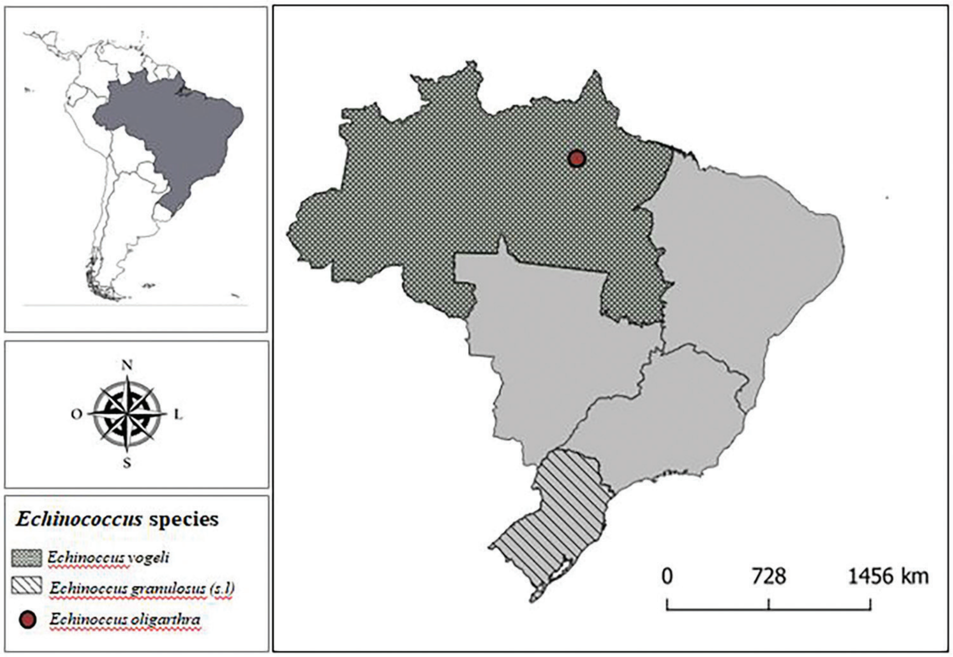

Figure 1. Map of Brazil showing endemic areas for *Echinococcus vogeli* and *Echinococcus granulosus (s.l.).*

The subsistence hunting of wild mammals is common and widespread in the rural and indigenous communities of the Amazon region (Peres & Palacios 2007), which paca and agouti are important game species to rural communities in central-western portion of Brazilian Amazon (Sampaio et al. 2022) and dogs are widely used for hunting (Bittencourt-Oliveira et al. 2018, Guimarães et al. 2019). Humans are considered to be an accidental intermediate host of *E. vogeli* (Rausch & Bernstein 1972) – they are infected through the accidental ingestion of eggs present in the feces of domestic dogs (Eckert & Thompson 2017).

In Brazil, most human cases of neotropical echinococcosis have been reported from the Amazonian states of Acre and Pará (Siqueira et al. 2013). In Acre, infection by *E. vogeli* has also been reported in both the paca (Meneghelli et al. 1992, Almeida et al. 2013, Oliveira 2016) and domestic dogs (Neves et al. 2017), which indicates the occurrence of both sylvatic and domestic cycles in this region. Despite these findings, relatively few data are available on the occurrence of the potential hosts of *E. vogeli*, whether definitive or intermediate, in most areas of Brazilian Amazonia.

In the present study, we used camera traps to survey forests in the vicinity of 46 human villages located within and immediately outside of six sustainable-use protected areas in the southwestern Brazilian Amazon in order to investigate the local occurrence of potential wild hosts of *E. vogeli*, that may maintain the wild cycle of this parasite in the region. Through interviews with 136 local hunters, we also evaluated the frequency of the consumption of the meat of these mammals of the local communities.

Material and Methods

1. *Study area*

The study was carried out in and around six sustainable-use protected areas located in southwestern Brazilian Amazonia in 2018, 2019, and 2020 (Figure 2). Four of these protected areas, the Cazumbá-Iracema Extractive Reserve (CIR), the Riozinho da Liberdade Extractive Reserve (RLR), the Liberdade State Forest (LF), and the Mogno State Forest (MF), hereafter Liberdade Reserves (LR), all protect areas above are located in the Brazilian state of Acre, while the other two – the Arapixi Extractive Reserve (AR) and the Médio Purus Extractive Reserve (MPR) – are located in Amazonas state. The families residing in the local communities live on plots of 300–500 ha, with a mean of four members per household, which are distributed along rivers, streams, and roads. The financial income of these families is derived from cattle ranching and farming (manioc, corn, and rice),

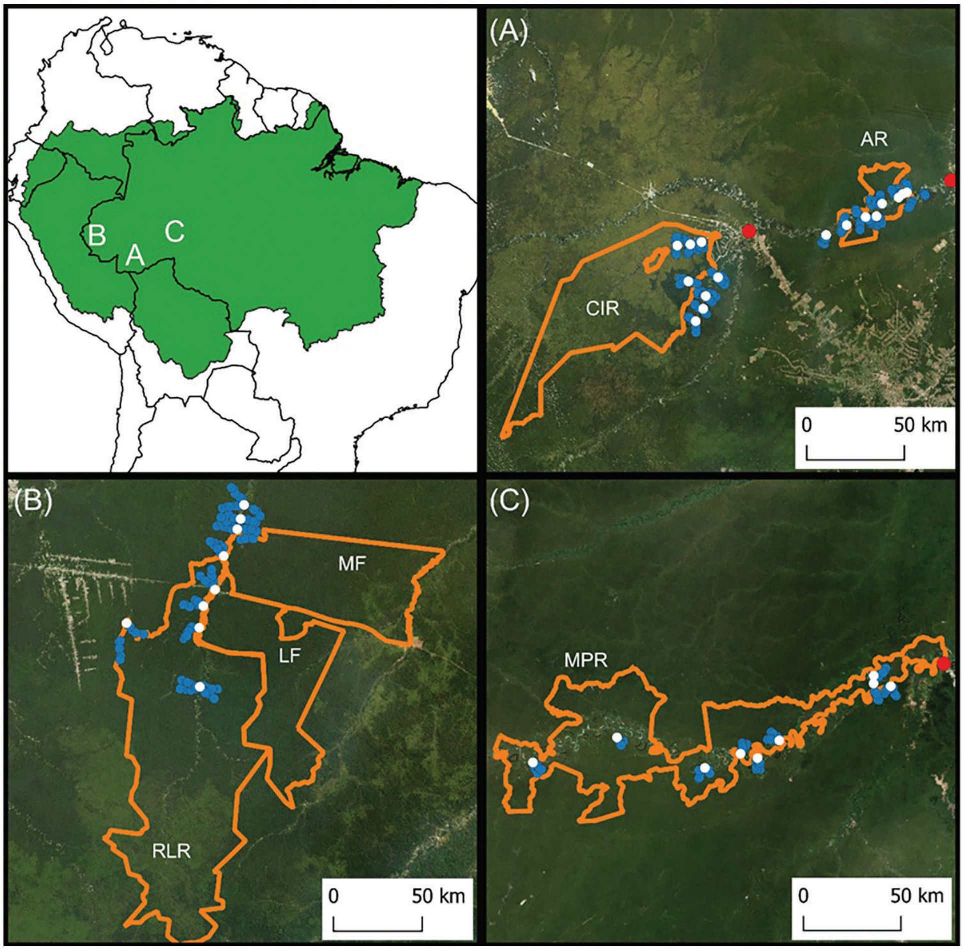

Figure 2. Location of the three study areas (panels A–C) within lowland Amazonia (green portion of the upper left panel), South America. (A) Cazumbá-Iracema Extractive Reserve (CIR) and Arapixi Extractive Reserve (AR); (B) Riozinho da Liberdade Extractive Reserve (RLR), Liberdade State Forest (LF) and Mogno State Forest (MF); and (C) Médio Purus Extractive Reserve (MPR). The maps show the 46 study communities (white dots), 452 camera traps (blue dots), the nearest urban centers (red dots), and the shapes of the protected areas (orange polygons).

as well as rubber tapping and the harvesting of Brazil nut from the forest (Oliveira & Calouro 2020). Subsistence is based on livestock, agricultural produce, forest resources, fishing, and hunting (Tourinho et al. 2013, Souza et al. 2021).

2. *Data collection and analysis*

The study areas were surveyed using unbaited Bushnell® digital camera traps, which are cameras triggered remotely by heat and motion. We used these devices to record the presence of potential wild mammalian reservoirs of polycystic echinococcosis during two distinct phases of sampling. A total of 452 camera traps were installed in the vicinity of 46 human communities in continuous primary *terra firme* forest. The total sampling effort was 21,909 trap-days, with each individual camera being operational for between half a day and 62 days (mean ± SD = 49.3±9 days).

The camera traps were deployed only in areas of primary forest found in the vicinity of each community, being distributed along a logarithmic gradient of distances of between 220 m and 7 km from the nearest community. The traps were affixed to tree trunks approximately 30–45 cm above the ground and programmed to operate continuously for 24 hours per day. Once triggered, each camera took photographs at 10-second intervals until no further movement was detected, with the following information being logged for each photograph: the date, time, season, and species (Srbek-Araujo & Chiarello 2013). The photographs were uploaded to the Camera Base (https://www.atrium-biodiversity.org/tools/camerabase/) and Wild.id (https://github.com/ConservationInternational/Wild.ID) databases for processing.

We calculated the frequency of sightings of each host species based on the number of photographs of a given species obtained by the same camera trap at an interval of at least one hour. These photographs were considered to be independent records of occurrence, following the recapture protocol of Srbek-Araujo & Chiarello (2013). We calculated the Relative Abundance (RA) of each species, where RA = the number of records of the species/the number of trap-days × 100) following Springer et al. (2012) and O'Brien (2010).

After obtaining explicit consent from all the participating communities and informants, we interviewed experienced subsistence hunters, who were willing informants and had been indicated to us based on a community-level snowball approach. A semi-structured questionnaire was applied to determine how often each hunter consumed the meat of the paca and agouti (reservoirs of *E. vogeli*). The study was approved by the Ethics Committee of the University of São Paulo (process number 2296078) and by the Brazilian Federal System of Biodiversity Information and Authorisation (SISBIO), through license number 68985-1.

Results

Based on a total sampling effort of 21,909 trap-days, we obtained 4,334 independent records of potential *E. vogeli* reservoirs (Table 1). We recorded the agouti (Figure 3a) in 44 (96%) of the communities surveyed, with detection distances in relation to the nearest community ranging from 293.6 to 7,316.6 meters (mean±SD = 3,135.4±1,650.5 m). This species was recorded most frequently in the early morning (between 6:27 am and 9:00 am) and around sunset (5:00 pm). We

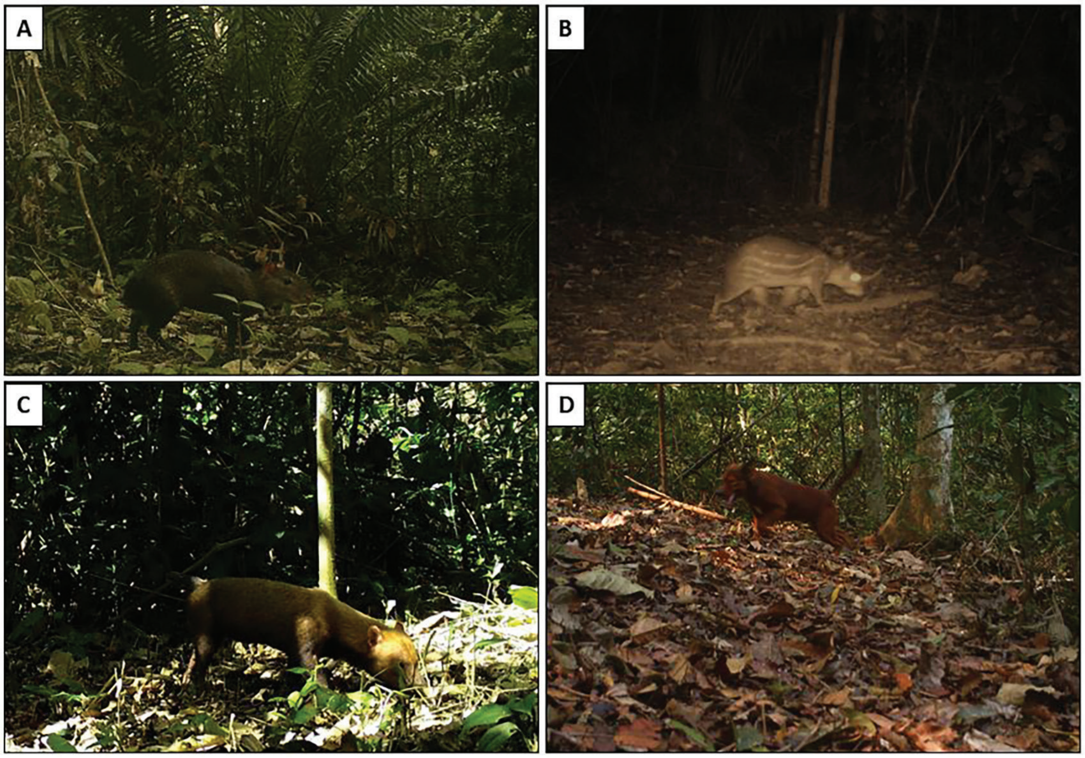

Figure 3. Potential wild and domestic hosts of *Echinococcus vogeli* captured by the camera traps deployed in the study region in the southwestern Amazon basin of Brazil (see Figure 2): (A) *Dasyprocta* ssp., (B) *Cuniculus paca*, (C) *Speothos venaticus*, and (D) *Canis familiaris.*

Table 1. Number of camera trap records (N) and the Relative Abundance (RA) of the four potential wild and domestic hosts of *Echinococcus vogeli* recorded in the communities located in and around the sustainable-use protected areas in the southwestern Brazilian Amazon basin.

Protected area	**Domestic dog**		**Paca**		**Agouti**		**Bush dog**		
	N	**RA (%)**	**N**	**RA (%)**	**N**	**RA (%)**	**N**	**RA (%)**	**Sampling effort (trap-days)**
Arapixi Extractive Reserve	7	0.15	120	2.53	577	12.14	5	0.11	4752
Cazumbá-iracema Extractive Reserve	64	0.96	418	6.27	1002	15.02	11	0.16	6671
Médio Purus Extractive Reserve	16	0.32	254	5.05	626	12.45	1	0.02	5029
Liberdade Reserves	49	0.90	362	6.63	819	15.01	3	0.05	5458
Total	**136**	**0.62**	**1154**	**5.27**	**3024**	**13.80**	**20**	**0.09**	**21909**

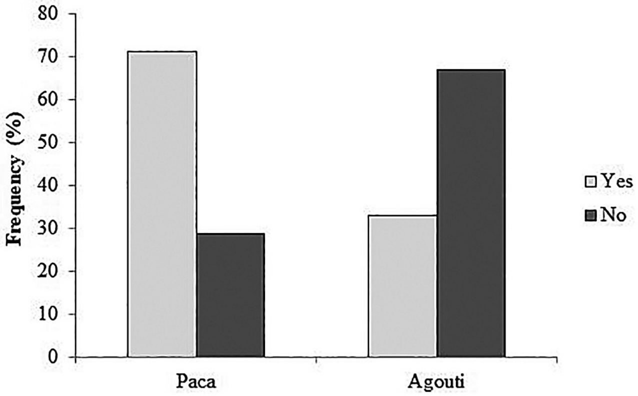

Figure 4. Frequency of the reports of the consumption of paca and agouti meat by the 136 subsistence hunters interviewed in the rural communities surveyed in the southwestern Amazon basin of Brazil (see Figure 2).

recorded the paca (Figure 3b) in 45 (98%) communities, at distances of between 293.6 and 7316.6 meters (mean = 3172.9 ± 1732.1 m), with the highest frequency of records being recorded between 7:00 pm and 11:00 pm.

We recorded the bush dog (Figure 3c) in only nine (20%) communities, where the photographs were obtained in the mid-morning, between 9:23 am and 12:32 pm, at distances of between 495.0 and 5,923.7 meters from the nearest community (mean = 3,538.6±1,683.4 m). Records of this species were more frequent in the communities in which pacas and agoutis were more abundant. Domestic dogs (Figure 3d) were recorded moving along the trails in the forests located in the vicinity of 30 (65%) communities, at distances of between 439.7 and 6,507.4 meters from the local community (mean = 2,509.4±1,604.8 m).

We interviewed 136 subsistence hunters resident in all the different communities of the study region. Most of the interviewees in all the communities indicated that they consume paca (71.3% – n = 96) and agouti (33.1% – n = 45) meat, with the paca being the species reported most often (Figure 4). All residents also reported that domestic dogs are fed with the raw viscera of these animals.

Discussion

The present study investigated the local occurrence of three wild mammals (the agouti, paca, and bush dog) and the domestic dog in the vicinity of 46 rural communities located both within and adjacent to six sustainable-use protected areas in southwestern Brazilian Amazonia. All these species are potentially important hosts of Neotropical echinococcosis, which is caused by *E. vogeli*, and are often found in areas close to human settlements, which are used as communal hunting grounds. Subsistence hunting is the only known route for the establishment of the domestic cycle of *E. vogeli* (Meneghelli et al. 1992, D'Alessandro et al. 2008, Almeida et al. 2013). This occurs through contact with the domestic dogs that accompany the hunts and are often fed raw game meat, which may sometimes be infected with *E. vogeli* (Siqueira et al. 2013, Bittencourt-Oliveira et al. 2018).

The bush dog is a rare species in the wild, and our records are new for its range in the Amazon basin (Michalski 2010, Rocha 2015, Oliveira et al. 2018), and possibly also the occurrence of *E. vogeli* in these areas. Oliveira & Calouro (2019) recently surveyed medium- and large-bodied mammals in the Cazumbá-Iracema Extractive Reserve through both direct observations (e.g. camera trapping, sightings, and the collection of vestiges and osteological material) and indirect records, such as interviews. While these authors reported the presence of the paca, agouti, and bush dog in this protected area, only the paca and agouti were recorded directly, with the bush dog only being reported by the local residents. The results of the present study confirm the findings of Oliveira & Calouro (2019), including the presence of the bush dog, which was recorded by the camera traps.

The first record of *E. vogeli* in a wild canid was from a bush dog captured in late 1969 in the province of Esmeraldas, Ecuador (Rausch and Bernstein 1972), while the second was from the municipality of Anajás, in the Brazilian state of Pará (Soares et al. 2014). Both these reports highlight the importance of the bush dog as a definitive host, which may maintain the natural cycle of the parasite in different regions of northern South America, in particular in the Brazilian Amazon biome.

Domestic dogs may play a crucial role in the transmission of *E. vogeli* eggs to humans, and the present study recorded these animals in all the habitats in which the wild mammals were recorded. Using molecular markers, Neves et al. (2017) identified *E. vogeli* eggs in fecal samples collected from domestic dogs in Sena Madureira (Acre state), which further highlights the potential role of dogs as a source of infection for humans, thereby establishing and maintaining the domestic cycle.

The first report of the presence of *E. vogeli* in pacas in the state of Acre dates to 1989 (Meneghelli et al. 1992), although no records are available for the state of Amazonas. Our findings show that the known hosts of *E. vogeli* are common in the study region, providing the conditions necessary to maintain its parasitic cycle in this region. Reports of infection by *E. vogeli* in agoutis (*Dasyprocta* spp.) are rare overall, with only one record from Brazil, in the state of Pará, in the eastern extreme of the

Amazon region (Soares et al. 1999). There are no other published records of the infection of agouti by *E. vogeli* in the Amazon region.

Most human cases of neotropical echinococcosis recorded in Brazil come from the Amazon region, where the disease is commonly known as “Paca Disease” (D’Alessandro & Rausch 2008, Daipert-Garcia et al. 2019). In the state of Amazonas, six cases of the disease were reported (Guimarães et al. 2005; Siqueira et al. 2013). In the state of Acre, many human cases have been recorded since 1992 (Meneghelli et al. 1992, Daipert-Garcia et al. 2019), which reflects the continuity of the parasitic cycle of the disease in the Amazon region. Three studies estimated the prevalence of infection in Acre based on serum antibody levels. In the first study, Pastore et al. (2003) recorded a frequency of 4% in a group of 1064 individuals from the municipality of Sena Madureira, while Pereira (2016) found a frequency of 25% when analyzing 332 samples collected in the municipalities of Sena Madureira, and Bujarí. Souza (2021) investigated 327 residents of the Cazumbá-Iracema Extractive Reserve, in Sena Madureira, and recorded positive serology in 8.6% of the individuals and hydatid cysts in 10.3%. These studies demonstrated that Neotropical echicoccosis is prevalent within the study area in Acre, where conditions may be favorable for the maintenance of the parasitic cycle.

The present study confirmed the presence of potential hosts of *E. vogeli*, both definitive and intermediate, within the same habitat in the southwestern Brazilian Amazon basin. This probably guarantees the full life cycle of this parasite through the contamination of the environment by bush dog feces infected with *E. vogeli*, which may be transferred to pacas and agoutis when they ingest eggs from contaminated soil (D’Alessandro & Rausch 2008). Both these rodents, in turn, are prey for the bush dog, which thus ensures the completion of the parasite’s wild cycle (Lima et al. 2009, 2012, Jorge et al. 2013), with the parasite being introduced into the domestic environment through intense subsistence hunting, as observed throughout the area of the present study.

Conclusions

The confirmation of the presence of potential wild reservoirs of Neotropical echinococcosis (caused by *Echinococcus vogeli*) in the study region, together with the frequent consumption of paca and agouti meat by local hunters and their families, indicate the existence of an environment favorable to the maintenance of both the wild and the domestic cycles of this parasite. These findings extend our understanding of the occurrence of the hosts of *E. vogeli*, which will be fundamental to the development of more systematic research and effective programs for the monitoring and control of this parasitic infection in the Amazon region.

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Associate Editor

Diego Astúa

Author Contributions

Leandro Siqueira de Souza: Collected, analyzed, and interpreted the data and prepared the manuscript.

Ricardo Sampaio: Collected, analyzed, and interpreted the data and prepared the manuscript.

Ana Paula Nascimento Gomes: Contributed to the preparation of the manuscript and revised the text critically.

Ronaldo G. Morato: Contributed to the preparation of the manuscript and revised the text critically.

Adriano G. Chiarello: Contributed to the preparation of the manuscript and revised the text critically.

Leilandio Siqueira De Souza: Contributed to the collection of data.

Francisco Glauco de Araújo Santos: Contributed substantially to the conception and design of the study, and the analysis and interpretation of the data.

Marcio Neves Boia: Contributed substantially to the conception and design of the study, and the analysis and interpretation of the data.

Rosângela Rodrigues e Silva: Contributed substantially to the conception and design of the study, and the analysis and interpretation of the data.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to the publication of this manuscript.

Ethics

The study was approved by the Ethics Committee of the University of São Paulo (process number 2296078) and by the Brazilian Federal System of Biodiversity Information and Authorization (SISBIO), through license number 68985-1.

Data Availability

Supporting data are available at <https://doi.org/10.5281/zenodo.6646839>

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Article

The sweat bees from Fernando de Noronha Archipelago, Brazil (Hymenoptera: Halictidae)

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Abstract: The sweat bees from Fernando de Noronha Archipelago are presented and illustrated herein. The species recorded are *Augochlora* (*Augochlora*) *laevipyga* (Kirby, 1890), *Augochlora* (*Augochlora*) sp., new record, and *Lasioglossum* (*Dialictus*) *atripyga* (Kirby, 1890). The Kirby species are redescribed based on recently collected specimens, including the first illustration of the male terminalia. The unidentified species is also shortly characterized.

Keywords: *Augochlora; Dialictus; Halictinae; Lasioglossum; oceanic islands fauna.*

Halictídeos do arquipélago de Fernando de Noronha (Hymenoptera: Halictidae)

Resumo: Os halictídeos do Arquipélago de Fernando de Noronha são aqui apresentados e ilustrados. As espécies registradas são *Augochlora* (*Augochlora*) *laevipyga* (Kirby, 1890), *Augochlora* (*Augochlora*) sp., novo registro, e *Lasioglossum* (*Dialictus*) *atripyga* (Kirby, 1890). As espécies descritas por Kirby são redescritas com base em espécimes recentemente coletados, incluindo a primeira ilustração das terminálias dos machos. A espécie não identificada também é resumidamente caracterizada.

Palavras-chave: *Augochlora; Dialictus; Halictinae; Lasioglossum; fauna de ilhas oceânicas.*

Introduction

Brazil has extraordinary biodiversity distributed in different types of environments and/or biomes throughout its vast territory, which includes a set of five oceanic islands poorly known in terms of insects diversity, but with many endemic species (Mohr et al. 2009). The best known among Brazilian oceanic islands in terms of its insect fauna is Fernando de Noronha, an equatorial South Atlantic archipelago located c. 360 km away from the nearest Brazilian coastline. Since the early 18th century when the archipelago was transformed into a penal colony for almost 200 years, a large part of the native vegetation was devastated while exotic plants and animals were introduced to serve as food (Teixeira et al. 2003, Serafini et al. 2010, Rafael et al. 2020).

Nevertheless, there are only a few studies including the entomological fauna in Fernando de Noronha (see Rafael et al. 2020). Of these, only three reported the presence of sweat bees (Halictidae). The first, Kirby (1890), described two species currently considered as valid, *Augochlora* (*Augochlora*) *laevipyga* (Kirby, 1890) and *Lasioglossum* (*Dialictus*) *atripyga* (Kirby, 1890) (Augochlorini and Halictini tribes, respectively). Several years later, Alvarenga (1962) collected specimens of these two species. After nearly six decades, Rafael et al. (2020) performed the most extensive collection effort in this archipelago, and these two species were once again collected, and additionally *Augochlora* (*Augochlora*) sp., one unidentified species, shortly characterized below, thereby increasing the species of sweat bees in Fernando de Noronha to three.

Considering that both genera are highly diverse and widely distributed in the New World (Michener 2007, Gibbs 2011, Lepeco & Gonçalves 2020), and that the original descriptions were relatively generic and brief, this work may support future taxonomic revisions for the genera in order to provide better understanding of the taxonomic status of these species. In addition, housing specimens in some essential and accessible collections will be equally crucial, as very few specimens have been sampled until now.

Material and Methods

The Brazilian oceanic archipelago of Fernando de Noronha (3º45′S to 3º57′S; 32º19′W to 32º41′W) has an estimated age ranging between 8–9 to 12 Ma and is entirely volcanic in its origin (Lopes & Ulbrich 2015), never having been connected to the mainland. The archipelago has a tropical climate with an annual temperature ranging from 23.5 ºC to 31.5 ºC (IBAMA 1990). The total land area is 18.4 km^2, of which 16.9 km^2 is the main island, and the remaining area is distributed among 20 smaller islets, of which Rata Island is the largest with 0.8 km^2 (Lopes & Ulbrich 2015, Rafael et al. 2020).

This work results from a research project which performed exhaustive samplings in Fernando de Noronha Archipelago with passive samplings methods such as Malaise interception traps and less exhaustive using active sweeping. Details about the sampling effort, methods, collection period, and the sampled points are detailed in the material and methods of Rafael et al. (2020). In addition to the collecting effort described in Rafael et al. (2020), there was an additional collection to observe the peridomestic areas of the urban places, with a concentrated effort in the urban gardens, carried out in November 2021.

Morphological terminology follows Michener (2007) in general lines except for the propodeal triangle, referred to here as the metapostnotum (Brothers 1976). The format for the redescription follows that of Gibbs (2011). The measurements of the specimens were performed from selecting the smallest and largest specimens observed. Label information from separate labels is segregated by double slashes "//". Typographic errors from labels were corrected, and the corrections were identified with square brackets "[ ]". Some color descriptions diverged from those of the original description, probably due to the different lighting devices used here, so there was a need to transcribe the originally described color between brackets "{ }". Photomicrographs were prepared using a Leica M205C stereomicroscope coupled with a Leica DFC295 and a Leica Application Suite V4.1 Interactive Measurements, Montage.

Institutional acronyms used in the sections on the material examined are: **CZMA**, Coleção Zoológica do Maranhão da Universidade Estadual do Maranhão, Caxias, Maranhão, Brazil; **INPA**, Coleção de Invertebrados do Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil; **MNRJ**, Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; **MZUSP**, Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil; **NHMUK**, Natural History Museum, London, United Kingdom; **UFRPE**, Universidade Federal Rural de Pernambuco, Pernambuco, Brazil. The type specimens of the two identified species are currently deposited in the NHMUK and were examined through photographs available on the institution's website (Natural History Museum 2014).

The collecting activities were approved by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) under the license number 62.821.

Results

Halictid specimens, distributed in three species, were collected during nine months using interception traps and during short periods using sweeping. The extensive collection effort over a long period and sampling a large area on the main island, in addition to the sporadic collection on the Rata Island, resulted in the collection of two previously known species from the archipelago described by Kirby (1890), *Augochlora* (*Augochlora*) *laevipyga* (four specimens) and *Lasioglossum* (*Dialictus*) *atripyga* (639 specimens), and additionally one unidentified species is being recorded for the first time, *Augochlora* (*A.*) sp., based on seven specimens.

The amount collected indicates that both *Augochlora* species should be treated as extremely rare species on the archipelago.

Augochlora (*Augochlora*) *laevipyga* (Kirby, 1890)

(Figures 1–2)

Halictus laevipyga Kirby, 1890: 542.

Augochlora laevipyga: Cockerell, 1909: 314 [taxonomic notes]; Alvarenga, 1962: 25 [Fernando de Noronha checklist].

Augochlora (*Augochlora*) *laevipyga*: Moure et al. 2007: 764 [catalog]; Rafael et al. 2020: 19 (Fernando de Noronha checklist).

Halictus alternipes Kirby, 1890: 542 [synonymized by Cockerell, 1909].

Diagnosis. Females can be recognized by the coloration pattern: integument dark metallic bluish-green. Apical surface of head notably dark brown, almost black, and blue reflections restricted to paraocular and supraclypeal areas and lateral areas of clypeus (Fig. 1b).

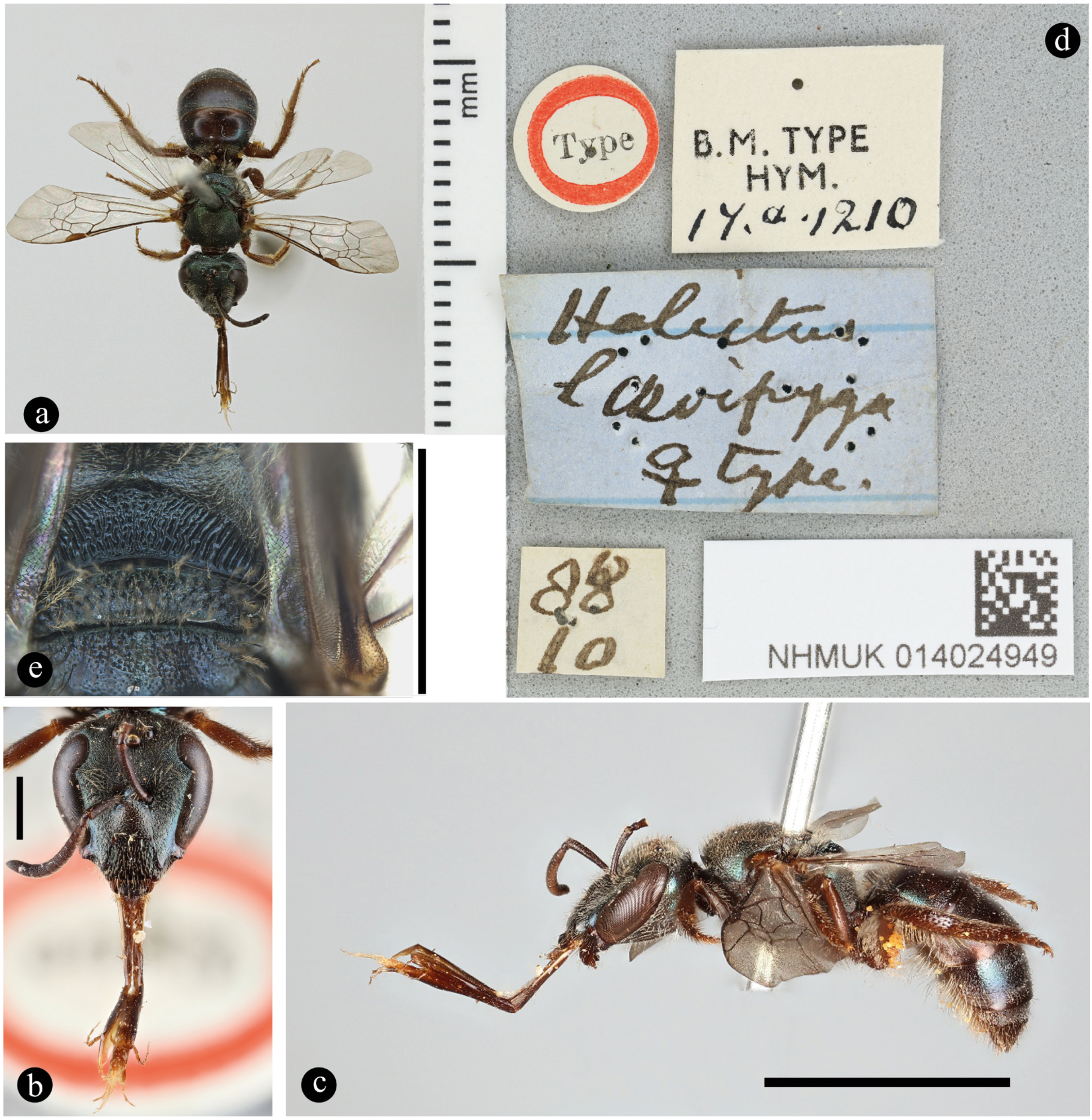

Figure 1. Female of *Augochlora* (*Augochlora*) *laevipyga* (Kirby, 1890). a–d, Type. a) dorsal habitus; b) head, frontal view; c) lateral habitus; d) Type labels; e) metapostnotum, dorsal view (figs. a and c, scale bar = 5 mm; figs. b and e, scale bar = 1 mm;); Photos credits a–d: Natural History Museum.

Redescription. FEMALE: Body length 8 mm {*10 mm*}; head length 2.2 mm; head width 2.1 mm; forewing length 5.5 mm.

Coloration. Integument dark metallic bluish-green {*head and thorax dark green, slightly bronzed*} (Figs. 1a–c and e). Apical surface of head dark brown, almost black, blue reflections restricted to paraocular and supraclypeal areas and lateral areas of clypeus. Mandible brown, apical third slightly yellowish. Antenna, brownish on ventral surface of flagellum. Tegula translucent brownish. Wing membrane hyaline, venation dark brown. Legs dark brown to ferruginous {*black*}. {*Abdomen shining, shading into violet at the extremity of the segments*}. Terga with translucent dark brown apical margins on T1–T4, sterna brownish.

Pubescence. Mainly white, inner surface of tibiae and tarsi with golden bristles. Head almost entirely covered by branched setae (1.5 OD) with subappressed tomentum. Clypeus covered by spaced simple hairs and supraclypeal, lower paraocular, and hypostomal areas without subappressed tomentum. Posterior margin of scutellum with long brown branched setae (3.5 OD). Mesepisternum, metanotum, and lateral and posterior surfaces of propodeum with dense plumose hairs (2–3 OD), metapostnotum glabrous. Anterior margin of T1 with long plumose hairs (2 OD), disc of T1 and T2 with very short simple setae, lateral bands longer (2 OD); T3–T5 with sparse short erect setae (1.5 OD) with short plumose hairs subappressed; T6 covered with long setae. Metasomal sterna covered with very long branched setae (4.5 OD), longer on S2–S4.

Surface sculpture. Face densely and minutely punctate. Clypeus punctate, punctures large and weak, loosely imbricate in between. Mesosoma densely fine punctured, slightly spaced on mesoscutellum. Metapostnotum strongly rugoso-carinulate (Fig. 1e). Metasomal terga evenly microsculptured and with very fine sparse punctation.

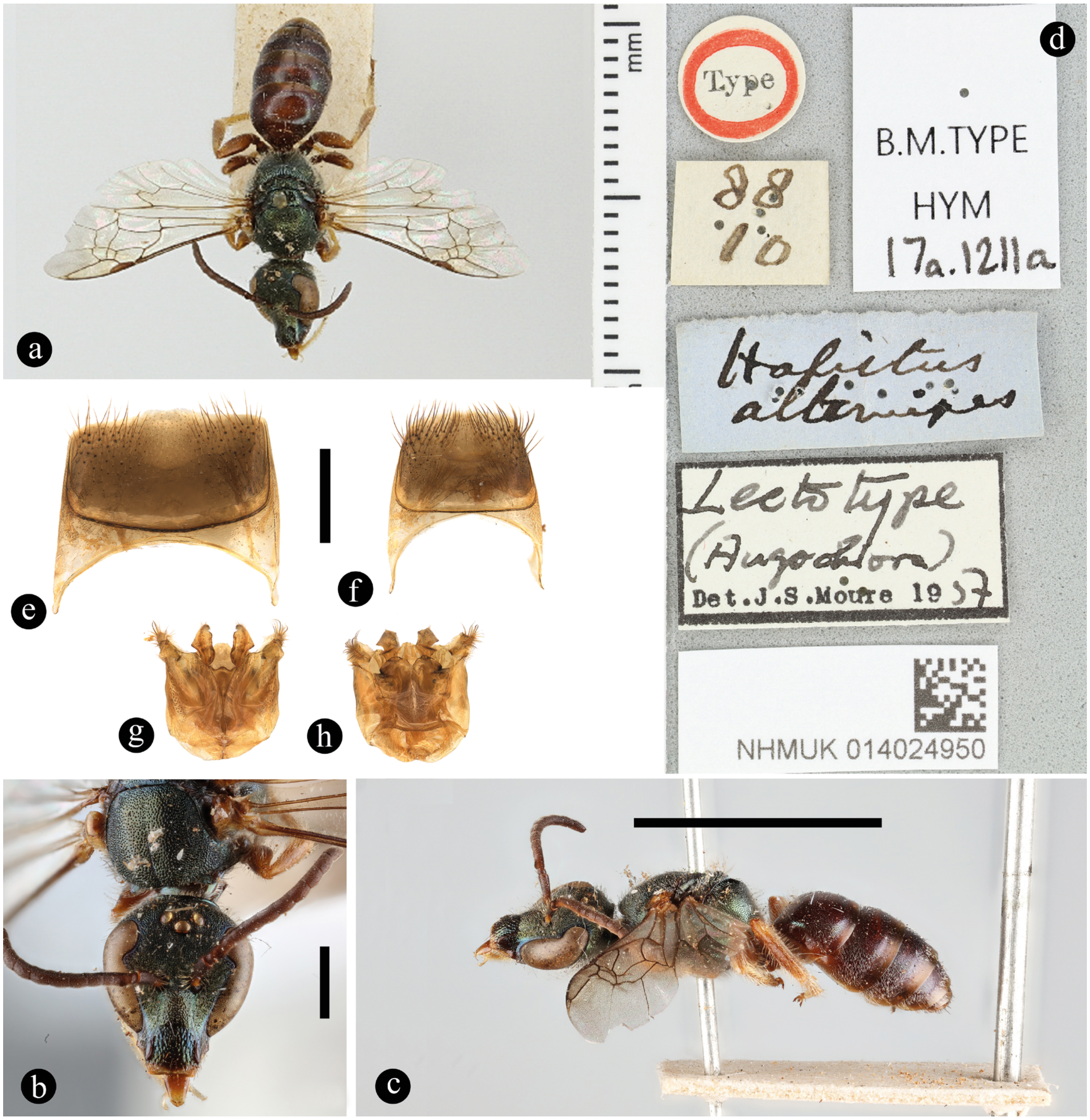

Figure 2. Male of *Augochlora* (*Augochlora*) *laevipyga* (Kirby, 1890). a–d, Type. a) dorsal habitus; b) head, frontal view; c) lateral habitus; d) Type labels; e) metasomal sternum 5; f) metasomal sternum 6; g) genital capsule, dorsal view; h) genital capsule, ventral view (figs. a and c, scale bar = 5 mm; fig. b, scale bar = 1 mm; figs. e–h scale bar = 0.5 mm); Photos credits a–d: Natural History Museum.

Structure. Ocellocular distance 2.5 OD. Gena broad, approximately 1.5 wider than compound eyes in lateral view. Mandible bidentate. Epistomal angle acute, strongly protruding over clypeus. Preoccipital carina lamellate, lamella expanded near post gena. Hypostomal carina not projected anteriorly. Metapostnotum slightly longer than metanotum. S1 with slight longitudinal median ridge.

MALE. Similar to female except as follows: body length 7.8–8.1 mm {*11 mm*}; head length 2.1–2.3 mm; head width 1.8–2 mm; forewing length 4.3–5 mm. Integument in general less darkened, metallic reflections more evident (Figs. 2a–c). Clypeus with yellow apical stripe. Tibiae and basitarsi yellowish. Punctures on mesoscutellum more spaced leaving large, polished areas on disc. Clypeus distinctly longer than wide, pronounced, giving an elongated aspect to head. Slight median longitudinal depression on mesoscutellum. Male terminalia structures as in Figure 2 (e–h).

Type material (examined through photographs). BRAZIL: Fern. Nor. [Fernando de Noronha], 88 10 [label verse] // Type // *Halictus laevipyga* ♀ type // B.M. Type 14.a.1210 // NHMUK 014024949 (Holotype ♀, NHMUK); Fern. Nor. [Fernando de Noronha], 88 10 [label verse] // Type // *Halictus alternipes* // B.M. Type 17a.1211a // NHMUK 014024950 // Lectotype (*Augochlora*) Det. J.S.Moure, 1957 (Syntype ♂, NHMUK).

Additional material examined. BRAZIL: Pernambuco, Arquipélago de Fernando de Noronha, Capim-Açu, 3°51′17″S, 32°26′26″W, 7-21.viii.2019, Malaise grande, J.A.Rafael, F.Limeira-de-Oliveira, L.C.Castro (1♀, INPA); *idem* Trilha Golfinhos, 7-22.vii.2019 (1♂, INPA); *idem* 9-23.vi.2019 (1♂, MNRJ); *idem* Trilha do Sancho, 12-27.ii.2020, Malaise pequena (1♂, CZMA).

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Biological notes. A bee's nest was found during the search for insects in a rotten trunk and carried to the laboratory of the Universidade Federal Rural de Pernambuco, where one adult specimen of *A. laevipyga* emerged. It is now known that this species nests in rotten wood.

Remarks. Kirby (1890) described two *Halictus* species, presently in the genus *Augochlora*, from Fernando de Noronha; *A. laevipyga* based on a female specimen, and *A. alternipes* based on both sexes. According to Kirby (1890), *A. alternipes* appeared to be "closely allied to *A. laevipyga*". In studying the types of these species in the NHMUK, Cockerrel (1909) synonymized both and since then they have been treated as synonymous (Moure et al. 2007). This species is quite difficult to be collected in the archipelago, and has not been observed in flowers yet. Only four specimens were collected in a restricted area in the more preserved flora of the south coast island.

Augochlora (*Augochlora*) sp.

(Figures 3–4)

Material examined. BRAZIL: Pernambuco, Arquipélago de Fernando de Noronha, Boldró, 3°51′02″S, 32°25′28″W, 16-19.xi.2021, Varredura, T. Mahlmann *Leg*. (3♀♀ and 4♂♂, INPA).

Remarks. This unidentified species could be interpreted as one of the synonym names above (*A. laevipyga* (Kirby, 1890) or *A. alternipes* (Kirby, 1890)). However, it can be easily distinguished by its smaller body size (about 5 mm) (versus 8–10 mm in *A. laevipyga*); by a head with a less elongated appearance (Fig. 3a) (versus head distinctly elongated in *A. laevipyga* (Fig. 1b)), by the notably greener metallic color (Figs. 3a–c) (versus dark metallic bluish-green in *A. laevipyga*, (Figs. 1a–c and e)) and by the male terminalia (Figs. 4d–g) (versus Figs. 2e–h of *A. laevipyga*). Due to these differences we herein consider it as a distinct species. *Augochlora* sp., as opposed to *A. laevipyga*, was only observed and collected in the peridomestic areas of the archipelago, in the central area of the main island visiting ornamental flowers such as Jetirana (*Merremia aegyptia* (L.) Urb.) (Fig. 5a), and it also seems to be an uncommon species. All specimens are being retained at the INPA collection for additional studies.

Lasioglossum (*Dialictus*) *atripyga* (Kirby, 1890)

(Figures 6–7)

Halictus atripyga Kirby, 1890: 543; Cockerell, 1909: 315 [taxonomic notes].

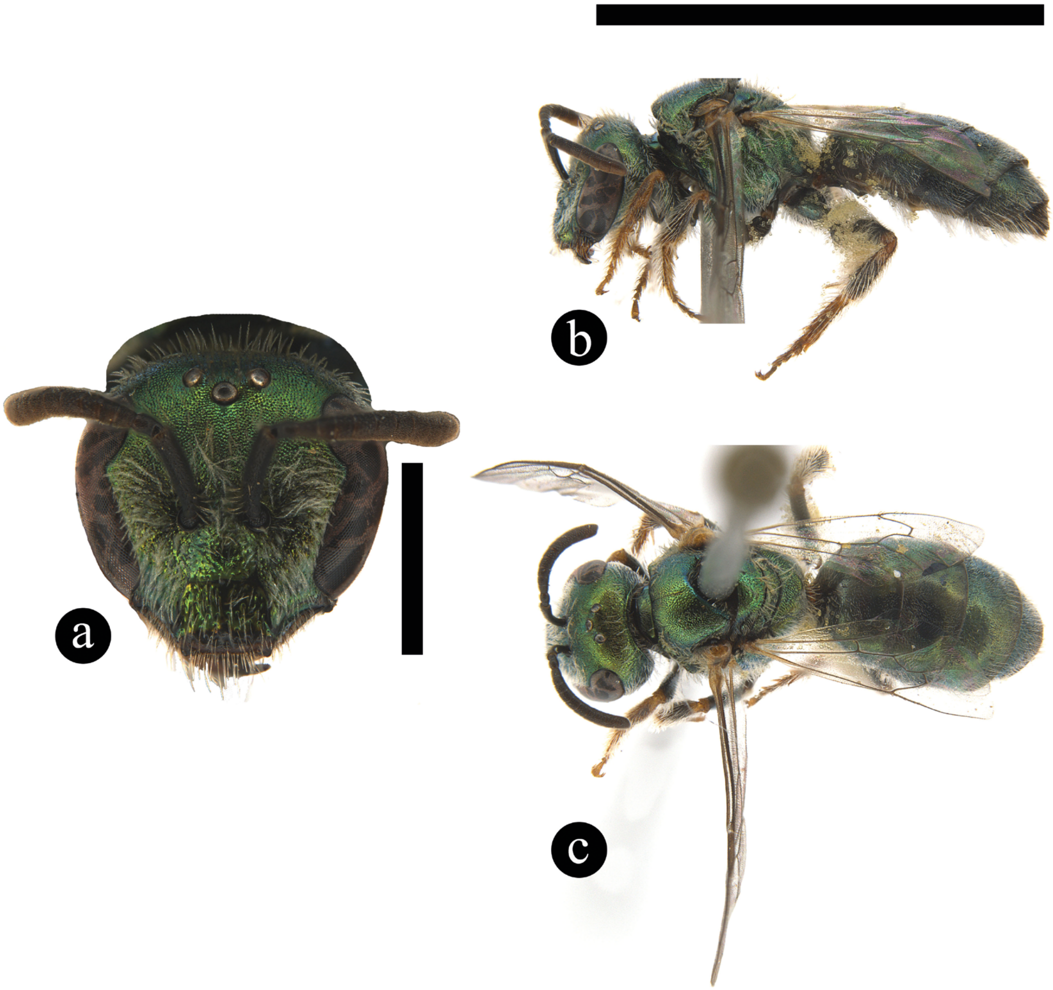

Figure 3. Female of *Augochlora* (*Augochlora*) sp. a) head, frontal view; b) lateral habitus; c) dorsal habitus (fig. a, scale bar = 1 mm; figs. b–c scale bar = 5 mm).

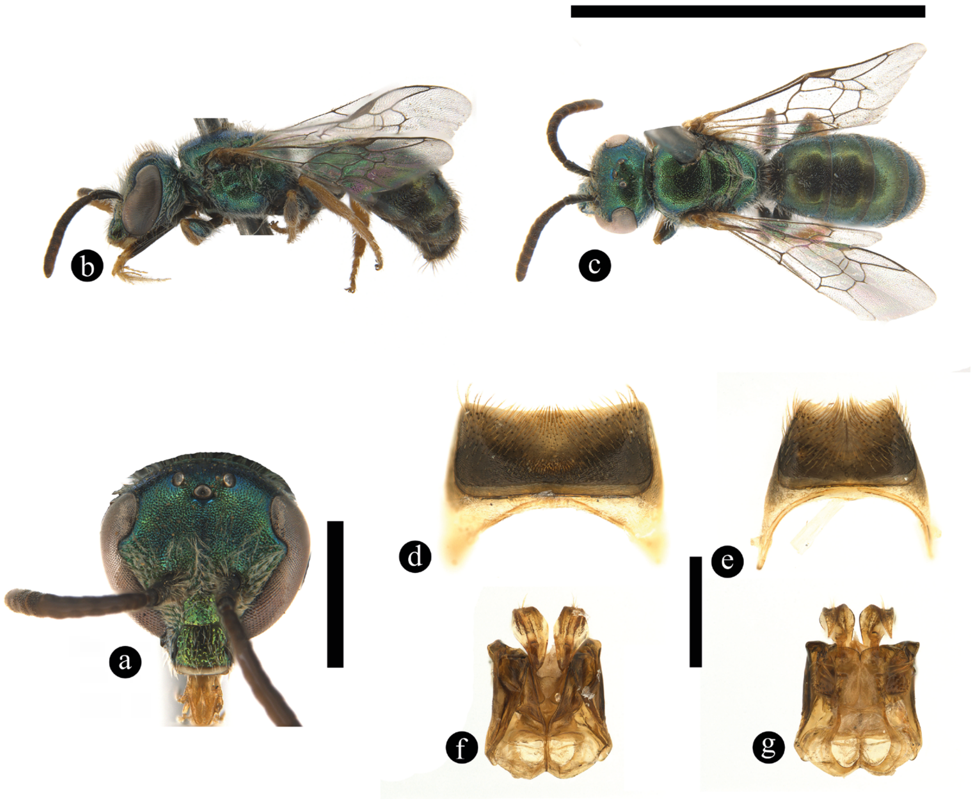

Figure 4. Male of *Augochlora* (*Augochlora*) sp. a) head, frontal view; b) lateral habitus; c) dorsal habitus; d) metasomal sternum 5; e) metasomal sternum 6; f) genital capsule, dorsal view; g) genital capsule, ventral view (fig. a, scale bar = 1 mm; figs. b–c scale bar = 5 mm; figs. d–g scale bar = 0.5 mm).

Figure 5. Sweat bees (Halictidae) visiting flowers in the Fernando de Noronha archipelago, Brazil. a) female of *Augochlora* (*Augochlora*) sp. on Jetirana (Convolvulaceae: *Merremia aegyptia* (L.) Urb.); b) female of *Lasioglossum* (*Dialictus*) *atripyga* on onze-horas (Portulacaceae: *Portulaca* sp.).

Dialictus (*Chloralictus*) *atripyga*; Alvarenga, 1962: 25 [Fernando de Noronha checklist].

Dialictus atripyga; Silveira et al. 2002: 185 [list, distribution]; Moure et al. 2007: 847 [catalog].

Lasioglossum (*Dialictus*) *atripyga*; Ascher & Pickering, 2015 [checklist]; Rafael et al. 2020: 19 (Fernando de Noronha checklist).

Diagnosis. Moderate-sized species (4.3–5.5 mm) with very singular coloration, mainly by the dull greenish bronzed body and yellowish brown on apical half of clypeus and pronotum and for the yellowish legs. Head rounded (length/width ratio about 1.1). Clypeus with depressed preapical fimbriae margin, laterally slightly projected at acute angle on each side.

Redescription. FEMALE: Body length 4.3–5.5 mm; head length 1.5–1.7 mm; head width 1.4–1.6 mm; forewing length 3.2–3.6 mm.

Coloration. Head and mesosoma largely dull greenish bronzed {*much bronzed*} (Figs. 6a–b, d–e). Mandible and apical half of clypeus yellowish brown. Antenna dark brown with basal third of scape and ventral surface of flagellum yellowish. Pronotum yellowish with translucent spots on anterior surface of pronotal lobes. Tegula translucent yellowish. Wing membrane hyaline, venation dark brown, pterostigma yellowish. Legs yellowish, except meso and metatibia brownish and dark brown spot on external surface of distitarsi. Terga brownish without metallic reflections and with translucent apical margins on T1–T4; sterna yellowish.

Pubescence. Mainly white, inner surface of tibiae and tarsi with golden bristles. Body with moderately dense hairs, sparse on hypostomal area and disc of T1–T3. Head covered almost entirely by plumose hairs (1.5 OD) with subappressed tomentum. Apical half of clypeus hairless. Clypeus and supraclypeal area, lower paraocular, and hypostomal areas without subappressed tomentum. Setae on dorsobasal area of scape longer than diameter of scape. Metafemur with strong scopa. Propodeum with dense plumose hairs on lateral and posterior surfaces (2–2.5 OD). Disc of T1 and T2 with very short simple setae, lateral bands longer (2–3 OD); T2 and T3 basally and laterally with short plumose hairs; T3 with sparse long branched setae, branches very short; T4 with sparse long branched setae similar to T3 with dense short plumose hairs subappressed; T5 and T6 covered with long plumose hairs, longer on lateral bands. Metasomal sterna covered with long plumose hairs, longer on S2; S1–S3 with apical short fringe.

Surface sculpture. Face imbricate, punctation fine. Clypeus entirely microsculptured, apical half almost unpunctured. Mesoscutum and mesepisternum strongly microsculptured with very fine sparse punctures. Mesoscutellum microsculptured with very fine sparse punctures anteriorly and with two sparse sculptured dorsal areas on each side. Metapostnotum weakly rugoso-carinulate, medial carina nearly reaching posterior margin (Fig. 6e). Metasomal terga polished evenly microsculptured and unpuctured.

Structure. Head round (length/width ratio about 1.1). Ocellocular distance 1.5 OD. Gena broad, approximately 1.5 wider than compound eyes in lateral view. Frontal line carinate, ending 2.3 OD below median ocellus. Clypeus with depressed preapical fimbriae margin, laterally slightly projected at an acute angle on each side. Labrum with apical process narrow, dorsal keel present. Mandible simple with small angular notch on preapical upper margin. Pronotal dorsal ridge weakly carinate from lateral angle to lobe. Three submarginal cells, first longer than two others together. Inner metatibial spur pectinate with 4–5 branches, sometimes less and asymmetrical (3 on one side and 5 on other). Metapostnotum moderately elongate, about two times the metanotum length. Propodeum without oblique carina, weak lateral carina not reaching dorsal surface.

MALE. Even though it is more slender and has longer antennae (Figs. 7a–c), it is similar to the female except as follows: body length 4.0–5.2 mm; head length 1.2–1.5 mm; head width 1.3–1.5 mm; forewing length 2.9–3.4 mm. Tegula, wing venation and legs darker brown. Metasoma dark brown. Clypeus evenly hairy; propodeal pilosity shorter; pilosity on metasomal sterna S2–S5 shorter medially. Metapostnotum coarsely rugoso-carinulate. Gena narrowed, almost as wide as the compound eyes in lateral view; mandible simple; scape shorter and F1 almost as long as wide and about half length of F2; inner metatibial spur not pectinate. Male terminalia structures as in figure 7 (d–f).

Type material examined. BRAZIL: Fern. Nor. [Fernando de Noronha], 88 10 [label verse] // atri-pyga, 30 // Syntype ♀, *Halictus atripyga* Kirby, det. D. Notton, 2015 // BMNH(E) #971054 (Syntype ♀, NHMUK).

Additional material examined. BRAZIL: Arquip. [Arquipélago], Fernando de Noronha, 03°50′S, 32°24′W, several data along the nine months of collection. Material examined totaling 79 ♀♀ and 560 ♂♂ to be deposited equally among the Brazilian collaborating collections: INPA, CZMA, MNRJ, MZUSP and UFRPE.

Remarks. Extremely common and apparently quite abundant species on the island, having been widely collected and observed visiting flowers of several species of plants, such as onze-horas (*Portulaca* sp.)

Figure 6. Female of *Lasioglossum* (*Dialictus*) *atripyga* (Kirby, 1890). a–d, Type. a) head, frontal view; b) lateral habitus; c) Type labels; d) dorsal habitus; e) metapostnotum, dorsal view (figs. a and e, scale bar = 1 mm; figs. b and d, scale bar = 5 mm); Photos credits a–d: Natural History Museum.

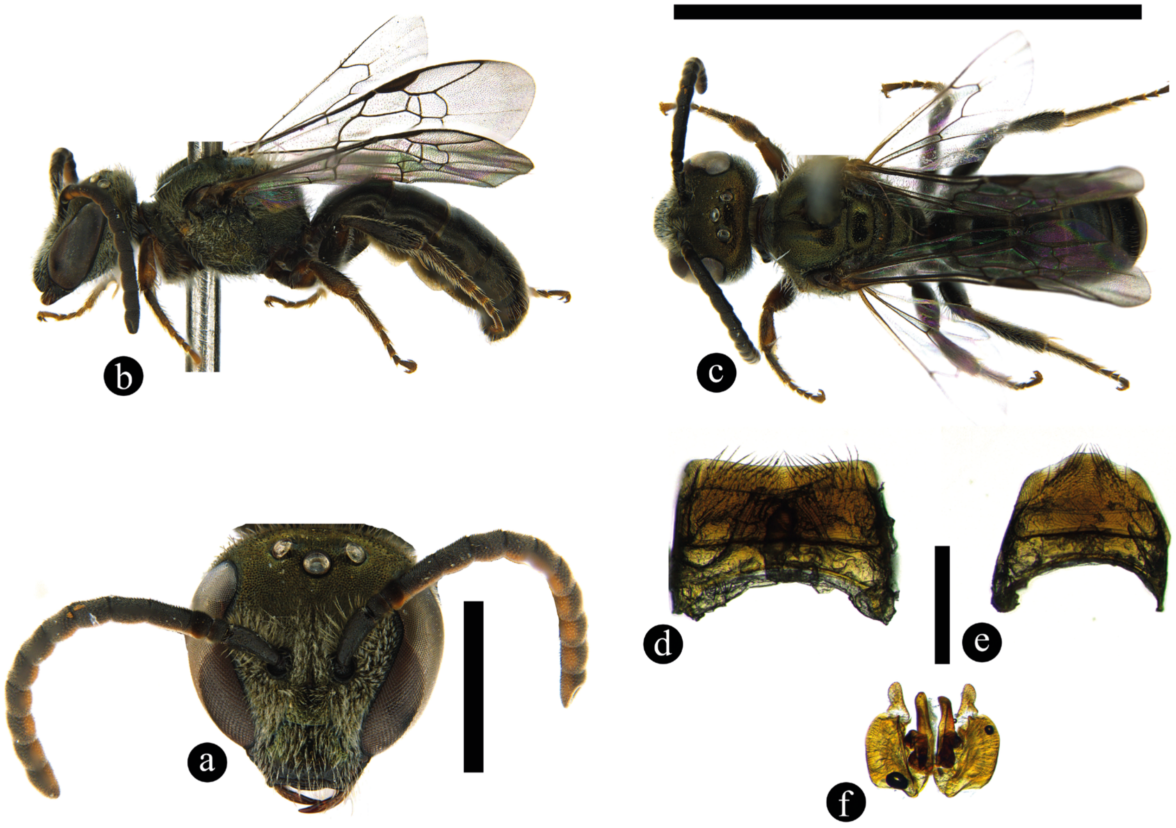

Figure 7. Male of *Lasioglossum* (*Dialictus*) *atripyga* (Kirby, 1890). a) head, frontal view; b) lateral habitus; c) dorsal habitus; d) metasomal sternum 5; e) metasomal sternum 6; f) genital capsule, dorsal view (fig. a, scale bar = 1 mm; figs. b–c scale bar = 5 mm; figs. d–f scale bar = 0.5 mm).

(Fig. 5b). Just like in *A. laevipyga*, the nesting behavior of this species has never been observed. However, a male specimen reported here was collected over a rotting wood, suggesting that this substrate might be explored for nesting. Michener (2007) states that a few species of *L.* (*Dialictus*) nest in rotting wood.

Discussion

Michener (2007) discussed the probable hypotheses of bee colonization on oceanic islands, commenting that the solitary to primitively social bees that nest in wood or stems are more likely to cross water barriers than those which nest in the ground, presumably because wood and stems containing nests are sometimes carried above water in floating islands of vegetation. However, he recognizes that the bee fauna of oceanic islands includes minute forms that nest in the soil, where dispersal presumably occurs by wind, at least for the small forms, whereas the larger ones probably came later and perhaps in some cases with the help of humans. We cannot be sure how or when exactly the colonization of the archipelago by insects began, but we agree with Carbonell (1996) that the Fernando de Noronha insect fauna is derived from the continental mainland, as these bees are common in the New World (Michener 2007, Gibbs 2011, Lepeco & Gonçalves 2020). The two described species are currently only recorded from Fernando de Noronha, an island with a low percentage of endemism (8%) for insects (Rafael et al. 2020).

Given the uncertainties about the biogeographical history of these two identified halictids, it is impossible to state when or how exactly these species appeared in the archipelago or whether these species can be found on the mainland. Nonetheless, more important than understanding how these species colonized the archipelago is to know when exactly this occurred, since isolation time of a population is decisive for evolution. Although it is impossible to precisely say when these species colonized the island, there are at least two possible and probable hypotheses. The first is related to the hypothesis of human intervention (i.e. boats, construction material such as earth and wood) in a recent period, probably between 1503 and 1890, corresponding to the period between the discovery of the island and the first record of the species, which could indicate living populations on the continent. The second is related to the hypothesis of earlier colonization (e.g., by wind or water as suggested by Michener 2007), wich could have favored the speciation process. Consequently, the chance that they are endemic is also greater.

According to Kirby (1890), *A. laevipyga*, cited as *A. alternipes*, "appears to be a very common" species; however, our results based on Malaise traps collection and sweeping, suggest that this species is not so common on the island.

Augochlora sp. is being recorded for the first time and it is possible that is a more recent introduction to the Fernando de Noronha archipelago.

The higher populational density of *L.* (*Dialictus*) *atripyga* probably has an economic impact on fruit culture activities on the main island. Kirby (1890) had already realized the importance of these bees for pollination on the island, when he declared that “these were taken in the flowers of the melons and the *Oxalis*, and play an important part in the fertilization of the flowers”. These bees are commonly found in the most diverse pollination studies, whether for crops or in natural landscapes and some species of the subgenus are known to be generalists on bee-plant interaction networks (Kleinert & Gianinni 2012).

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Author Contributions

Thiago Mahlmann: was responsible for the identification and illustration of the species; contributed to data collection and manuscript preparation

Francisco Limeira-de-Oliveira: contributed to data collection and manuscript preparation.

José Albertino Rafael: contributed to data collection and manuscript preparation.

Conflicts of Interest

The authors declares that they have no conflict of interest related to the publication of this manuscript.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

https://doi.org/10.48331/scielodata.B57TLW

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Short Communication

Abnormal average increase in sea surface temperature may promote the first documented mortality event of a marine sponge in the Southeastern Brazil

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Abstract: Frequent heat waves and mass mortality events on marine biota are positively correlated to ocean warming. Although literature has indicated some species of marine sponges, and some oceanic regions, like the Brazilian Exclusive Economic Zone, may be less affected or seem to be more resilient under future scenarios of climate changes, few studies have focused on the species responses on the climate change issue along Brazilian coast. This paradigm was undone throughout 2019 after an exceptional average increase of 2 °C in the sea surface temperature (SST) and on precipitation values since 2015 at Ilha Grande Bay (IGB, SE Brazil). The combination of SST and precipitation average increase possibly favored an environmental context for the unprecedented strong population decline and mass mortality rate of the marine sponge species *Desmapsamma anchorata* in the austral spring. The species used to be one of the most frequent benthic species at IGB however it was only recorded in 41.7% sites (n = 12). From 162 individuals recorded at Abraãozinho along 180 m rocky shore, 83 individuals (51.2%) were healthy, 74 (45.7%) were intensively covered by cyanobacteria and locally bleached, and five (3.1%) were completely bleached or died. *Desmapsamma anchorata* population deterioration in a biogeographic transition zone (Rio de Janeiro state) may reflect a shift in the marine community of IGB, opening space for opportunistic species establishment and coverage increase, since IGB has a high species turnover. The three-dimensionality, the shelter for several species, the high competitive ability and the potential to indicate polluted or not polluted areas make *D. anchorata* a key species for IGB monitoring in a climate change scenario.

Keywords: *Climate changes; Desmapsamma anchorata; Population decline; Heat waves; Ilha Grande Bay.*

Aumento na temperatura média do mar pode ter causado o primeiro evento registrado de mortalidade de esponjas marinhas no Sudeste do Brasil

Resumo: Ondas de calor e eventos de mortalidade em massa da biota marinha são cada vez mais frequentes e estão positivamente correlacionados ao aquecimento do oceano. Embora a literatura tenha indicado que algumas espécies de esponjas marinhas e algumas regiões oceânicas, como a Zona Econômica Exclusiva do Brasil, podem ser menos afetadas ou serem mais resilientes em cenários futuros de mudanças climáticas, poucos estudos focaram na resposta das espécies à problemática das mudanças climáticas na costa brasileira. Esse paradigma foi desfeito em 2019 após um excepcional aumento médio de 2 °C na temperatura da superfície do mar e nos valores de precipitação, desde 2015 na Baía da Ilha Grande (BIG, SE Brasil). Essa combinação de fatores possivelmente favoreceu um contexto ambiental sem precedentes, levando ao forte declínio populacional e alta taxa de mortalidade da esponja marinha *Desmapsamma anchorata* na primavera austral. A espécie costuma ser uma das espécies bentônicas mais frequentes na BIG, mas só foi observada em 41,7% dos sítios (n = 12). De 162 indivíduos registrados em Abraãozinho ao longo de 180 m de costão rochoso, 83 indivíduos (51,2%) estavam saudáveis, 74 (45,7%) estavam cobertos por cianobactéria e localmente branqueados e cinco (3,1%) estavam completamente branqueados ou mortos. A deterioração da população de *D. anchorata* na zona de transição biogeográfica (estado do Rio de Janeiro) pode refletir em uma alteração na comunidade marinha da BIG, abrindo espaço para o estabelecimento de espécies oportunistas, uma vez que a BIG possui alto *turnover*. A tridimensionalidade, o abrigo a diversas espécies, a alta capacidade competitiva e o potencial de indicar áreas poluídas ou não tornam *D. anchorata* uma espécie chave no monitoramento da BIG em um cenário de mudanças climáticas.

Palavras-chave: *Mudanças climáticas; Desmapsamma anchorata; Declínio populacional; Ondas de calor; Baía da Ilha Grande.*

Introduction

Ocean warming is one of the major events affecting marine biota from organism to ecosystem scales (Hoegh-Guldberg and Bruno 2010; Zhou et al. 2021). Marine species bleaching due to loss zooxanthellae and/or pigments (Glynn 1996), and mass mortality events on marine biota are positively correlated with this phenomenon, causing physiological changes, populations decline, interspecific relationships decrease, resulting in phase shift in the ecosystems (Yao and Somero 2014; Inagaki et al. 2020; Teixeira et al. 2021). Overall, ocean warming and diseases were surveyed on coral species from coral reefs, but other groups, such as Phylum Porifera, have also melted worldwide with global change (Vicente 1990; Fromont and Garson 1999; Pérez et al. 2000; Garrabou et al. 2009; Cebrian et al. 2011; Stevely et al. 2011; Rubio-Portillo et al. 2016). Understanding the response of different taxonomic groups into global change is the only way to promote practical restoration programs and constitute refugia zones.

Sponges have been considered winners under the stressful climate change phenomenon since their resilience in comparison to other groups (Fabricius et al. 2011; Peck et al. 2015; Bell et al. 2018). Some examples of sponges' tolerance to ocean warming were evidenced in the Great Barrier Reef (GBR, Schönberg and Ortiz 2008; Wisshak et al. 2012), Caribbean reefs (Duckworth et al. 2012), Bahia reefs, Brazil (Kelmo et al. 2013), sea-grass habitat at Peconic Bay (NY), USA (Duckworth and Peterson 2013) and Hawaiian reefs (Vicente et al. 2016). Bioeroding sponges were positively impacted with an increase in bioerosion rates (GBR, NY), while nonbioeroding sponges were not highly affected in their growth, survival, and biochemical synthesis (Duckworth et al. 2012). No effect on growth and survival of *Iotrochota birotulata* (Higgin, 1877) was evidenced after an experimental increase in 2.2 ºC in seawater temperature (Duckworth et al. 2012). An increase in the abundance of excavator sponges was the first response of boring species after a major coral bleaching event in GBR, suggesting that these sponges benefit from the warming of the oceans, as mortality of corals will possibly provide greater availability of space (Schönberg and Ortiz 2008). Specifically at Brazilian reefs, a sponge assemblage stability was found before and after an El Niño Southern Oscillation (ENSO) in 1997-98, which had increased the sea surface temperature (SST) by 2 °C (Kelmo et al. 2013). Even some sponges winning extreme thermal scenarios, it becomes irrelevant with the surrounding environment depreciation.

South Atlantic marine ecosystems have been documented as less impacted than Indo-Pacific and Caribbean ones in relation to thermal stress events (Baird and Marshall 2002; Perry et al. 2013; Kelmo et al. 2013; DeCarlo et al. 2017; Hughes et al. 2018; Mies et al. 2020). However, the impact of climate changes within Brazilian ZEE is poorly understood, with only local evidence of severe impacts on marine biota (Coutinho et al. 2016; Teixeira et al. 2019, 2021; Duarte et al. 2020; Gaspar et al. 2021). At Rio de Janeiro state, for example, Carvalho (2019) observed a persistent increase in air temperature overtaking 40 °C at Marambaia barrier island from September to February (austral spring and summer) in the XXI century, Skinner (2018a, b) have detected 33 ºC for SST with sensor *in situ*, in two sites of Ilha Grande Bay (IGB), from 2012 to 2017, and Coutinho et al. (2016) documented SST overtaking the daily range of 30 °C at Arraial do Cabo (RJ), a coastal city with historical predominance of cold waters, due to the influence of a strong upwelling during spring and summer months (Valentin 2001). These frequent and high SST values highlight the need for studies assessing the effect of rising SST on Brazilian coastal ecosystems.

The year of 2019 was exceptionally hot in Brazil causing an unprecedented mass mortality event on the major reef building hydrocoral *Millepora alcicornis* (Linnaeus, 1758) at the biggest coral reef of the South Atlantic, Abrolhos (Duarte et al. 2020), on the endemic coral species *Siderastrea stellata* Verrill, 1868 in the Rocas Atoll (Gaspar et al. 2021), and bleaching on cnidarians in Rio de Janeiro, Southeast Brazil (Santos et al. 2021). This heat wave throughout the year may also have caused a population decline and the first documented mortality event on the marine sponge species *Desmapsamma anchorata* (Carter, 1882) in the Southwestern Atlantic, Rio de Janeiro, IGB (Figure 1). The aim of this short communication is to report the population decline/mass mortality of *D. anchorata* at IGB. It is a relevant report, as the species is ecologically important due high abundance, competition

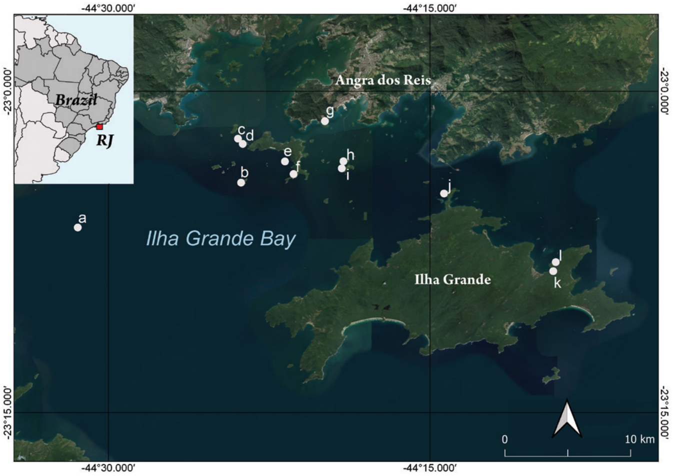

Figure 1. Map of the 12 sites where *Desmapsamma anchorata* was searched at Ilha Grande Bay, Rio de Janeiro (RJ), Brazil. Brazilian map is illustrated at the top-left corner. (a) Ilha da Laje Preta; (b) Ilha do Papagaio; (c) Ilha do Meio; (d) Ilha da Josefa; (e) Praia das flechas; (f) Praia do Dentista; (g) Ilha do Bonfim; (h) Ilha dos Porcos Pequena; (i) Ilha dos Porcos Grande; (j) Ilha dos Macacos; (k) Abraãozinho left rock shore; (l) Abraãozinho right rock shore.

with invasive species and potential for pollutant indicator (Silva 2018; Silva et al. 2017, 2022; Fortunato et al. 2020). Also, mass mortality of sponges was never documented along the Brazilian coastline, and there is scarce data of ocean warming affecting marine species at Rio de Janeiro state (Coutinho et al. 2016; Santos et al. 2021).

Material and Methods

Overall, IGB rocky shores are shallow, with average depth of 5.5 m in the Central channel, between 20 and 30 m depth on the west side and between 10 and 25 m on the east side (Creed 2009). Austral summer is 25–27 °C in SST average, and the benthic community is dominated by turf multispecies algae and the zoanthid *Palythoa caribaeorum* Duchassaing & Michelotti, 1860 (Creed et al. 2007; Mantelatto et al. 2022), but *D. anchorata* is commonly recorded as one of the major space-occupying species there (Mantelatto et al. 2013; Fortunato et al. 2020). An unusual absence of *D. anchorata* was observed during 20 minutes SCUBA dives at two depths (3 m – back and 10 m – forth), in 12 sites of IGB, in October 2019, aiming to collect the invasive ophiuroid *Ophiothela mirabilis* Verrill, 1867 being hosted by *D. anchorata*, as both species are intrinsically related in the region (Mantelatto et al. 2016; Tavares et al. 2019; Fortunato and Lôbo-Hajdu 2021). The absence of *D. anchorata* was recorded and a putative explanation is enlightened herein.

In the same survey,several individuals of *D. anchorata* were recorded at Abraãozinho beach rocky shores. Then, its population was quantified by three visual censuses along 30 × 1 m (30 m²) belts at 3 m depth and organisms were categorized as healthy (orange-pinkish color), unhealthy (pale color, locally bleached or covered by algae or cyanobacteria, and dead (partial or total necrosis). Arcsine transformed values for each category was statistically tested with ANOVA and Tukey *a posteriori* (JAMOVI Software) to identify how healthy the population was at that moment.

Monthly averaged SST dataset was obtained from Giovanni platform (Beaudoing and Rodell 2020) for the period 2015–2019, based on MODIS-Aqua satellite imagery with 4 km spatial resolution and compiled in an Excel file. ANOVA repeated measures was applied to evaluate statistical differences between years, after Shapiro-Wilk normality test indicate those values as normal (Jamovi 2021). Additionally, air temperature and precipitation dataset, for same time span, were obtained from an automatic station (Marambaia station) kept by the National Institute of Meteorology (INMET). It is an automatic station, located on the eastern side of the Marambaia barrier island (Rio de Janeiro southern coast). Therefore, oceanographic, and atmospheric data from IGB and Marambaia are comparable. Monthly and annually averages were computed for SST, air temperature and accumulated precipitation at MATLAB® to identify differences in the abiotic data from 2015 to 2019. Also, SST medians were statistically analyzed with the non-parametric Kruskal-Wallis test (Ernst 2004) using the PAST Software.

Results

From 12 sites where *D. anchorata* is routinely recorded at IGB, we only found the species in five sites (41.7%) indicating a strong decrease in the local population. From 162 individuals recorded at Abraãozinho, 83 individuals (51.2%) were healthy (Figure 2a–b), 74 individuals (45.7%) were intensively covered by cyanobacteria and locally bleached (Figure 2c–e), and five individuals (3.1%) were completely bleached or died (Figure 2f). Statistical differences were only recorded for the died category in relationship to the others (One-Way ANOVA F: 7.36, p = 0.01; Post-Hoc Tukey test: healthy:died – $p < 0.001$ and unhealthy:died – p = 0.001).

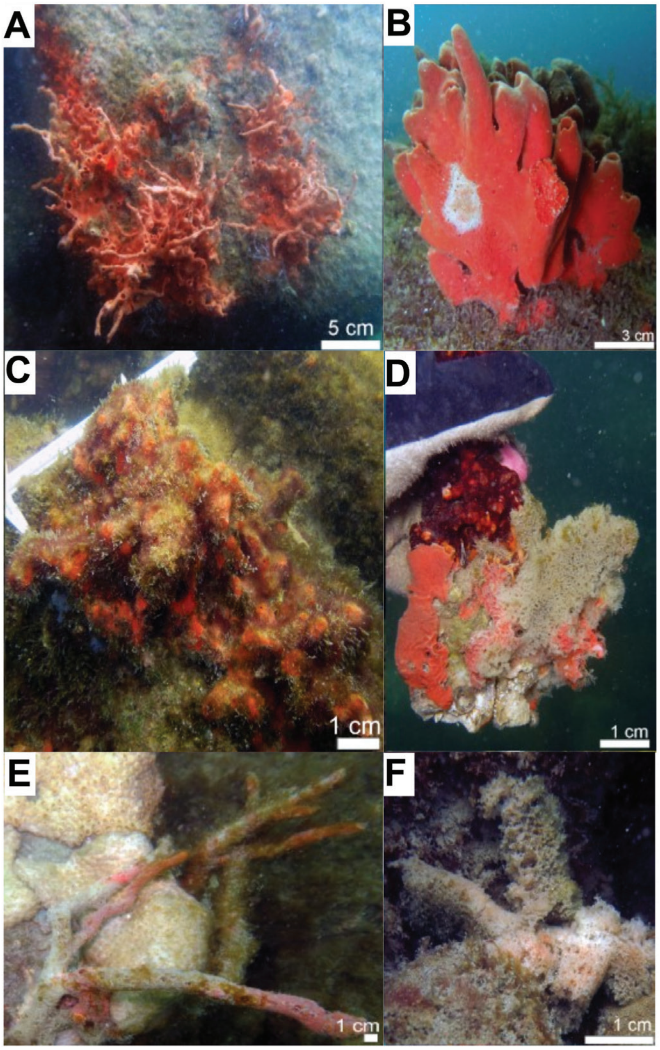

Figure 2. Life status of *Desmapsamma anchorata* at Abraãozinho in the austral spring of 2019. (a) Healthy pinkish arborescent specimen; (b) Lobate pink specimen with a bitten white mark; (c) Unhealthy massive specimen hugely covered by algae and cyanobacteria; (d) Partially healthy (pink) and dead (necrosed mass) in association with the bryozoan *Schizoporella errata* (Waters, 1878); (e) Unhealthy branching specimen with bleached and necrosed base and cyanobacteria cover in apical branches; (f) Dead digitiform specimen.

Monthly averaged SST revealed an abnormal elevation of 2 °C (26.6 °C) for 2019 in comparison to other years (2015–2018), while 2019 air temperature was only 0.1 °C higher than previous years (Table 1). Also, average precipitation values for 2019 are much higher than the other years. When monthly averages were compared to other years, 2019 months had the highest SST values with exception for July (no variation) and November (−0.7 °C). October 2019 (26.5 °C) was 3.5 °C warmer than the average between 2015–2018 (23 °C), 2019 had the highest SST values for all seasons in average, with austral

Table 1. Annual average values of Sea Surface Temperature (SST) from Ilha Grande Bay and annual average values of air temperature (AIR), annual accumulated precipitation, and average accumulated monthly precipitation for each year in Marambaia meteorological station from 2015 to 2019. The last column indicates the difference between the 2019 data and the highest ever recorded since 2015. Standard deviation values are inside parentheses.

Factor	2015	2016	2017	2018	2019	Variation
SST	24.6 (±2.15)	24.4 (±2.50)	23.9 (±2.49)	24.5 (±2.15)	26.6 (±2.92)	2.0
AIR	23.8 (±2.22)	23.6 (±2.49)	23.1 (±2.40)	23.5 (±1.96)	23.9 (±2.19)	0.1
AAP	1102.0	876.4	1043.6	1178.2	1679.4	501.2
AMP	91.8 (±71.12)	73.0 (±68.52)	87.0 (±63.63)	98.2 (±73.10)	140.0 (±136.96)	41.8

Note: SST: sea surface temperature; AIR: air temperature; AAP: annual accumulated precipitation; AMP: average accumulated monthly precipitation for each year.

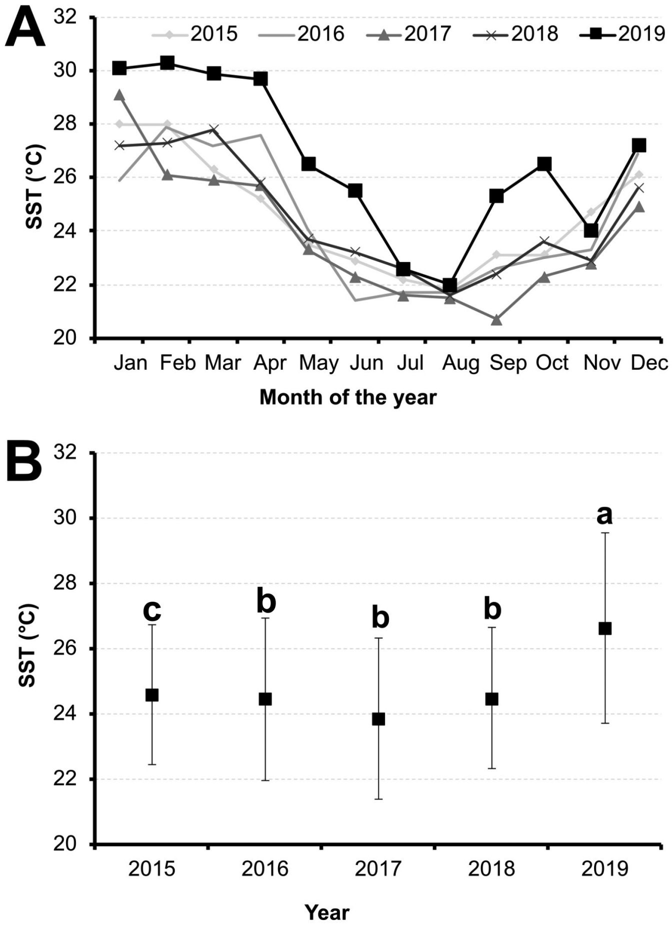

Figure 3. Sea surface temperature (SST) average values for both (a) months from 2015 to 2019, and (b) years obtained from Giovanni platform. In (b), statistical differences are shown by letters a, b (p ≤ 0.001), and c (p = 0.005) after ANOVA Repeated Measures and post-hoc Tukey test.

spring 1.6 °C warmer than the other years 2015–2018, and 2019 presented statistically higher values (Repeated Measures ANOVA F: 17.6, $p < 0.001$) SST than all compared years (Figure 3). The largest variations in air temperature occur during September (13.4−39.6 °C) and October (15.6−41.3 °C) (beginning of austral spring), while the largest accumulated precipitation values are recorded from January to March (281−473 mm) (austral summer and beginning of fall) (Supplementary Figure).

Discussion

Desmapsamma anchorata is widely spread in the Tropical Western Atlantic realm (Spalding et al. 2007), generally in high abundance, fast growing and aggressive competitive behavior (Aerts and van Soest 1997; McLean and Yoshioka 2008; Hajdu et al 2011; Silva et al. 2017). This sponge dominates Brazilian tropical bays rocky shores (Muricy and Hajdu 2006; Hajdu et al. 2011; Fortunato et al. 2020), but it also likes sedimented substrates from the Caribbean Sea to Rio de Janeiro state (McLean and Yoshioka 2008; Hajdu et al 2011; Fortunato et al. 2020). In general, few factors directly affect the species density in Brazil, such as presence of a more abundant species in Todos os Santos Bay (Bahia state) (see Oliveira and Lanna 2018) and hydrodynamics in IGB (Rio de Janeiro state) (see Fortunato et al. 2020).Specifically to IGB, it is one of the most frequent benthic species throughout the year in both abundance and relative cover in the bay side (Mantelatto et al. 2013, 2022; Fortunato et al. 2020). Their fragments presented fast growth from September to November during a manipulated experiment, doubling their volumes within a month (Ferreira 2016), and it can outgrow the invasive sun corals *Tubastraea* spp. locally (Silva et al. 2017, 2022). However, it seems sensitive to abrupt environmental changes through its distribution, such as high seawater temperature (Vilanova et al. 2004), pollution (Vilanova et al. 2004; Silva 2018) and storms (Wulff 2008). *Desmapsamma anchorata* may be considered as negatively affected to ocean warming in terms of gene expression, reproductive output, filtration capability, higher bleaching and necrosis due heat shock protein expression, and others (see Bell et al. 2018 for more examples). At IGB it is considered a putative sentinel species for urbanization pollutants (Silva 2018) and it is not observed in the assemblage close to thermal power plant water outlets (Vilanova et al. 2004).

Although 2019 SST was statistically warmer than other years at IGB, we cannot prove the direct relationship between the occurrence of high SST in 2019 and *D. anchorata*'s population decline and mortality, since we do not have information about annual cover or abundance data of the species for each year at IGB. However, an exceptional average increase of 2 °C in the SST since 2015 at Ilha Grande Bay (SE Brazil) and the species death are facts. Also, this year had extreme heat waves episodes that severely impacted Brazilian fauna in both Northeast (Duarte et al. 2020; Gaspar et al. 2021) and Southeast regions (Santos et al. 2021). In contrast to the survival of sponge assemblages after ENSO (Kelmo et al. 2013), Gaspar et al. (2021) suggests a higher impact on corals when ENSO and longer heat waves occur sequentially. Probably, this high SST in synergy with high precipitation values in

2019 (in comparison to other years) and more frequent and strong heat waves, favored an environmental context for this unprecedented strong population decline, bleaching and mortality rate of the marine sponge species *Desmapsamma anchorata* in the austral spring. While ocean warming may disrupt morphological and physiological changes in sponge species (Bell et al. 2018), run off may affects sponge species by increasing sedimentation that clog poriferans filtration system (i.e. Cerrano et al. 2001). Also, 45.7% of *D. anchorata* was intensively covered by cyanobacteria, a group favored by CO_2 rising (Visser et al. 2016) and harmful for corals (Ribeiro et al. 2018). The effect of this group on marine sponges is scarce (Rützler 1988; Webster 2007) but may not be underestimated.

Our biological record with marine sponges is the first along the Brazilian coast indicating population deterioration during an abnormal increase in the SST in the austral spring of 2019, when almost half of *D. anchorata* population was covered by cyanobacteria, macroalgae, bleached and/or necrosed and dead. Although some sponge species have tolerance to ocean warming and ocean acidification, most of the species are intensively affected by climate change (Peck et al. 2015; Bell et al. 2018), with several records of marine sponges death after high temperature and heat waves worldwide in the last years. It has been much more pronounced than historical mortality events (Smith 1941; Vacelet and Gallisian 1978; Rützler 1988; Webster 2007; Webster et al. 2002). Stronger heat waves and ocean warming provoke physiological and morphological lethal effects, benthic community shift from coral to seaweeds, cyanobacterial booms, and bacterial and viral diseases (Fromont and Garson 1999; Pérez et al. 2000; Stevely et al. 2011; Carballo and Bell 2017; Luter and Webster 2017). Outbreak in the *D. anchorata* population was possibly a synergy of several factors that we could not test. Physiologically and chemically monitoring the species is important to understand what factors may affect the species.

Desmapsamma anchorata population deterioration in the warmer austral spring from 2015–2019 in a climate change context in a biogeographic transition zone may reflect a shift in the marine community of IGB by decreasing the associated cryptic diversity and, in turn, opening space for other species arrival and coverage increase, since IGB has a high species turnover (Carlos-Júnior et al. 2019). Ilha Grande Bay holds about a thousand marine species and is considered a local biodiversity sanctuary (Creed et al. 2007). Absence of difference between healthy and unhealthy individuals of *D. anchorata* indicates a clear outbreak in its population. This collapse is dangerous once the species promotes three-dimensionality due its massive-arborescent shape plasticity, shelter for several species, high competitive ability and potential to indicate polluted or unpolluted areas. Therefore, *D. anchorata* is a key species for IGB monitoring in a climate change scenario.

Supplementary Material

The following online material is available for this article:

Figure S1 – Oceanographic and meteorological data from 2015 to 2019: (a) Monthly sea surface temperature variation in Ilha Grande Bay; (b) Monthly air temperature variation and (c) Monthly average accumulated precipitation in Marambaia station. Vertical bars are standard deviation values, dots are outliers above and below standard deviation, box represent 75% of the data and, line within box is the median.

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Humberto Freitas de Medeiros Fortunato: Substantial contribution in the concept and design of the study; Contribution to data collection, Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

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Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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Inventory

Tree species composition in Ilha Grande, Rio de Janeiro, Brazil

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BARROS A.A.M., KURTZ, B.C., MACHADO, D.N.S., OLIVEIRA, R.R., RIBAS, L.A., PESSOA, S.V.A. **Tree species composition in Ilha Grande, Rio de Janeiro, Brazil**. Biota Neotropica 22(3): e20221336. https://doi.org/10.1590/1676-0611-BN-2022-1336

Abstract: In the present study a specific and comprehensive analysis of the arboreal flora of Ilha Grande, located in the municipality of Angra dos Reis, on the southern coast of the state of Rio de Janeiro, Brazil, is presented. Unpublished data and contributions from studies already carried out at the site that investigated issues related to the composition and richness of tree species, the degree of threat, endemism and the history of occupation and/or changes in land use were gathered and analyzed. This study is part of the PPBio Mata Atlântica – Programa de Pesquisa em Biodiversidade (Biodiversity Research Program) which, through phytosociological inventories of the tree component, has been contributing, since 2010, to the increase in the floristic knowledge of Ilha Grande. The inventory identified 509 tree species, belonging to 220 genera and 74 families. Of these, 34 species were categorized as threatened, two of which are critically endangered, 18 are endangered and 14 are vulnerable. 53 exotic tree species were indicated. The results presented here reinforce the importance of these inventories as indispensable tools for the construction of strategies and actions for conservation, restoration and management of diversity in the context of the Atlantic Forest.

Keywords: *Atlantic Forest; conservation of biological diversity; endemism; insular environments; protected areas.*

Composição de espécies arbóreas na Ilha Grande, Rio de Janeiro, Brasil

Resumo: No presente estudo é apresentada uma análise específica e abrangente da flora arbórea da Ilha Grande, localizada no município de Angra dos Reis, litoral Sul do estado do Rio de Janeiro, Brasil. Informações inéditas e contribuições dos estudos já conduzidos no local que investigaram questões relacionadas à composição e riqueza de espécies arbóreas, grau de ameaça, endemismos e histórico de ocupação e/ou alterações de uso da terra foram reunidas e analisadas. Este estudo é parte do Programa de Pesquisa em Biodiversidade (PPBio) Mata Atlântica que, através de inventários fitossociológicos do componente arbóreo, vêm contribuindo, desde 2010, para o incremento do conhecimento florístico da Ilha Grande. O inventário identificou 509 espécies arbóreas, pertencentes a 220 gêneros e 74 famílias. Dessas, 34 espécies foram categorizadas como ameaçadas de extinção, sendo duas criticamente em perigo, 18 em perigo e 14 vulneráveis. Foram indicadas 53 espécies arbóreas exóticas. Os resultados aqui apresentados reforçam a importância desses inventários como ferramentas indispensáveis para a construção de estratégias e ações de conservação, restauração e manejo da diversidade no contexto da Mata Atlântica.

Palavras-chave: *Mata Atlântica; conservação da diversidade biológica; endemismo; ambientes insulares; áreas protegidas.*

Introduction

Knowing and evaluating the biological diversity present in different ecosystems is an important tool for the conservation of natural environments (Ashton 1992). In this sense, the study of natural areas impacted by human activities is of crucial importance for understanding the damage caused (Coelho et al. 2020), as well as for taking adequate measures for their conservation, restoration, management and impact mitigation (Juffe-Bignoli et al. 2021).

Among the factors responsible for the degradation of biodiversity, the loss and fragmentation of natural environments represent one of the main sources of threat (Laurance & Cochrane 2001, Metzger 2006). In tropical forest regions, changes and increases in the intensity of land use have led to changes in biodiversity patterns, with influences on the abundance and distribution of species (Pereira et al. 2007), determining the loss of potentially significant features and functions (Cardinale et al. 2012). A recent study shows that land use change would account for the highest values of total loss of habitat for plants in the Atlantic Forest, with a deleterious impact on species with a more restricted distribution (Leão et al. 2021).

Island environments have long instigated biogeographic investigations (e.g., MacArthur & Wilson 1967, Whittaker 1998). As islands vary in shape, size, spatial arrangement, geology, environments and biotic characteristics, investigations conducted on islands contribute to the understanding of fragmented continental landscapes (Tavares et al. 2019; Pessoa & Araujo 2020), interpreted as habitat islands (Whittaker 1998). On the southern coast of Rio de Janeiro, especially between the municipalities of Mangaratiba and Paraty, studies carried out both in continental areas (Marques et al. 1997, Maurenza et al. 2018) and in islanders (e.g., Callado et al. 2009) have shown relevance as sources of biological information, especially in relation to biodiversity conservation in fragmented areas (Carvalho et al. 2007).

In this region, the proximity of the Serra do Mar mountain range to the Atlantic Ocean accounts for the presence of abrupt and continuous walls with a crystalline basement (Barros 2008). The extension of the relief of this coast also generated a large number of coastal islands, originated in the last marine transgression, when the sea level rose between 17,000 and 5,100 years BP (Tessler & Goya 2005). Among these, there is Ilha Grande, considered a coastal island due to its location on the continental shield and a past connection to the mainland. Its geological formation belongs to the same events that gave rise to the Serra do Mar and Mantiqueira mountain ranges, the coastal massifs and the Baía de Guanabara graben (Ramos et al. 2015). Thus, Ilha Grande represents the top of a submerged mountain and has basically two types of relief: mountains and narrow coastal plains (Gralato 2016).

The largest island in the state of Rio de Janeiro and the third largest in the country (Ramuz 1998), Ilha Grande is part of the Serra do Mar biological corridor. Considered an ecological sanctuary, not only for its natural beauty, but mainly for its rich biological diversity and endemism (Callado et al. 2009, Nunes-Freitas et al. 2009). It represents one of the most important remnants of Atlantic Forest in Southeast Brazil (Alho et al. 2002). Botanical and plant population ecology studies carried out on this island concentrated efforts in the region of Reserva Biológica Estadual da Praia do Sul (Araujo & Oliveira 1988, Oliveira 2002, Nunes-Freitas et al. 2006, Cruz & Nunes-Freitas 2019) or focused on specific botanical families (Pederneiras et al. 2012, Nunes-Freitas et al. 2009, Santo 2016, Rosa 2017). As important as the works mentioned, there are those related to biological invasion (e.g., Ribas et al. 2010, Caires 2015, Zucaratto et al. 2020), endangered species (Vianna Filho et al. 2020) and scientific dissemination (Caires 2021).

However, there is still no specific and comprehensive analysis of the arboreal flora of Ilha Grande in the literature. In this inventory, contributions from studies already carried out at the site that investigated issues related to the composition and richness of tree species, the degree of threat, endemism and the history of occupation and/or changes in land use were gathered and analyzed. This study is part of the PPBio Mata Atlântica – Programa de Pesquisa em Biodiversidade (Biodiversity Research Program) which, through phytosociological inventories of the tree component, has been contributing, since 2010, to the increase in the floristic knowledge of Ilha Grande.

In this sense, the present study aims to answer the following questions: a) What is the current composition of tree species on Ilha Grande? b) Which species are new occurrences? c) Which ones are categorized as endangered? and d) How can the current composition of native and exotic species reflect the history of occupation and alteration of the vegetation mosaic of Ilha Grande?

Material and Methods

1. *Study site*

Ilha Grande (23 k 7445626.33S – 591101.45 E and 7429707.18 S – 564711.27 E, UTM, SIRGAS 2000) is located in the municipality of Angra dos Reis, in Baía da Ilha Grande, south coast of the state of Rio de Janeiro, Brazil (Figure 1). It is located in the coastal portion of Serra do Mar, which reaches the Atlantic Ocean through steep slopes. In this region, part of the coastal massif was isolated from the mainland, forming a set of islands and islets, especially Ilha Grande, with an area of 193 km^2 and approximately 30 km long and 12 km wide (Araujo & Oliveira 1988, Santiago et al. 2009). Ilha Grande has three conservation units (UC), which together protect about 80% of its territory: PEIG – Parque Estadual da Ilha Grande (Ilha Grande State Park), RBEPS – Reserva Biológica Estadual da Praia do Sul (Praia do Sul State Biological Reserve) and RDSA – Reserva de Desenvolvimento Sustentável do Aventureiro (Adventurer's Reserve for Sustainable Development) (INEA 2021). In addition to being part of the Área de Proteção Ambiental de Tamoios (Tamoios Environmental Protection Area). In 2019, Ilha Grande was considered a UNESCO World Cultural and Natural Heritage Site.

Two geomorphological domains make up the relief, the first consisting of igneous rocks (granites and charnockites) that form the steep slopes in most of the island. The second is formed with the deposition of sediments from climatic actions, marine deposition and erosion of rocks that make up the lowlands and coastal plains of the restingas in the coves close to the sea. The region comprises a mountainous relief with two drainage dividers that are arranged in the North-South and East-West directions, being interconnected through their topographic highs (Gama et al. 2009). For its largest part, it is below 500 m altitude, with the highest points being Serra do Retiro (1.031 m), Pico da Pedra d'Água (1.011 m) and Pico do Papagaio (959 m), positioned in the Central-Eastern portion of the island (Oliveira 2002). The predominant soil types are Cambisol and Spodosol (Gama et al. 2009). The climate is hot and humid (*Af*, *sensu* Köppen-Geiger), with no well-defined dry season. The rainfall is high and unevenly distributed across the island, e.g., varying between 1,245 and 4,531 mm

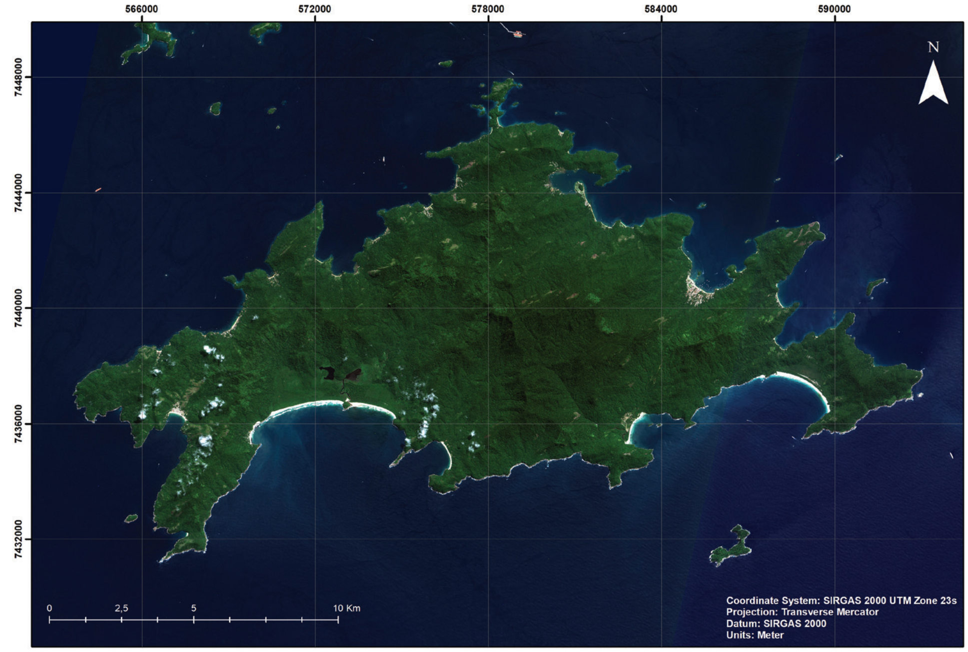

Figure 1. Map of Ilha Grande, Angra dos Reis, RJ, Brazil, showing its vegetation cover.

in different areas in a period of one year. Extreme values observed in the period of 1997–1998 (Oliveira & Coelho Netto 2001), with higher rainfall in summer and relative air humidity of 80% throughout the year. In January, average temperatures vary between 23 and 25°C and, in July, between 19 and 20°C (Salgado & Vasquez 2009).

The vegetation is inserted in the Dense Rainforest (*sensu* IBGE 2012), with predominance of Submontane and Montana formations, in addition to pioneers with marine influence (restingas and rocky shores), fluviomarine (mangrove) and fluvial (alluvial formations) (Callado et al. 2009) (Figure 2). The vegetation cover is characterized today by large extensions of secondary formations, in different stages of regeneration, with small patches of most conserved forests restricted to the higher altitudes.

Economic activities promoted major environmental changes on Ilha Grande and began with Portuguese colonization. The first period runs from the 16th century to the end of the 19th century. The second lasted during the development of prison activities (1903–1994) and the third, with the implementation of tourism in Ilha Grande, started in 1970, but intensified after the implosion of the maximum security prison Instituto Penal Cândido Mendes in 1994. During colonization, there was a predominance of agricultural exploitation and, in its heyday, this process was greatly increased. From the 17th century onwards, the coffee (*Coffea arabica* L.) season began on the farms of Abraão, Dois Rios, Palmas, Sant'Anna and Sítio Forte. This activity thrived until the 19th century (Ramuz 1998; Ribas et al. 2010). In the 19th century, with the expansion of coffee farming to the Vale do Paraíba region and also with the end of the slave trade, Ilha Grande went into great decline, with the coffee plantations and the entire structure of the farms abandoned (Santiago et al. 2009). With the implementation of conservation units in Ilha Grande, environmental protection led to a new phase, which encouraged tourism associated with nature and allowed the vegetation to regenerate.

2. *Data collection and analyzes*

In this work, a tree was considered to be any woody plant over 3.0 m tall, with a well-defined trunk, branches above the base and a root system fixed to the soil throughout its life cycle (Lima & Guedes-Bruni, 1997). Woody species that begin their life cycle as epiphytes were also accepted, of which the best known are popularly called "figueiras mata-pau". These plants go through three phases during their development: epiphytic, hemiepiphytic and arboreal or free-living (Coelho 2005). Arborescent ferns were not included.

Samples were obtained using the walking method (Filgueiras et al. 1994) and the phytosociological inventory in permanent plots of the PPBio Mata Atlântica, using the RAPELD methodology (Magnusson et al. 2005, Ribeiro et al. 2012). The core material is registered in the RFFP herbarium. The floristic inventory was complemented through consultations with the JABOT (2021) and INCT (2021) platforms, using the term "Ilha Grande" as a search filter. This material is found mainly in the RFFP, HRJ, HB, GUA and RB herbaria (acronyms according to Thiers 2021). Tree species considered exotic (Zenni & Ziller, 2011) were not included in the main list, but aggregated in a separate list. Species indicated as native in Flora e Funga do Brasil (2022), but not naturally occurring on Ilha Grande, are here considered exotic. They were addressed in the current conservation context (Dechoum et al. 2018, Sharrock et al. 2018) and associated with the history of occupation of Ilha Grande (Barros et al. 2022). Geographic origin data were consulted in Lorenzi et al. (2003).

The identification of the material was carried out through specialized bibliography, herbarium collections and, when necessary, consultation with specialists. The floristic list was organized according to the APG IV (2016), with the exception of Leguminosae, which followed the proposal of the LPWG (2017). The nomenclature of native species was conferred by Flora e Funga do Brasil (2022) and that of exotic species by The World

Figure 2. Types of vegetation that occur in Ilha Grande, Angra dos Reis, RJ, Brazil: a) Dense Rainforest; b) Restinga in Praia do Sul; c) Forest of Restinga in Lopes Mendes; d) Rocky Outcrop Vegetation on the East Coast; e) Rocky Outcrop Vegetation at Morro do Cavalinho; f) Mangrove in Saco do Céu; g) Flooded Forest in Lopes Mendes. Images: a, c, d, g) A.A.M. de Barros; b, f) Ilha Grande Portal; e) D.N.S. Machado.

Flora Online (2021). The classification of species according to their conservation status at the national level was based on MMA (2022) and CNCFlora (pers. comm., for non-threatened species) and, for the state of Rio de Janeiro, on Martinelli et al. (2018). Species not mentioned in published works (Araujo & Oliveira 1988, Oliveira 2002, Lobão et al. 2005, Callado et al. 2009, Pederneiras et al. 2011a, 2011b, 2012, Rosa 2013, 2017, Santo 2016, Ferreira et al. 2018, Lopes et al. 2019, Vianna Filho et al. 2020) were considered new occurrences for the vegetation of Ilha Grande.

Species sampled were classified according to their ecological group, into early-stage species (pioneers and early secondary) and late-stage species (late secondary). Information on the successional characterization of the species was obtained from the literature and the determination of the categories followed the proposal by Gandolfi et al. (1995).

The Venn diagram (Gotelli & Ellison 2016) was built to assess species sharing between the Rainforest areas and pioneer formations of Restinga. The Jaccard index (Magurran 2013) was used to assess the similarity between the arboreal flora of Ilha Grande and that of the Área de Proteção Ambiental (APA) de Cairuçu (Marques et al. 1997) and of the APA de Mangaratiba/Parque Estadual Cunhambebe (Maurenza et al. 2018). These conservation units are located on the mainland and are approximately 20 km and 7 km away, respectively, from Ilha Grande.

Results

1. *Floristic analysis*

The inventory identified 509 tree species, belonging to 220 genera and 74 families (Table 1). The families with the highest species richness were: Myrtaceae (87 species), Leguminosae (57), Rubiaceae (38), Melastomataceae (26), Lauraceae (25), Euphorbiaceae (19), Annonaceae

Table 1. Floristic list of tree species inventoried in Ilha Grande, Angra dos Reis, state of Rio de Janeiro, Brazil, with indications of new occurrences (NO), distinguishing those from general collections (G) and from the sampling of RAPELD Plots (R) and the respective categories of threat of extinction (IUCN) at the national (BR) and state (RJ) levels and the numbers of falls in the herbaria.

Family (nº genera/species)/Scientific Name	**NO**		**IUCN**		**Voucher**
	G	**R**	**BR**	**RJ**	
Acanthaceae (1/1)					
Avicennia schaueriana Stapf & Leechm. ex Moldenke	X		NE		RFFP12931
Achariaceae (1/1)					
Carpotroche brasiliensis (Raddi) A.Gray	X		NE		RFFP18233
Anacardiaceae (3/3)					
Anacardium occidentale L.			NE		HB85315
Schinus terebinthifolia Raddi			NE		RFFP13344
Tapirira guianensis Aubl.			NE		RFFP13310
Annonaceae (6/14)					
Anaxagorea dolichocarpa Sprague & Sandwith			LC		RBR38283
Annona cacans Warm.			LC		RFFP20321
Annona dolabripetala Raddi			LC		RFFP12869
Annona glabra L.			LC		RFFP12495
Annona mucosa Jacq.	X		NE		GUA39997
Duguetia pohliana Mart.			NE	EN	RBR32929
Guatteria australis A.St.-Hil.			LC		RFFP12752
Guatteria candolleana Schltdl.		X	LC		RFFP20322
Guatteria ferruginea A.St.-Hil.	X		LC		HRJ12455
Guatteria latifolia R.E.Fr.			NE		FCAB5441
Oxandra espintana (Spruce ex Benth.) Baill.		X	NE		RFFP18683
Oxandra martiana (Schltdl.) R.E.Fr.			LC		HRJ12212
Xylopia brasiliensis Spreng.			VU		RFFP16702
Xylopia langsdorffiana A.St.-Hil. & Tul.			NT		HRJ11631
Apocynaceae (4/4)					
Aspidosperma pyricollum Müll.Arg.			NE		RB259048
Geissospermum laeve (Vell.) Miers			NE		RBR38330
Malouetia cestroides (Nees ex Mart.) Müll.Arg.		X	LC		HRJ12214
Tabernaemontana laeta Mart.			NE		RFFP3746
Aquifoliaceae (1/5)					
Ilex cerasifolia Reissek			LC		RFFP20559
Ilex dumosa Reissek			NE		RB390925
Ilex integerrima (Vell.) Reissek			NE		HRJ12215
Ilex paraguariensis A.St.-Hil.			LC		GUA27861
Ilex theezans Mart. ex Reissek		X	NE		RB385112
Araliaceae (2/2)					
Didymopanax angustissimus Marchal			NE		HRJ11352
Oreopanax capitatus (Jacq.) Decne. & Planch.			LC		HB85431
Arecaceae (5/5)					
Astrocaryum aculeatissimum (Schott) Burret			LC		HB88051
Attalea dubia (Mart.) Burret			NE		RB710214

Continue...

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Family (nº genera/species)/Scientific Name	NO		IUCN		Voucher
	G	R	BR	RJ	
Bactris setosa Mart.			NE		RB710226
Euterpe edulis Mart.			VU		RB710284
Syagrus romanzoffiana (Cham.) Glassman			LC		RB725399
Asteraceae (1/1)					
Vernonanthura discolor (Spreng.) H.Rob.		X	NE		RBR32933
Bignoniaceae (5/6)					
Cybistax antisyphilitica (Mart.) Mart.			NE		RFFP17549
Jacaranda obovata Cham.			LC		RB699062
Jacaranda puberula Cham.		X	LC		RFFP19404
Handroanthus heptaphyllus (Vell.) Mattos			LC		HRJ12218
Sparattosperma leucanthum (Vell.) K.Schum.			NE		RFFP17915
Tabebuia stenocalyx Sprague & Stapf			NE		HRJ12219
Burseraceae (1/3)					
Protium brasiliense (Spreng.) Engl.			NE		NY608751
Protium glaziovii Swart		X	EN		RFFP20323
Protium widgrenii Engl.			LC		HRJ11671
Calophyllaceae (1/1)					
Kielmeyera membranacea Casar.			LC		RFFP18658
Cannabaceae (2/2)					
Celtis iguanaea (Jacq.) Sarg.			NE		not collected
Trema micrantha (L.) Blume			NE		RFFP12766
Capparaceae (1/1)					
Crateva tapia L.	X		NE		GUA35930
Cardiopteridaceae (1/1)					
Citronella paniculata (Mart.) R.A.Howard	X		NE		HRJ12294
Caricaceae (1/2)					
Jacaratia heptaphylla (Vell.) A.DC.			NE		HRJ11621
Jacaratia spinosa (Aubl.) A.DC.		X	LC		RFFP20324
Celastraceae (3/9)					
Cheiloclinium cognatum (Miers) A.C.Sm.		X	NE		RFFP18504
Monteverdia aquifolia (Mart.) Biral			LC		RFFP20325
Monteverdia ardisiifolia (Reissek) Biral			LC		RFFP14986
Monteverdia brasiliensis (Mart.) Biral		X	LC		RFFP12797
Monteverdia communis (Reissek) Biral	X		NE		HRJ12296
Monteverdia gonoclada (Mart.) Biral	X		NE		GUA36156
Monteverdia littoralis (R.M.Carvalho-Okano) Biral	X		LC		GUA16995
Monteverdia obtusifolia (Mart.) Biral			LC		HB85336
Peritassa laevigata (Hoffmanns. ex Link.) A.C.Sm.	X		NE		HRJ11624
Chloranthaceae (1/1)					
Hedyosmum brasiliense Mart. ex Miq.	X		NE		RFFP12753

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Chrysobalanaceae (5/6)				
Chrysobalanus icaco L.			NE	RB568633
Couepia monteclarensis Prance	X		LC	RB712178
Hirtella hebeclada Moric. ex DC.		X	LC	HRJ12199
Licania octandra (Hoffmanns. ex Roem. & Schult.) Kuntze			NE	HRJ12226
Licania riedelii Prance	X		LC	HRJ11503
Parinari brasiliensis (Schott) Hook.f.			LC	RBR32941
Clethraceae (1/1)				
Clethra scabra Pers.			LC	HB85200
Clusiaceae (4/8)				
Clusia criuva Cambess. subsp. *criuva*			LC	HB85488
Clusia criuva subsp. *parviflora* Vesque			LC	RB716884
Clusia fluminensis Planch. & Triana	X		NE	RFFP12732
Clusia lanceolata Cambess.			NE	RFFP14455
Garcinia brasiliensis Mart.			NE	RB489232
Garcinia gardneriana (Planch. & Triana) Zappi		X	NE	RFFP18218
Tovomita leucantha (Schltdl.) Planch. & Triana			NE	RFFP20560
Tovomitopsis paniculata (Spreng.) Planch. & Triana	X		NE	not collected
Combretaceae (2/2)				
Combretum laxum Jacq.		X	NE	RFFP20326
Laguncularia racemosa (L.) C.F.Gaertn.			NE	RFFP13374
Cordiaceae (1/6)				
Cordia aberrans I.M.Johnst.		X	LC	RFFP17998
Cordia magnoliifolia Cham.			LC	RFFP13367
Cordia sellowiana Cham.		X	NE	RFFP20327
Cordia taguahyensis Vell.			NE	RFFP18678
Cordia trichoclada DC.	X		LC	RBR32937
Cordia trichotoma (Vell.) Arráb. ex Steud.	X		NE	RFFP17168
Cunoniaceae (1/1)				
Lamanonia ternata Vell.			NE	RFFP3819
Dichapetalaceae (1/1)				
Stephanopodium estrellense Baill.		X	NE	HRJ11869
Elaeocarpaceae (1/3)				
Sloanea garckeana K.Schum.			LC	RB715139
Sloanea guianensis (Aubl.) Benth.		X	NE	RB532588
Sloanea hirsuta (Schott) Planch. ex Benth.		X	LC	RFFP17164
Erythropalaceae (1/2)				
Heisteria perianthomega (Vell.) Sleumer		X	NE	RFFP20339
Heisteria silvianii Schwacke			NE	HRJ12170
Erythroxylaceae (1/4)				
Erythroxylum ambiguum Peyr.			LC	HB85506
Erythroxylum cuspidifolium Mart.			NE	RFFP12992
Erythroxylum passerinum Mart.	X		LC	HB88343
Erythroxylum pulchrum A.St.-Hil.			LC	RFFP12870

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Family (nº genera/species)/Scientific Name	NO		IUCN		Voucher
	G	R	BR	RJ	
Euphorbiaceae (13/19)					
Actinostemon concolor (Spreng.) Müll.Arg.	X		NE		HRJ12303
Actinostemon klotzschii (Didr.) Pax		X	NE		RFFP16699
Actinostemon verticillatus (Klotzsch) Baill.	X		NE		RFFP13332
Alchornea glandulosa subsp. *iricurana* (Casar.) Secco			NE		RB412990
Alchornea triplinervia (Spreng.) Müll.Arg.			NE		RFFP13312
Algernonia brasiliensis Baill.	X		VU		RFFP19623
Algernonia leandrii (Baill.) G.L.Webster			LC		RFFP12899
Aparisthmium cordatum (A.Juss.) Baill.			NE		HRJ12209
Caryodendron grandifolium (Müll.Arg.) Pax		X	LC		RFFP14490
Croton floribundus Spreng.			LC		RFFP19393
Croton organensis Baill.	X		LC		RB385014
Gymnanthes multiramea (Klotzsch) Müll.Arg.			NE		RFFP16584
Mabea fistulifera Mart.	X		NE		RFFP16692
Mabea piriri Aubl.			NE		GUA27547
Pachystroma longifolium (Nees) I.M.Johnst.	X		NE		HRJ11540
Pausandra morisiana (Casar.) Radlk.			LC		RFFP16722
Sapium glandulosum (L.) Morong			NE		GUA38848
Senefeldera verticillata (Vell.) Croizat			LC		HRJ11302
Tetrorchidium rubrivenium Poepp.			LC		RFFP17260
Humiriaceae (2/2)					
Humiria balsamifera (Aubl.) A.St.-Hil.			NE		RB717541
Humiriastrum dentatum (Casar.) Cuatrec.	X		NE		GUA40466
Lacistemaceae (1/2)					
Lacistema pubescens Mart.			NE		HRJ11718
Lacistema serrulatum Mart.			LC		RB198184
Lamiaceae (2/2)					
Aegiphila integrifolia (Jacq.) Moldenke			NE		HB86574
Vitex polygama Cham.		X	NE		RBR33021
Lauraceae (10/25)					
Aiouea saligna Meisn	X		NE		RB718010
Aniba firmula (Nees & Mart.) Mez			LC		RFFP16246
Beilschmiedia angustifolia Kosterm.			NE	EN	HRJ11886
Beilschmiedia emarginata (Meisn.) Kosterm.	X		LC		HRJ12328
Cryptocarya moschata Nees & Mart.			NE		HRJ11597
Cryptocarya saligna Mez	X		NE		RFFP16694
Endlicheria glomerata Mez		X	LC		HRJ11599
Endlicheria paniculata (Spreng.) J.F.Macbr.			NE		GUA26991
Licaria armeniaca (Nees) Kosterm.	X		NE		GUA29936
Nectandra membranacea (Sw.) Griseb.			NE		RFFP18741
Nectandra puberula (Schott) Nees			NE		RFFP16231

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Ocotea corymbosa (Meisn.) Mez	X		NE		HRJ12330
Ocotea daphnifolia (Meisn.) Mez	X		LC		HRJ12221
Ocotea diospyrifolia (Meisn.) Mez			NE		FCAB5486
Ocotea dispersa (Nees & Mart.) Mez	X		NE		HRJ12331
Ocotea divaricata (Nees) Mez			NE		RFFP15030
Ocotea glaziovii Mez		X	NE		RFFP13451
Ocotea indecora (Schott) Mez	X		NE		HRJ12332
Ocotea odorifera (Vell.) Rohwer	X		EN		HRJ12334
Ocotea puberula (Rich.) Nees	X		NT		GUA40408
Ocotea pulchella (Nees & Mart.) Mez	X		LC		RB718523
Ocotea silvestris Vattimo-Gil	X		LC		HRJ12335
Ocotea teleiandra (Meisn.) Mez			LC		FCAB5453
Rhodostemonodaphne macrocalyx (Meisn.) Rohwer ex Madriñán	X		NE		HRJ11609
Urbanodendron bahiense (Meisn.) Rohwer			EN		HRJ12336
Lecythidaceae (3/3)					
Cariniana estrellensis (Raddi) Kuntze			NE		HRJ12337
Couratari pyramidata (Vell.) Kunth			EN	EN	HB85300
Lecythis pisonis Cambess.			NE		HRJ1233
Leguminosae (29/57)					
Abarema brachystachya (DC.) Barneby & J.W.Grimes			NE		RFFP16121
Abarema cochliacarpos (Gomes) Barneby & J.W.Grimes	X		LC		RFFP13621
Albizia pedicellaris (DC.) L.Rico	X		NE		HRJ13002
Anadenanthera colubrina (Vell.) Brenan			NE		RFFP14974
Anadenanthera peregrina (L.) Speg.	X		NE		HB96163
Andira fraxinifolia Benth.			NE		RB748871
Andira ormosioides Benth.			NE		RFFP13591
Bauhinia forficata Link	X		NE		HB96148
Bauhinia longifolia (Bong.) Steud.	X		LC		RFFP18255
Cassia ferruginea (Schrad.) Schrad. ex DC.			NE		RFFP14969
Chamaecrista ensiformis (Vell.) H.S.Irwin & Barneby		X	NE		RFFP13400
Copaifera langsdorffii Desf.	X		NE		HRJ12316
Copaifera lucens Dwyer			LC		HRJ12315
Copaifera trapezifolia Hayne			NE		RFFP18536
Dahlstedtia pinnata (Benth.) Malme			LC		RFFP12799
Erythrina speciosa Andrews			LC		RFFP11901
Hymenaea courbaril L.	X		LC		HRJ12319
Inga bullata Benth.	X		NT		RFFP12803
Inga capitata Desv.		X	NE		RFFP15011
Inga cordistipula Mart.	X		VU		HRJ11179
Inga edulis Mart.			NE		RFFP12868
Inga flagelliformis (Vell.) Mart.		X	NE		RFFP18577
Inga lanceifolia Benth.			LC		FCAB5445
Inga laurina (Sw.) Willd.	X		LC		RFFP12744

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Family (nº genera/species)/Scientific Name	NO		IUCN		Voucher
	G	R	BR	RJ	
Inga marginata Willd.			NE		RB491062
Inga maritima Benth.	X		EN		HRJ13177
Inga sellowiana Benth.			LC		RB371309
Inga sessilis (Vell.) Mart.	X		LC		HB96158
Inga striata Benth.			NE		NY413947
Inga subnuda subsp. *luschnathiana* (Benth.) T.D.Penn.			NE		RFFP16906
Inga tenuis (Vell.) Mart.			NE		FCAB5443
Inga vera subsp. *affinis* (DC.) T.D.Penn.	X		NE		RB351749
Lonchocarpus cultratus (Vell.) A.M.G.Azevedo & H.C.Lima			NE		RB418225
Mimosa bimucronata (DC.) Kuntze			NE		RFFP13480
Myrocarpus frondosus Allemão		X	LC		RFFP20328
Ormosia arborea (Vell.) Harms			LC		RB489077
Ormosia fastigiata Tul.	X		LC		HRJ12322
Piptadenia gonoacantha (Mart.) J.F.Macbr.			LC		HB96257
Platymiscium floribundum Vogel	X		NE		RB505773
Pseudopiptadenia contorta (DC.) G.P.Lewis & M.P.Lima			LC		FCAB5444
Pseudopiptadenia schumanniana (Taub.) G.P.Lewis & M.P.Lima		X	LC		RFFP19622
Pterocarpus violaceus Vogel	X		NE		RFFP12922
Schizolobium parahyba (Vell.) Blake			NE		HRJ13205
Senegalia polyphylla (DC.) Britton & Rose			NE		not collected
Senna macranthera (DC. ex Collad.) H.S.Irwin & Barneby	X		NE		RFFP19976
Senna multijuga (Rich.) H.S.Irwin & Barneby			NE		RFFP14968
Senna pendula (Humb. & Bonpl. ex Willd.) H.S.Irwin & Barneby			NE		RFFP17545
Stryphnodendron polyphyllum Mart.	X		NE		RFFP16130
Swartzia acutifolia Vogel	X		LC		FCAB7124
Swartzia flaemingii Raddi var. *flaemingii*	X		LC		RB553376
Swartzia myrtifolia Sm.			NE		HRJ12324
Swartzia oblata R.S.Cowan			LC		HRJ11716
Tachigali denudata (Vogel) Oliveira-Filho			NT		HRJ12325
Tachigali paratyensis (Vell.) H.C.Lima	X		LC		RFFP16685
Vatairea heteroptera (Allemão) Ducke			LC		HRJ12326
Zollernia glabra (Spreng.) Yakovlev			LC		HRJ13207
Zygia latifolia (L.) Fawc. & Rendle	X		NE		RFFP15388
Malpighiaceae (2/3)					
Bunchosia maritima (Vell.) J.F.Macbr.			LC		RFFP17273
Byrsonima chrysophylla Kunth	X		NE		GUA48565
Byrsonima sericea DC.			NE		RFFP3699
Malvaceae (6/9)					
Ceiba crispiflora (Kunth) Ravenna	X		EN		GUA30140
Ceiba speciosa (A.St.-Hil.) Ravenna			NE		HB85261
Eriotheca gracilipes (K.Schum.) A.Robyns	X		NE		RB491172

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Eriotheca pentaphylla (Vell.) A.Robyns		LC		HB86443
Guazuma ulmifolia Lam.	X	NE		BHCB76003
Luehea conwentzii K.Schum.	X	LC		HB85464
Luehea divaricata Mart.		NE		RFFP20330
Quararibea similis C.D.M.Ferreira & Bovini		NE		RFFP18237
Talipariti pernambucense (Arruda) Bovini		NE		RFFP3811
Melastomataceae (6/26)				
Huberia ovalifolia DC.		NE		RFFP3818
Leandra acutiflora (Naudin) Cogn.		NE		RB482272
Leandra variabilis Raddi		NE		RFFP13334
Meriania claussenii (Naudin) Triana	X	LC		RFFP14.982
Meriania glazioviana Cogn.		NE	EN	RFFP3824
Meriania longipes Triana		NE	EN	RFFP16243
Miconia albicans (Sw.) Triana		NE		RFFP13608
Miconia brasiliensis (Spreng.) Triana		LC		HRJ13125
Miconia calvescens DC.		NE		RFFP11877
Miconia cinerascens Miq.		NE		RB482222
Miconia cinnamomifolia (DC.) Naudin		NE		RB433995
Miconia cubatanensis Hoehne		LC		HRJ12345
Miconia dodecandra Cogn.		NE		RFFP13257
Miconia flammea Casar.		NE		RB482230
Miconia formosa Cogn.		LC		HRJ12627
Miconia holosericea (L.) DC.		NE		HRJ13141
Miconia ibaguensis (Bonpl.) Triana		LC		RFFP13392
Miconia latecrenata (DC.) Naudin		NE		HRJ13145
Miconia mirabilis (Aubl.) L.O.Williams		NE		HRJ11344
Miconia prasina (Sw.) DC.		NE		RFFP12755
Miconia pusilliflora (DC.) Naudin		NE		RFFP16348
Mouriri arborea Gardner		LC		HRJ12347
Mouriri doriana Saldanha ex Cogn.		EN		HRJ12348
Pleroma estrellense (Raddi) P.J.F.Guim. & Michelang.		NE		RFFP17923
Pleroma granulosum (Desr.) D.Don		NE		HRJ13169
Pleroma thereminianum (DC.) Triana		NE	EN	RFFP3770
Meliaceae (4/12)				
Cabralea canjerana (Vell.) Mart.		NE		RFFP16708
Cedrela odorata L.		VU		RFFP16703
Guarea guidonia (L.) Sleumer		NE		RFFP3720
Guarea macrophylla subsp. *tuberculata* (Vell.) T.D.Penn.		NE		RFFP14859
Trichilia casaretti C.DC.		LC		RFFP12953
Trichilia catigua A.Juss.	X	LC		not collected
Trichilia elegans A.Juss.		NE		HB87106
Trichilia hirta L.		LC		FCAB5429
Trichilia lepidota subsp. *schumanniana* (Harms) T.D.Penn.		LC		HRJ12612

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Family (nº genera/species)/Scientific Name	**NO**		**IUCN**		**Voucher**
	G	**R**	**BR**	**RJ**	
Trichilia martiana C.DC.			NE		RFFP18042
Trichilia pallida Sw.	X		NE		RB385110
Trichilia silvatica C.DC.			LC		RB701357
Monimiaceae (2/11)					
Macrotorus utriculatus (Mart.) Perkins	X		LC		RFFP12967
Mollinedia acutissima Perkins			VU	EN	RFFP16442
Mollinedia glabra (Spreng.) Perkins			LC		HRJ12352
Mollinedia heteranthera Perkins		X	NE		RFFP20331
Mollinedia lamprophylla Perkins		X	NT		RFFP20344
Mollinedia longifolia Perkins			LC		RFFP12979
Mollinedia oligantha Perkins	X		NE		RFFP11331
Mollinedia ovata Ruiz & Pav.	X		LC		RFFP17206
Mollinedia schottiana (Spreng.) Perkins			NE		RFFP18508
Mollinedia triflora (Spreng.) Tul.	X		NE		RFFP11330
Mollinedia uleana Perkins	X		NE		RB645857
Moraceae (3/12)					
Brosimum guianense (Aubl.) Huber			NE		GUA39782
Ficus adhatodifolia Schott in Spreng.			LC		RFFP11892
Ficus arpazusa Casar.			NE		RFFP13541
Ficus cyclophylla (Miq.) Miq.			NT		RB691862
Ficus eximia Schott	X		LC		HRJ11539
Ficus gomelleira Kunth			NE		RB693040
Ficus organensis (Miq.) Miq.			NE		RFFP13248
Ficus pulchella Schott			LC		HRJ 12982
Ficus trigona L.f.			NE		GUA28423
Ficus vermifuga (Miq.) Miq.			LC		RB692352
Sorocea guilleminiana Gaudich.			LC		RB693382
Sorocea hilarii Gaudich.			NE		RFFP13445
Myristicaceae (1/2)					
Virola bicuhyba (Schott ex Spreng.) Warb.			EN		HRJ12357
Virola gardneri (A.DC.) Warb.			NE		RFA31267
Myrtaceae (9/87)					
Campomanesia guaviroba (DC.) Kiaersk.			NE		HRJ11742
Campomanesia guazumifolia (Cambess.) O.Berg.	X		NE		HRJ11714
Campomanesia schlechtendaliana (O.Berg) Nied.			LC		RFFP20332
Eugenia astringens Cambess.			LC		RFFP16716
Eugenia bahiensis DC.			LC		RFFP18247
Eugenia batingabranca Sobral	X		LC		HRJ12392
Eugenia bimarginata DC.	X		LC		GUA16998
Eugenia brasiliensis Lam.			LC		RFFP12930
Eugenia bunchosiifolia Nied.			VU		HB85574

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Eugenia cerasiflora Miq.		X	LC		RFFP20333
Eugenia copacabanensis Kiaersk.	X		LC		GUA41452
Eugenia disperma Vell.			EN		RB385023
Eugenia dodonaeifolia Cambess.	X		NE		RBR32988
Eugenia expansa Spring ex Mart.	X		LC		HRJ12618
Eugenia excelsa O.Berg			LC		GUA40417
Eugenia fusca O.Berg			NE		RFFP15001
Eugenia involucrata DC.			NE		RBR32989
Eugenia longohypanthiata Giaretta			EN		RB701829
Eugenia macahensis O.Berg	X		EN		RFFP20334
Eugenia macrobracteolata Mattos	X		EN		RFFP17265
Eugenia magnibracteolata Mattos & D.Legrand	X		LC		RBR38303
Eugenia magnifica Spring ex Mart.	X		LC		GUA43917
Eugenia malacantha D.Legrand	X		VU		SPF223476
Eugenia marambaiensis M.C.Souza & M.P.Lima	X		CR	EN	RFFP18235
Eugenia monosperma Vell.			LC		FCAB5470
Eugenia mosenii (Kausel) Sobral	X		NE		RB413044
Eugenia multicostata D.Legrand	X		NE		RFFP20347
Eugenia neoglomerata Sobral			NE		HRJ12398
Eugenia neosilvestris Sobral		X	LC		RFFP20335
Eugenia pisiformis Cambess.			LC		RFFP16602
Eugenia plicata Nied.	X		NE		GUA35902
Eugenia pluriflora DC.			LC		RB368853
Eugenia prasina O.Berg			LC		RFFP19568
Eugenia pruinosa D.Legrand		X	EN		RFFP20336
Eugenia pruniformis Cambess.	X		NE		HRJ12402
Eugenia puberula Nied.	X		LC		RFFP18008
Eugenia speciosa Cambess.			NE		RFFP13308
Eugenia stigmatosa DC.			NE		RB391566
Eugenia sulcata Spring ex Mart.	X		NE		GUA40474
Eugenia tenuipedunculata Kiaersk.	X		VU		GUA45028
Eugenia zuccarinii O.Berg			LC		RFFP18057
Myrceugenia miersiana (Gardner) D.Legrand & Kausel	X		LC		RFFP16689
Myrceugenia myrcioides (Cambess.) O.Berg			LC		RFFP19395
Myrcia aethusa (O.Berg) N.Silveira	X		NE		RFFP17251
Myrcia anacardiifolia Gardner	X		LC		HRJ12409
Myrcia brasiliensis Kiaersk.			NE		RBR38302
Myrcia crocea Kiaersk.			NE		RB388777
Myrcia eugenioides Cambess.			NE		HRJ11745
Myrcia excoriata (Mart.) E.Lucas & C.E.Wilson			NE		HRJ12236
Myrcia flagellaris (D.Legrand) Sobral	X		NT		GUA38481
Myrcia fusiformis (M.L.Kawas.) A.R.Lourenço & E.Lucas			NE		RFFP3723
Myrcia glomerata (Cambess.) G.Burton & E.Lucas		X	NE		HRJ12377

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Family (nº genera/species)/Scientific Name	**NO**		**IUCN**		**Voucher**
	G	**R**	**BR**	**RJ**	
Myrcia guianensis (Aubl.) DC.		X	LC		RFFP20337
Myrcia ilheosensis Kiaersk.			NE		RFFP8338
Myrcia insigniflora M.F.Santos	X		NE		RFFP15026
Myrcia laxiflora Cambess.	X		NE		HRJ12619
Myrcia legrandii A.R.Lourenço & E.Lucas	X		LC		HRJ12381
Myrcia lonchophylla A.R.Lourenço & E.Lucas	X		NE		HRJ12379
Myrcia loranthifolia (DC.) G.P.Burton & E.Lucas			NE		HRJ12237
Myrcia martiusiana (DC.) A.R.Lourenço & E.Lucas			NE		RB298713
Myrcia multiflora (Lam.) DC.			NE		RFFP13309
Myrcia neoblanchetiana E.Lucas & Sobral			NE		RFFP13447
Myrcia neocaudata A.R.Lourenço & E.Lucas	X		DD		HRJ12376
Myrcia neolucida A.R.Lourenço & E.Lucas			NE		HB85267
Myrcia neosuaveolens E.Lucas & C.E.Wilson	X		LC		RFFP18056
Myrcia ovata Cambess.			LC		RFFP14448
Myrcia pubipetala Miq.	X		LC		RFFP19399
Myrcia racemosa (O.Berg) Kiaersk.			NE		RFFP13314
Myrcia spectabilis DC.			NE		HRJ12602
Myrcia splendens (Sw.) DC.			NE		RFFP13564
Myrcia strigipes Mart.			NE		RFFP16437
Myrcia strigosa A.R.Lourenço & E.Lucas		X	NE		RFFP18532
Myrcia subsericea A.Gray	X		LC		RFFP3855
Myrcia vellozoi Mazine		X	LC		GUA28478
Myrciaria floribunda (H.West ex Willd.) O.Berg			LC		RFFP13557
Myrciaria glomerata O.Berg			LC		HB84982
Myrciaria pumila (Gardner) O.Berg	X		NE		HRJ12417
Myrciaria tenella (DC.) O.Berg	X		DD		HRJ12418
Neomitranthes amblymitra (Burret) Mattos	X		EN		HRJ12419
Neomitranthes glomerata (D.Legrand) D.Legrand			LC		HRJ12420
Neomitranthes warmingiana (Kiaersk.) Mattos		X	LC		HRJ12421
Pimenta pseudocaryophyllus (Gomes) Landrum	X		NT		HRJ12422
Plinia edulis (Vell.) Sobral			VU		HRJ12423
Plinia peruviana (Poir.) Govaerts	X		LC		RFFP11928
Plinia rivularis (Cambess.) Rotman			NE		HRJ12424
Psidium cattleyanum Sabine			LC		RFFP13313
Psidium guineense Sw.			NE		RFFP13589
Nyctaginaceae (2/3)					
Guapira opposita (Vell.) Reitz			NE		RFFP 3800
Guapira hirsuta (Choisy) Lundell	X		LC		RB284426
Neea floribunda Poepp. & Endl.	X		NE		GUA26542
Ochnaceae (1/5)					
Ouratea cuspidata (A.St.-Hil.) Engl.			LC		RFFP13317

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Ouratea multiflora (Pohl) Engl.	X		LC	RFFP16128
Ouratea oliviformis (A.St.-Hil.) Engl.	X		LC	HB94006
Ouratea parviflora (A.DC.) Baill.	X		NE	RB198181
Ouratea vaccinioides (A.St.-Hil. & Tul.) Engl.	X		LC	HB93082
Pentaphyllacaceae (1/1)				
Ternstroemia brasiliensis Cambess.			LC	RFFP8348
Peraceae (2/2)				
Chaetocarpus myrsinites Baill.	X		NE	GUA38579
Pera glabrata (Schott) Baill.			NE	RFFP13281
Phyllanthaceae (1/1)				
Hyeronima alchorneoides Allemão			NE	HRJ11299
Petiveriaceae (1/1)				
Gallesia integrifolia (Spreng.) Harms	X		NE	HRJ11637
Picramniaceae (1/3)				
Picramnia ciliata Mart.	X		NE	HRJ12452
Picramnia gardneri Planch.			NE	RB413139
Picramnia ramiflora Planch.	X		NE	RFFP17267
Polygonaceae (1/3)				
Coccoloba alnifolia Casar.			NE	HB88250
Coccoloba glaziovii Lindau			NE	RFFP3709
Coccoloba declinata (Vell.) Mart.			NE	GUA26158
Primulaceae (1/5)				
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.			NE	RFFP11894
Myrsine guianensis (Aubl.) Kuntze			NE	RFFP12734
Myrsine lineata (Mez) Imkhan.	X		NE	not collected
Myrsine umbellata Mart.			NE	RB354244
Myrsine venosa A.DC.	X		NE	GUA25718
Proteaceae (1/2)				
Roupala montana Aubl.		X	NE	HRJ12367
Roupala sculpta Sleumer			EN	RBR32998
Putranjivaceae (1/1)				
Drypetes sessiliflora Allemão	X		LC	HRJ12368
Quinaceae (1/1)				
Quiina glaziovii Engl.			LC	RFFP17210
Rhizophoraceae (1/1)				
Rhizophora mangle L.			NE	HRJ226
Rubiaceae (17/38)				
Alseis floribunda Schott			NE	RBR33000
Amaioua intermedia Mart. ex Schult. & Schult.f.			NE	RFFP16859
Amaioua pilosa K.Schum.	X		LC	HB96215
Bathysa gymnocarpa K.Schum.	X		LC	RBR33003
Bathysa mendoncaei K.Schum.			LC	RFFP16620
Bathysa stipulata (Vell.) C.Presl			NE	RFFP18282

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Family (nº genera/species)/Scientific Name	NO		IUCN		Voucher
	G	R	BR	RJ	
Cordiera myrciifolia (K.Schum.) C.H.Perss. & Delprete		X	NE		RFFP14868
Coussarea accedens Müll.Arg.			VU		RB390917
Coussarea meridionalis var. *porophylla* (Vell.) M.Gomes			NE		RFFP17169
Coutarea hexandra (Jacq.) K.Schum.			NE		RFA37418
Faramea hyacinthina Mart.			LC		HRJ11731
Faramea pachyantha Müll.Arg.			LC		RFFP19561
Faramea stipulacea (Cham. & Schltdl.) DC.	X		NE		RFFP12746
Faramea truncata (Vell.) Müll.Arg.	X		LC		RBR 33006
Guettarda viburnoides Cham. & Schltdl.		X	LC		RB491703
Melanopsidium nigrum Colla			VU		RFFP16600
Palicourea racemosa (Aubl.) G.Nicholson			NE		RB490069
Palicourea sessilis (Vell.) C.M.Taylor			NE		RFFP18685
Posoqueria latifolia (Rudge) Schult.			LC		RB490121
Posoqueria longiflora Aubl.			NE		RFFP18573
Psychotria carthagenensis Jacq.			LC		RB385029
Psychotria cupularis (Müll.Arg.) Standl.	X		LC		RB491706
Psychotria glaziovii Müll.Arg.	X		VU		HRJ12229
Psychotria nuda (Cham. & Schltdl.) Wawra			NE		RFFP18034
Psychotria pedunculosa Rich.		X	NE		RB491628
Psychotria pubigera Schltdl.		X	NE		RFFP16210
Randia armata (Sw.) DC.			NE		RFFP16144
Rudgea coronata (Vell.) Müll.Arg.	X		LC		RFFP13389
Rudgea interrupta Benth.			LC		HRJ11337
Rudgea jasminoides subsp. *corniculata* (Benth.) Zappi			NE		HRJ12231
Rudgea macrophylla Benth.			NT		RB490068
Rudgea minor (Cham.) Standl.	X		LC		RFFP17256
Rudgea recurva Müll.Arg.	X		LC		HRJ11605
Rudgea reticulata Benth.			LC		RFFP17255
Rustia formosa (Cham. & Schltdl.) Klotzsch			LC		RFFP18249
Rustia gracilis K.Schum.	X		EN		RFFP16464
Simira alba (Mart.) Delprete, Margalho & Groppo	X		LC		HRJ11546
Tocoyena sellowiana (Cham. & Schltdl.) K.Schum.	X		LC		HRJ12200
Rutaceae (7/11)					
Conchocarpus macrocarpus (Engl.) Kallunki & Pirani	X		NE		HRJ12373
Conchocarpus ruber (A.St.-Hil.) Bruniera & Groppo	X		NE		RFFP15017
Dictyoloma vandellianum A.Juss.			NE		RFFP17754
Esenbeckia grandiflora Mart.	X		NE		HRJ13187
Galipea jasminiflora (A.St.-Hil.) Engl.	X		NE		RFFP18571
Galipea laxiflora Engl.	X		LC		RFFP19390
Neoraputia alba (Nees & Mart.) Emmerich ex Kallunki		X	NE		RFFP20340
Neoraputia magnifica (Engl.) Emmerich ex Kallunki	X		NE		RFFP 16337

Continue...

...Continuation

Pilocarpus giganteus Engl.	X		NT	RFFP16467
Pilocarpus spicatus A.St.-Hil.			NE	RB347076
Zanthoxylum rhoifolium Lam.			NE	RBR33013
Sabiaceae (1/1)				
Meliosma sellowii Urb.	X		NE	HRJ12369
Salicaceae (2/6)				
Casearia commersoniana Cambess.			NE	RFFP13352
Casearia decandra Jacq.			NE	FCAB7698
Casearia obliqua Spreng.		X	LC	RFFP20341
Casearia pauciflora Cambess.			LC	RFFP14981
Casearia sylvestris Sw.			NE	RFFP17733
Xylosma glaberrima Sleumer			NT	P4734754
Sapindaceae (5/13)				
Allophylus leucoclados Radlk.			LC	RFFP14429
Allophylus petiolulatus Radlk.			NE	RFFP3805
Allophylus racemosus Sw.			NE	RB723997
Cupania concolor Radlk.			NT	HB93807
Cupania emarginata Cambess.			NE	RFFP13370
Cupania furfuracea Radlk.			NT	HB96177
Cupania oblongifolia Mart.			NE	RFFP16683
Cupania racemosa (Vell.) Radlk.			LC	HRJ11309
Matayba grandis Radlk.			LC	GUA29342
Matayba intermedia Radlk.			NE	RB413958
Matayba talisioides Radlk			DD	R229705
Sapindus saponaria L.			NE	HB93999
Tripterodendron filicifolium Radlk.			LC	RFFP18052
Sapotaceae (6/13)				
Chrysophyllum flexuosum Mart.			LC	RFFP18511
Chrysophyllum splendens Spreng.			NT	HB85195
Ecclinusa ramiflora Mart.			NE	RFA 31279
Manilkara subsericea (Mart.) Dubard			LC	RFA37290
Micropholis crassipedicellata (Mart. & Eichler) Pierre			LC	RFA 31265
Micropholis gardneriana (A.DC.) Pierre		X	NE	HRJ11717
Pouteria bangii (Rusby) T.D.Penn.	X		NE	RFFP20346
Pouteria beaurepairei (Glaz. & Raunk.) Baehni	X		LC	RB489237
Pouteria caimito (Ruiz & Pav.) Radlk.		X	NE	HRJ12468
Pouteria coriacea (Pierre) Pierre	X		NE	RFFP12820
Pouteria durlandii (Standl.) Baehni		X	NE	HRJ12469
Pouteria gardneri (Mart. & Miq.) Baehni	X		NE	RB413968
Pradosia kuhlmannii Toledo			EN	HRJ11413
Schoepfiaceae (1/1)				
Schoepfia brasiliensis A.DC.			NE	GUA30106
Simaroubaceae (1/1)				
Homalolepis floribunda (A.St.-Hil.) Devecchi & Pirani		X	CR	RFFP20342

Continue...

...Continuation

Family (nº genera/species)/Scientific Name	NO		IUCN		Voucher
	G	R	BR	RJ	
Symplocaceae (1/1)					
Symplocos laxiflora Benth.		X	NE		RFFP20343
Siparunaceae (1/2)					
Siparuna brasiliensis (Spreng.) A.DC.			LC		RFFP11912
Siparuna guianensis Aubl.			NE		RFFP12887
Solanaceae (2/8)					
Cestrum axillare Vell.			NE		HB87444
Cestrum schlechtendalii G.Don		X	NE		RFFP17165
Solanum carautae Carvalho			NT		RB671567
Solanum castaneum Carvalho			LC		RFFP3798
Solanum mauritianum Scop.	X		NE		RB186794
Solanum melissarum Bohs	X		LC		RB346712
Solanum pseudoquina A.St.-Hil.			LC		RFFP13403
Solanum swartzianum Roem. & Schult.			NE		RFFP3796
Strombosiaceae (1/1)					
Tetrastylidium grandifolium (Baill.) Sleumer		X	LC		HRJ12363
Thymelaeaceae (2/3)					
Daphnopsis martii Meisn.			LC		RFFP14432
Daphnopsis racemosa Griseb.	X		NE		MO100318668
Funifera brasiliensis (Raddi) Mansf.	X		VU		RFFP12981
Urticaceae (2/4)					
Cecropia glaziovii Snethl.			LC		RFFP14492
Cecropia pachystachya Trécul			NE		HB88898
Coussapoa curranii S.F.Blake			EN		HRJ13007
Coussapoa microcarpa (Schott) Rizzini			NE		HB85311
Verbenaceae (1/1)					
Citharexylum myrianthum Cham.			NE		RBR33020
Violaceae (1/1)					
Amphirrhox longifolia (A.St.-Hil.) Spreng.			NE		RFFP12995
Vochysiaceae (2/6)					
Qualea cryptantha (Spreng.) Warm.			LC		GUA46649
Qualea glaziovii Warm.			LC		HRJ12477
Vochysia bifalcata Warm.			LC		RFFP20254
Vochysia laurifolia Warm.		X	LC		RB685396
Vochysia oppugnata (Vell.) Warm.	X		LC		HRJ12479
Vochysia saldanhana Warm.			NT		RBR33022
Ximeniaceae (1/1)					
Ximenia americana L.	X		NE		RFFP12818

Categories – VU: Vulnerable; EN: Endangered; CR: Critically Endangered; NE: Not Evaluated; LC: Least Concern; NT: Near Threatened; DD: Data Deficient.

(14), Sapindaceae and Sapotaceae (13 species each), Meliaceae and Moraceae (12 species each), Monimiaceae and Rutaceae (11 species each), totaling 67% of the inventoried species (Figure 3). The other 61 families had less than 10 species, with 25 families represented by a single species. Due to their richness, the genera *Eugenia* (38 species), *Myrcia* (31), *Inga* and *Miconia* (15 species each), *Ocotea* (12), *Mollinedia* (10), *Ficus* (9), *Trichilia* (8), *Monteverdia* and *Rudgea* (7 species each) stood out, making up 30% of the total species (Figure 4). Of the total inventoried, 207 species (41%) are new occurrences for Ilha Grande, with 54 (11%) sampled in the permanent plots of the PPBio (Table 1).

Of the 509 inventoried species, 471 (93%) occur in the Rainforest, 87 (17%) in Restinga environments and only 49 (10%) are present in both (Figure 5). Regarding ecological groups, 188 (37%) are late secondary, 143 (28%) from early stages (20 pioneers [4%] and 123 early secondary [24%]) and 178 (35%) remain unclassified. The Jaccard similarity index between the arboreal flora of Ilha Grande and the APA de Cairuçu was 0.39 and between the former and the APA de Mangaratiba/ Parque Estadual Cunhambebe, 0.38. More than half of the tree species on Ilha Grande are shared with the APA de Cairuçu (53%) and the APA de Mangaratiba/Parque Estadual Cunhambebe (53%).

2. *Species of conservation interest*

Regarding to conservation status at the national level, 34 species were categorized as threatened, with two critically endangered, 18 endangered and 14 vulnerable. The others are distributed in the categories data deficient (3 species), near threatened (16 species), of least concern (184 species) and not evaluated (272 species) (Table 1). *Eugenia marambaiensis* and *Homalolepis floribunda* were categorized as critically endangered. Among those categorized as endangered, *Ocotea odorifera*, *Inga maritima*, *Couratari pyramidata*, *Ceiba crispiflora*, *Virola bicuhyba* and *Pradosia kuhlmannii* can be cited. In the vulnerable category, *Euterpe edulis*, *Algernonia brasiliensis*, *Cedrela*

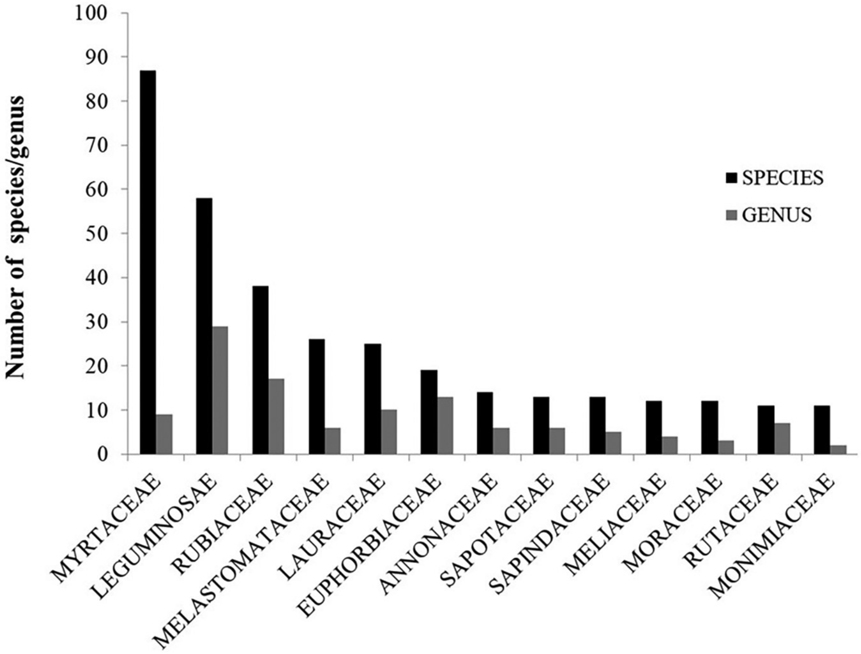

Figure 3. Angiosperm families with the highest tree species richness in Illha Grande, Angra dos Reis, RJ, Brazil.

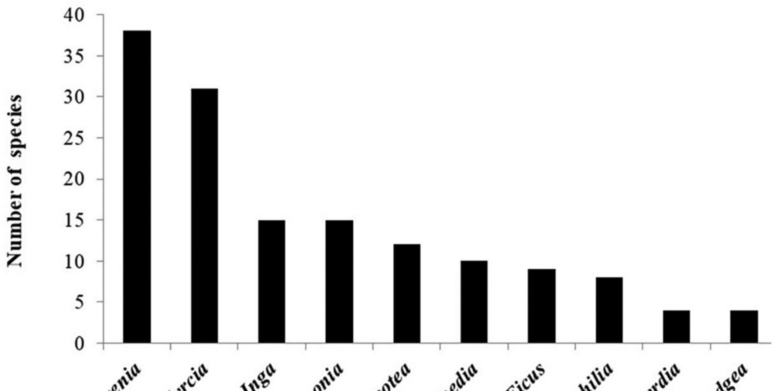

Figure 4. Angiosperm genera with the highest tree species richness in Ilha Grande, Angra dos Reis, RJ, Brazil.

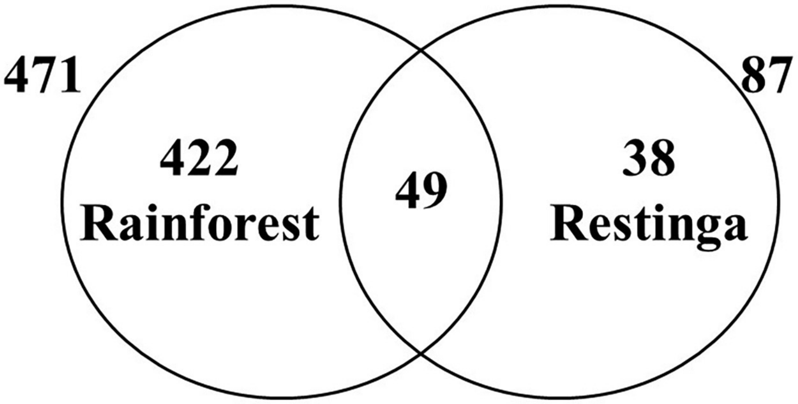

Figure 5. Sharing of tree Angiosperm species between the Rainforest and the pioneer formations of Restinga da Ilha Grande, Angra dos Reis, RJ, Brazil.

odorata, *Eugenia bunchosiifolia*, *Plinia edulis* and *Melanopsidium nigrum*, among others, were classified.

Among the endemic species of the state of Rio de Janeiro, eight were categorized with some degree of threat: *Eugenia marambaiensis*, critically endangered; *Mollinedia acutissima*, vulnerable; and in the endangered category, *Beilschmiedia angustifolia*, *Couratari pyramidata*, *Duguetia pohliana*, *Meriania glazioviana*, *Meriania longipes* and *Pleroma thereminianum* (Table 1). For the species *Eugenia marambaiensis, Mollinedia acutissima*, *Beilschmiedia angustifolia*, *Couratari pyramidata* and *Duguetia pohliana*, Ilha Grande represents a new place of occurrence.

3. Exotic and invasive tree species

Fifty-three exotic tree species were inventoried on Ilha Grande, two of which were Gymnosperms (*Araucaria angustifolia* and *Araucaria columnaris*). The others are Angiosperms belonging to 26 families and 41 genera (Table 2). Most of them originate in Asia and are basically fruit trees, such as *Artocarpus altilis*, *Carica papaya*, *Citrus limon*, *Cocos nucifera*, *Eriobotrya japonica*, *Mangifera indica* and *Persea americana*, among others. Some were or are being cultivated for ornamental purposes, windbreaks, shading or even constitute species commonly used in urban afforestation and include *Couroupita guianensis*, *Ficus elastica*, *Melia azedarach*, *Moquilea tomentosa* and *Pachira aquatica*.

Carapa guianensis, *Clitoria fairchildiana*, *Couroupita guianensis*, *Libidibia ferrea*, *Mimosa caesalpiniifolia*, *Moquilea tomentosa*, *Pachira aquatica*, *Peltophorum dubium*, *Spondias mombin* and *Sterculia apetala*, although native to Brazil, were brought from other parts of the state of Rio de Janeiro or the country and cultivated with different purposes. Others, such as eucalyptus (*Eucalyptus grandis* and *Eucalyptus tereticornis*), may have been used in constructions from the prison period on Ilha Grande. *Albizia lebbeck*, *Clitoria fairchildiana* and *Mimosa caesalpiniifolia* date back to ancient reforestation practices using non-native species. Common on the edge of streets and roads, they do not depend on management for their reproduction.

The greatest occurrence of exotic species is at the ends of the trails, close to the villages, in the stretches where there were old dwellings, in the forks and parts of the trails that cross the villages. The settlements on Ilha Grande are located by the sea, on coastal plains, largely due to the rugged relief, with only a few lowland areas.

DISCUSSION

1. Floristic analysis

The observed results corroborate the species richness of Euphorbiaceae, Lauraceae, Leguminosae, Melastomataceae, Myrtaceae and Rubiaceae, families indicated among the most diverse in the Atlantic Forest and among the ten with the greatest richness among Angiosperms in Brazil (BFG 2015). The prominence presented by these families was also observed in studies of the structure and composition of different stretches of Atlantic Forest in the state of Rio de Janeiro (e.g., Kurtz & Araujo 2000, Barros 2008, Machado 2018, Pessoa & Araujo 2020) and in investigations of the flora of Área de Proteção Ambiental de Mangaratiba/Parque Estadual Cunhambebe (Maurenza et al. 2018) and Área de Proteção Ambiental de Cairuçu (Marques et al. 1997). The genera *Eugenia* and *Myrcia*, highlighted in this study, are also identified as the most diverse in the country (BFG 2015). The results obtained here for other families and genera and found in the aforementioned studies suggest the presence of similar floristic patterns.

The presence of widely distributed species in different formations of the Southeast Atlantic Forest (Oliveira-Filho & Fontes 2000), such as: *Alchornea glandulosa*, *Alchornea triplinervia*, *Andira fraxinifolia*, *Cabralea canjerana*, *Cariniana estrellensis*, *Casearea sylvestris*, *Cordia sellowiana*, *Endlicheria paniculata*, *Guapira opposita*, *Guarea guidonia*, *Hymenaea courbaril*, *Nectandra oppositifolia*, *Pera glabrata*, *Piptadenia gonoacantha* and *Tapirira guianensis*, reinforces the existence of similarity in floristic patterns of the tree component. The floristic similarity (Jaccard > 0.25, or 25%, *sensu* Mueller-Dombois & Ellenberg 1974) of Ilha Grande with the APA de Cairuçu and APA de Mangaratiba/Parque Estadual Cunhambebe is, most likely, related to geographic proximity and similar physiographic conditions and occupation history.

In natural environments, species richness is closely related to the variety of environments and the size of the area of occurrence. This variety provides different environmental characteristics and its size provides the necessary home range for each species. In this sense, the richness of tree species observed in this study and of flora in general (Callado et al. 2009, Vianna Filho et al. 2020) is most likely due to the fact that Ilha Grande presents distinct altitudinal bands and, in these, different formations, sometimes in different successional stages of regeneration. The addition of another 207 species to the previously

Table 2. Floristic list of exotic tree species inventoried in Ilha Grande, Angra dos Reis, state of Rio de Janeiro, Brazil, with indications of vernacular name, use and continent of origin.

Family (nº genera/species)/Scientific Name	Vernacular Name	Use	Origin
ANGIOSPERMS			
Adoxaceae (1/1)			
Sambucus nigra L.	sabugueiro	Me	Europe
Anacardiaceae (2/2)			
Mangifera indica L.	mangueira	A	Asia
Spondias mombin L.	cajazeiro	A	Brazil
Annonaceae (1/1)			
Annona muricata L.	gravioleira	A,Me	America
Arecaceae (4/6)			
Cocos nucifera L.	coqueiro	A,O	Asia
Dypsis lutescens (H.Wendl.) Beentje & J.Dransf.	palmeira-areca	O	Africa
Livistona chinensis (Jacq.) R.Br. ex Mart.	palmeira-leque	O	Asia
Roystonea borinquena O.F.Cook.	palmeira-imperial-de-porto-rico	O	America
Roystonea oleracea (Jacq.) O.F.Cook	palmeira-imperial	O	America
Roystonea regia (Kunth) O.F.Cook.	palmeira-imperial-de-cuba	O	America
Bignoniaceae (1/1)			
Spathodea campanulata P.Beauv.	espatódea, tulipeira	O	Africa
Caricaceae (1/1)			
Carica papaya L.	mamoeiro	A	America
Casuarinaceae (1/1)			
Casuarina equisetifolia L.	casuarina	O,Q	Asia
Chrysobalaceae (1/1)			
Moquilea tomentosa Benth.	oitizeiro	O	Brazil
Combretaceae (1/1)			
Terminalia catappa L.	amendoeira	S	Africa, Asia
Ebenaceae (1/1)			
Diospyros kaki L.f.	caquizeiro	A	Asia
Lamiaceae (1/1)			
Clerodendrum quadriloculare (Blanco) Merr.	flor-cotonete	O	Asia/Oceania
Lauraceae (2/2)			
Laurus nobilis L.	louro	A,Me	Asia/Europe
Persea americana Mill.	abacateiro	A	America
Lecythidaceae (1/1)			
Couroupita guianensis Aubl.	abricó-de-macaco	O	Brazil
Leguminosae (6/6)			
Albizia lebbeck (L.) Benth.	língua-de-sogra	R,S	Asia
Clitoria fairchildiana R.A.Howard	sombreiro	O,S	Brazil
Delonix regia (Bojer ex Hook.) Raf.	flamboyant	O,S	Africa
Mimosa caesalpiniifolia Benth.	sabiá	O,Cv,R	Brazil
Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	pau-ferro	O	Brazil
Peltophorum dubium (Spreng.) Taub.	canafístula	O	Brazil

Continue...

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Family (nº genera/species)/Scientific Name	Vernacular Name	Use	Origin
Lythraceae (1/1)			
Punica granatum L.	romãzeira	Me	Asia
Malvaceae (2/2)			
Pachira aquatica Aubl.	munguba	O	Brazil
Sterculia apetala (Jacq.) H.Karst.	chichá	O	Brazil
Meliaceae (2/2)			
Carapa guianensis Aubl.	andiroba	Me	Brazil
Melia azedarach L.	melia	O	Asia
Moraceae (2/5)			
Artocarpus altilis (Parkinson) Fosberg	fruta-pão	A	Asia
Artocarpus integer (Thunb.) Merr.	champedaque	A	Asia
Artocarpus heterophyllus Lam.	jaqueira	A	Asia
Ficus elastica Roxb.	figueira-da-borracha	O	Asia
Ficus microcarpa L.f.	figueira-asiática	O	Asia
Myristicaceae (1/1)			
Myristica fragrans Houtt.	noz-moscada	A,Me	Asia
Myrtaceae (3/6)			
Eucalyptus grandis W.Hill ex Maiden	eucalipto	Ma	Oceania
Eucalyptus tereticornis Sm.	eucalipto	Ma	Oceania
Psidium guajava L.	goiabeira	A	America
Syzygium aromaticum (L.) Merr. & L.M.Perry	cravo-da-Índia	A,Me	Asia, Oceania
Syzygium cumini (L.) Skeels	jamelão	A	Asia
Syzygium malaccense (L.) Merr. & L.M.Perry	jambeiro-vermelho	A	Asia
Oxalidaceae (1/1)			
Averrhoa carambola L.	caramboleira	A,Me	Asia
Peraceae (1/1)			
Chaetocarpus echinocarpus (Baill.) Ducke	pitoma-de-espinho	O	Brazil
Rosaceae (1/1)			
Eriobotrya japonica (Thunb.) Lindl.	nespereira, ameixa-amarela	A	Asia
Rubiaceae (1/1)			
Coffea arabica L.	cafeeiro	A	Africa
Rutaceae (1/3)			
Citrus limon (L.) Osbeck	limoeiro	A,Me	Asia
Citrus reticulata Blanco	tangerineira	A,Me	Asia
Citrus sinensis (L.) Osbeck	laranjeira	A,Me	Asia
Sapotaceae (1/1)			
Mimusops coriacea (A.DC.) Miq.	abricó-da-praia	A,O	Africa
GIMNOSPERMS			
Araucariaceae (1/2)			
Araucaria angustifolia (Bertol.) Kuntze	pinheiro-do-Paraná	A,O	Brazil
Araucaria columnaris (J.R.Forst.) Hook.	pinheiro-de-Natal	O	Oceania

Use: A = food, Cv = hedge, O = ornamentation, Ma = timber, Me = medicinal, Q = windbreak, R = reforestation and S = shading.

known list demonstrates the existence of collection gaps, even in an area with a history of botanical investigations (Araujo & Oliveira 1988, Araujo 2000, Oliveira 2002, Lobão et al. 2005, Callado et al. 2009, Pederneiras et al. 2011a, 2011b, 2012, Rosa 2013, 2017, Santo 2016, Ferreira et al. 2018, Lopes et al. 2019, Vianna Filho et al. 2020), while reinforcing the importance of the PPBio Mata Atlântica in increasing the floristic knowledge of Ilha Grande.

The result for the distribution of species in the different plant formations reflects the spatial predominance of the Rainforest formation in the island's landscape, despite the structural and floristic transformations that occurred as a result of the occupation history (Prado 2003, Ribeiro et al. 2009). It is not uncommon to find remnants of old farms and houses, traces of caiçara plantations (i.e., subsistence plantations developed by indigenous populations that inhabit the coastline of Southeastern Brazil) and activities associated with the prison period, as evidence of past occupations (Oliveira & Coelho Netto 1996, Santiago et al. 2009). In the Restinga environment, considered a marginal or peripheral habitat by Scarano (2002), environmental filters such as high atmospheric temperature, salinity effect, water and nutritional deficiency in the soil are limiting factors for plant development, especially for tree species. This vegetation formation is restricted to small areas in the coves of Ilha Grande, except for Reserva Biológica da Praia do Sul and Praia de Lopes Mendes; the latter the vegetation is significantly altered due to anthropic actions.

The long history of use by human populations has significantly influenced the current floristic composition of Ilha Grande. Among the historical uses, two stand out, from the 18th century onwards: the farms for the production of coffee and brandy and the caiçara plantations. The latter, made in the slash-and-burn model, achieved a virtual omnipresence on Ilha Grande, as evidenced by ruins of old dwellings in various parts of the territory of Ilha Grande (Oliveira & Fernandez, 2016). In addition to these vestiges of material culture, long-lived pioneer species (e.g., *Guarea guidonia*, *Miconia cinnamomifolia* and *Schizolobium parahyba*) also contribute to the spatialization of old plantations (Delamonica et al. 2002, Callado & Guimarães 2010, Oliveira et al. 2013) and can be identified as indicators of the history of human intervention on the forested environment of Ilha Grande. These long-cycle pioneer species also play an important ecological role in the remaining secondary forests, as they allow forest regeneration under their canopies, favoring typical associations of early and late secondary species (Oliveira 2002).

The results found for the distribution of species by ecological group, suggest a balance between early and late-stage species, reinforcing the affirmation of the vegetation cover of Ilha Grande as a vegetation mosaic resulting from natural disturbances and/or caused by anthropic action. Although part of the species has not been classified into ecological groups, the results suggest that forest vegetation is in an average to advanced stage of regeneration. The regeneration of a forest generally moves towards a greater complexity of forms, directly influenced by the type of disturbance and time arising from the disturbance. The existence of shaded environments expands the possibility of establishing late-stage species, which are more common in forests in advanced stage. Temporal changes typical of the dynamic process of the community, such as the gap, construction and mature phases (Swaine & Whitmore 1988) intervene in the success of species recruitment, and small glades may have more late secondary species than early secondary and pioneer species (Tabarelli & Mantovani 1997). Although the classification of species into ecological groups may be questionable, as several species can survive and grow under relatively wide gradients of light intensity, this classification has proved to be a useful tool in the evaluation of the regeneration process and the maintenance of species diversity in tropical forests (Tabarelli & Mantovani 1999).

2. *Species of conservation interest*

In the state of Rio de Janeiro, as in other coastal states, large extensions of the original natural territory were suppressed by human occupation (Fundação SOS Mata Atlântica & INPE 2021). Among the main risk factors for species, habitat loss and degradation, as well as competition with exotic species and over-exploitation by humans, are identified as preponderant in the assessment of the conservation status of species (Martinelli & Moraes 2013, Martinelli et al. 2018). Among the endangered, *Inga maritima*, endemic to the restingas of the state of Rio de Janeiro, is threatened precisely due to the fragmentation of these areas (e.g., Rocha et al. 2007). *Euterpe edulis*, classified as vulnerable, has been subject to intense extractivism for use in food (Leitman et al. 2013). *Ocotea odorifera*, *Pradosia kuhlmannii* and *Virola bicuhyba*, categorized as endangered, are recorded in different state protected areas, but with greatly reduced populations due to logging over time. In Ilha Grande, there are examples of species with wide local use, exploited for use as firewood, boards, beams, rafters and slats (Santiago et al. 2009, Santos 2009, Ribas 2015, Mendes 2017).

For endemic and threatened species in the state of Rio de Janeiro, the increase in field expeditions and the identification of samples deposited in herbariums have expanded the distribution of some, such as *Couratari pyramidata*, known for the municipalities of Cachoeiras de Macacu, Guapimirim, Maricá, Niterói, Paraty and Rio de Janeiro (Ribeiro et al. 2018), and now registered in Ilha Grande. *Eugenia marambaiensis*, also collected on Ilha Grande, was considered endemic to Restinga de Marambaia (Souza & Morim 2008) and later collections identified it in Morro do Telégrafo, municipality of Niterói (Barros 2008). *Pleroma thereminianum,* known only from collections from Angra dos Reis, Mangaratiba, Paraty and Rio Claro, occurs on Ilha Grande, but with few populations (Rosa 2017, Baumgratz et al. 2018). These results reinforce the importance of intensifying collections, even in places with a long history of field research.

3. *Exotic and invasive tree species*

Different historical moments of occupation and use of natural resources contributed, directly or indirectly, to the movement of translocation of exotic species to Ilha Grande (Barros et al. 2022). Phytosociological studies (Caires 2015, Mendes 2017) inventoried forest remnants in this locality, suggesting that there are no "untouched" forests and that the regenerating forest retains the marks of this historical presence in its structure and composition (Oliveira 2015). However, some species are dispersing beyond the original point where they were initially cultivated, as is the case of the imperial palm (*Roystonea oleracea*) (Zucaratto et al. 2020) and jackfruit tree (*Artocarpus heterophyllus*) (Caires 2015, Bergallo et al. 2016).

Roystonea oleracea is an imposing palm that has been cultivated as an ornamental in many parts of the world (Lorenzi et al. 2004). Its dissemination in Brazil is associated with historical issues involving the Portuguese imperial family and its introduction as an ornamental tree, especially in old coffee farms. Once the species has reached the final stage of invasion on Ilha Grande, eradication or control measures are urgently required (Zucaratto et al. 2020). Rodrigues (2021) showed, however, based on anatomical characteristics, that part of the individuals on Ilha Grande does not correspond only to *Roystonea oleracea*, but to two other very similar species, *Roystonea brinquena* and *Roystonea regia*.

The jackfruit tree is the exotic tree with the highest number of studies on Ilha Grande (Raíces et al. 2008, 2017, Mello et al. 2015, Bergallo et al. 2016). The evaluation of the presence of exotic plants in certain trails (Ribas et al. 2010, Caires 2015, Bergallo et al. 2016) points to jackfruit tree in more than half of them. However, two trails, Freguesia de Santana – Bananal and Vila Dois Rios – Caxadaço, stand out for their density much higher than all the others, possibly because they are paths that gave access to old farms (Bergallo et al. 2016), in which jackfruit served as food for enslaved Africans (Ribas et al. 2010).

The invasive character of jackfruit tree constitutes a serious environmental problem, as its expansion is facilitated by the lack of predators and by the allelopathic effects on the germination of native species (Pereira & Kaplan 2013). Research carried out on Ilha Grande shows that such behavior has negatively influenced the process of natural restoration of the forest, since some species of small mammals are helping to expand the distribution area of this species to the detriment of native plants that could also compose its diet. In addition, it leads to a decrease in populations of animals that do not consume its fruits, favoring those that use this resource (Raíces et al. 2017). However, jackfruit can be understood as a biocultural species (Sousa, 2014), since its use on Ilha Grande, in the ethnobotanical context, goes beyond food. Wood was used in the construction of houses and canoes and is also considered ritualistic for some African peoples who practice the phytolatry of worshiping deities in the tree itself, which dates back to the period of slavery (Caires 2015).

The effects of introducing invasive exotic species are disproportionately greater in island environments. Species native to islands generally have small populations and limited distribution, making them more vulnerable to invasive exotic species than those from mainland areas (Vitousek 1997). Thus, the concern with the presence of exotic species is greater, as the islands harbor a peculiar biological diversity, due to their geographic isolation and the richness of occurring endemic species (Dechoum et al. 2018, Rocha 2018). In the case of Ilha Grande, the proximity to the mainland does not actually represent significant geographic isolation, but biological invasion is an environmental threat factor that cannot be neglected. The use of such species for the most diverse purposes devalues the local biological diversity, mischaracterizing the native floristic composition and favoring the development of a culture increasingly distant from the surrounding natural environment (Leão et al. 2011).

The results presented here reinforce the importance of these inventories as indispensable tools for the construction of strategies and actions for conservation, restoration and management of diversity in the context of the Atlantic Forest. At the same time, they also demonstrate that, despite adverse factors caused by changes aroused by human, the creation of conservation units on Ilha Grande was decisive in mitigating the loss of natural vegetation. By inhibiting threats, such as selective logging or the introduction of invasive species, conservation units help to reduce the loss and/or extinction of species. In addition, the flora studied can also be considered as a repository of stories of the man/nature relationship on Ilha Grande. Other coastal islands in Southeast Brazil, such as Ilha Anchieta (Guillaumon et al. 1989), Ilha de São Sebastião (Leonel 2015) and Ilha do Cardoso (Barros et al. 1991), currently with their territories partially or fully protected by conservation units, experienced occupation histories very similar to Ilha Grande and also keep this man/nature relationship.

Associated with flora inventory surveys, the creation of PaB – Parque Botânico do Ecomuseu Ilha Grande (Botanical Park of the Ilha Grande Ecomuseu), in 2015, constitutes an effective action for the conservation of local biodiversity, in view of its contribution to *ex situ* and *in situ* conservation, mainly of rare, endangered or even locally extinct species (Callado et al. 2020). At PaB, the “Vila Dois Rios Exotic Plants Circuit” was created. Based on interviews with visitors, it was observed that, even not knowing the term “exotic plants” and the environmental impacts, after the interviewers explained the topic, most visitors responded that they considered this knowledge and its unfolding important for the conservation of native insular flora (Moreira et al. 2021).

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Conflicts of Interest

The authors declare they have no conflicts of interest related to the publication of this manuscript.

Ethics

The manuscript is an original and unpublished contribution and is not being evaluated for publication by any other journal and follows the appropriate guidelines established by the ethics committees.

Data Availability

Supporting data are available at <https://ipt.sibbr.gov.br/sibbr/manage/resource?r=uerj_ilhagrande_01>.

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Article

Population density estimates for three endangered bird taxa from the Pernambuco Endemism Center, northeastern Brazil

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Abstract: Determining the relative risks of extinction of declining taxa is important to delineate conservation priorities and to guide the investments in conservation. Brazil concentrates the greatest number of endangered avian taxa on Earth, yet demographic information is lacking for most of them. Here we present distance-sampling population density estimates for three endangered bird taxa endemic to the Pernambuco Endemism Center (PEC), the most critically disturbed Atlantic Forest region. The analyzed taxa were the White-shouldered Antshrike *Thamnophilus aetiops distans* (Endangered), the Brown-winged Mourner *Schiffornis turdina intermedia* (Vulnerable), and the White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Vulnerable). The estimated numbers of individuals/ha in an approximately 1,000 ha forest fragment were 0.21, 0.14, and 0.73, respectively. Our findings corroborated the premise that even taxa classified in similar threat categories based on habitat characteristics alone can have different population densities and consequently, divergent risks of extinction. Although population densities can vary among fragments, the extrapolation of our data to the whole PEC confirmed the Vulnerable status of the Brown-winged Mourner, and indicated the Vulnerable and Least Concern categories for the White-shouldered Antshrike and for the White-bellied Tody-tyrant, suggesting that for the two later taxa, the current classifications (Endangered and Vulnerable) based on their Areas of Occupancy must prevail.

Keywords: *Aves; Census; Distance sampling; Tropical forest; Atlantic Forest.*

Estimativas de densidade populacional em três táxons de aves ameaçados de extinção do Centro de Endemismo Pernambuco, nordeste do Brasil

Resumo: A determinação dos riscos relativos de extinção dos táxons ameaçados é importante para o delineamento de ações de recuperação e para o direcionamento dos investimentos em conservação. O Brasil é o país que possui o maior número de táxons ameaçados de aves, no entanto, informações sobre aspectos demográficos são inexistentes para a maioria deles. Neste trabalho são apresentadas estimativas de densidades populacionais, baseadas no método de amostragem por distância, para três táxons ameaçados de extinção endêmicos do Centro de Endemismo Pernambuco (CEP), a região mais degradada de toda a Mata Atlântica. Os táxons analisados foram a choca-lisa *Thamnophilus aetiops distans* (Ameaçada), o flautim-marrom *Schiffornis turdina intermedia* (Vulnerável) e a maria-de-barriga-branca *Hemitriccus griseipectus naumburgae* (Vulnerável). Os números de indivíduos/ha estimados para um fragmento de floresta de aproximadamente 1000 ha foram respectivamente 0,21, 0,14 e 0,73. Com isto, foi possível confirmar a premissa de que mesmo táxons classificados em uma mesma categoria de ameaça com base apenas em informações de hábitats podem possuir densidades populacionais bastante divergentes e portanto diferentes graus de riscos de extinção. Embora as densidades populacionais possam variar entre fragmentos, a extrapolação destes dados para toda a área do CEP confirmou a classificação de Vulnerável para o flautim-marrom e indicou as categorias Vulnerável e Pouco Preocupante para a choca-lisa e para a maria-de-barriga-branca, sugerindo que para as duas últimas, as classificações atuais baseadas nos tamanhos das suas Áreas de Ocupação (Ameaçada e Vulnerável) devem prevalecer.

Palavras-chave: *Aves; Censo; Amostragem por distância; Floresta tropical; Mata Atlântica.*

Introduction

Determining the relative risks of extinction of declining taxa is essential to indicate conservation priorities, and to optimize the investments in conservation (Rodrigues et al. 2006, Bennun et al. 2018). Red lists are predicted to provide this information to conservation managers, but a species assessment relies on a set of demographic information that are often unavailable (Bachman et al. 2019, Santini et al. 2019). Then, criteria related to habitat conservation and distribution, such as former and current habitat extension, reduction tendencies, and levels of fragmentation have been the most frequent parameters used for the categorization of many species (see ICMBio 2018, Santini et al. 2019). Although these criteria have been sufficient to include a relevant number of taxa in red lists, knowledge on demographic aspects is important for at least three main reasons: first, species vary naturally in population densities within target habitats (Gottschalk & Huettmann 2011), in such a way that in a same geographic region different species can have highly divergent population sizes; second, species sharing the same endangered habitats may respond differently to the effects of habitat disturbances, meaning that their risks of extinction are not uniform (Powell et al. 2015), and third, the determinants of the demographic parameters of many taxa may not be related only to habitat amount and quality, but also to other anthropogenic effects such as poaching and trapping (Bernardo et al. 2011, Alves et al. 2017). Then, censuses are essential to address the relative risks of extinction of endangered taxa, and their publications in the form of scientific articles, with detailed methodological descriptions, permit their reproducibility and the monitoring of future population tendencies (Alves et al. 2017, Tonetti & Pizo 2016).

Brazil is the richest country in the world in number of bird species, but it also concentrates the greatest number of endangered taxa (BirdLife 2021). Species inhabiting the Atlantic Forest are of special concern because this is where 120 (51%) of the 234 Brazilian endangered taxa, including subspecies, can be found (ICMBio 2018). Although the destruction and unsustainable exploitation of the Atlantic Forest has the potential for causing a catastrophic wave of global bird extinctions, censuses estimates are available only for very few taxa (see Alves et al. 2017, Tonetti & Pizo 2016).

The Pernambuco Endemism Center (hereafter PEC) is the portion of the Atlantic Forest distributed in northeastern Brazil, northern from São Francisco River, in the states of Alagoas, Pernambuco, and Paraíba. While it shelters a unique biota, with elevated levels of endemism (Tabarelli et al. 2006, Pontes et al. 2016), this is the most fragmented and degraded of the Atlantic Forest regions, with only about 12% of the forested areas remaining, all in small fragments (Ribeiro et al. 2009). This region has alarmed conservation practitioners because three bird species endemic to the PEC were recently recognized as globally extinct: the Pernambuco Pygmy-owl (*Glaucidium mooreorum*), the Cryptic Treehunter (*Cichlocolaptes mazarbarnetti*), and the Alagoas Foliage-gleaner (*Philydor novaesi*), and many others are on the verge of extinction (Pereira et al. 2014, ICMBio 2018). Paradoxically, demographic information needed to give raise to conservation plans is unavailable for most of them.

Here we provide distance sampling population density estimates for three endangered bird taxa endemic to the PEC, the White-shouldered Antshrike *Thamnophilus aetiops distans* (Endangered), the Brown-winged Mourner *Schiffornis turdina intermedia* (Vulnerable), and the White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Vulnerable), from an Atlantic Forest fragment from the state of Alagoas, Brazil. Our findings were consistent with the premise that taxa classified in similar threat categories for inhabiting the same threatened habitats can have different population densities and likely divergent risks of extinction. It reinforced the fact that demographic information is urgently needed to improve the conservation planning of Atlantic Forest birds.

Material and Methods

1. Study area

Censuses estimates were performed in a 978-ha Private Natural Heritage Reserve (PNHR Mata do Cedro; 9°31'23.82"S; 35°55'6.53"O; altitude 120 m), at the municipality of Rio Largo, Alagoas state, northeastern Brazil (Figure 1). The area is surrounded by sugar cane plantations and the vegetation is classified as open ombrophilous forest (Roda & Santos 2005). Despite the selective logging occurred in the decades of 1970 and 1980 in most PEC fragments, tall forests with open understory can be found in slopes, and level areas are currently composed of tracts of habitats in middle and late regeneration stages, with tangled understory and emergent trees already present, e.g. *Parkia* and *Attalea* palms (Silveira et al. 2003, Roda & Santos 2005, Pereira et al. 2014, 2016). The climate is AS', following Köppen classification: tropical with a well-defined dry season from October through January, and a long rainy season corresponding to the months of the autumn and winter. Average annual rainfall is 1600–1700 mm, and average minimum and maximum temperatures range from 21–22°C, and 30–31°C, respectively (Roda & Santos 2005, Barros et al. 2012).

2. Studied taxa

The White-shouldered Antshrike *Thamnophilus aetiops distans* (Thamnophilidae) is an insectivorous passerine that occur in the understory of mature or secondary forests in late generation stages (ICMBio 2018). It forages near the ground and can follow army-ants to capture invertebrates, not rarely being a component of mixed-species flocks (Zimmer & Isler 2020). The species is known to occur in only 25 forest fragments from Alagoas, Pernambuco, and Paraíba states and it was classified as endangered (EN) due to an estimated occupancy area of only 244 km^2, (24.400 ha) that is highly fragmented and still experience severe threats (ICMBio 2018).

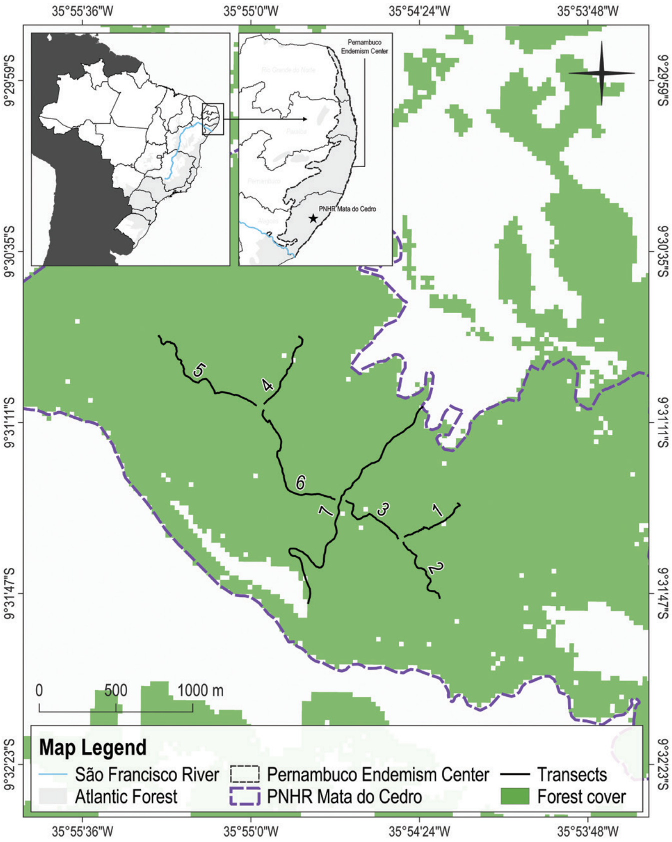

Figure 1. Pernambuco Endemism Center (PEC) in northeastern Brazil, and PNHR Mata do Cedro, located at the municipality of Rio Largo, state of Alagoas. The seven transects used for Distance-sampling population density estimates are represented by the numbered black lines.

The White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Tyrannidae) is a small flycatcher that occurs in the understory and midstory of forested areas, where they are commonly seen capturing insects (Schulenberg 2020). Considering that the entire PEC is estimated to preserve 2.200 km^2 of Atlantic Forest (ICMBio 2018), and that the White-bellied Tody-tyrant avoids small fragments, the occupancy area of the species was estimated to be about 2000 km^2 by the Red List committee, reason why it was classified as Vulnerable (VU) (ICMBio 2018).

The Brown-winged Mourner *Schiffornis turdina intermedia* (Tityridae) is also restricted to the forested areas of the PEC. It inhabits forest mid-strata and feeds on fruits and insects (Snow & Kirwan 2020). It was classified as VU for the same reason of the White-bellied Tody-tyrant. Even in the absence of censuses, the population was estimated to be about 10,000 individuals, distributed in highly fragmented areas that cannot hold more than 1,000 individuals each, which, however, is still to be confirmed. All of these subspecies are endemic to the PEC; are geographically isolated from other subspecies and present diagnostic characteristics that led them to be classified as different forms (Schulenberg 2020, Snow & Kirwan 2020, Zimmer & Isler 2020). Taxonomic reviews, however, are still needed to confirm if they could receive the status of full species (ICMBio 2018).

3. *Population density estimates*

To estimate population densities of the three taxa, we used a line-transect distance sampling approach (Buckland et al. 1993, 2001). We established seven line-transects, with lengths varying from 0.5 to 2.17 km, that were distributed in forest interior and totaled 6.36 km. To avoid pseudoreplications, these transects were at least 100 m apart in the portions in which they were closest to each other (Figure 1). Field work was performed from October 2019 to January 2020, corresponding to the summer, when the days are longer and birds vocalize intensely, mainly in the morning, easing the detection by this method. Transects were walked 10 times by a single trained observer (LCP), with at least 10 days intervals, from 4:30–9:00 am, at an average speed of 1.5–2 km/h. The order of the transects walked in a day, as well as their directions were always previously assorted. For each bird detected visually or audibly, the perpendicular distance between the initial detection point and the transect line was sampled using a laser measuring tool (Stanley tlm100 – 30 mt) to improve data accuracy. To minimize potential detection errors related to unrecognized vocalizations performed by the studied taxa, the observer accumulated at least 5 hr of observations for each taxa before the start of the population density surveys to become familiar with their sounds. We did not establish truncation distances, we sampled both sides of the transects, and individuals of all ages and sex were considered. In total, we accumulated 140 hr of field work, distributed across 31 days. We have not performed surveys during rainy or windy days to avoid detection problems, and we never used playbacks to stimulate bird responses.

4. *Statistical analyses*

Population densities were estimated using the model selection procedure of the software Distance 7.0 (Thomas et al. 2010), by which pre-defined detection functions (uniform, hazard-rate, half-normal, and negative exponential key functions) are applied to model how detection probability decreases across perpendicular distance classes, generating corrected population density estimates (Buckland et al. 1993, 2001, Thomas et al. 2010). Since each of the four detection functions can be associated to cosine, hermite polynomial, and simple polynomial adjustments, we exploited a total of 12 different models for each taxon. To select the model that best fitted the data, we used Akaike's Information Criteria (AIC), the goodness-of-fit test of Kolmogorov-Smirnov, and the visual analyses of quantile-quantile plots (Q-q plots). To reach the minimum number of 50 records necessary for Distance efficient modeling (Buckland et al. 1993, 2001, Thomas et al. 2010), the set of transects was treated as a unique longer transect for the statistical analyses, and the records obtained in the different transects were pooled together (see also Bernardo et al. 2011). Then, the obtained number of individuals per hectare was subdivided by the number of replicates (n = 10) to generate the actual population density estimates. We used the analytical approach, with default parameters settings, to estimate the coefficients of variation (dCV) and lower and upper 95% confidence intervals associated to population density data. For comparative purposes, we also used Distance 7.0 to estimate the average probabilities of detection (PD) of the individuals of the different taxa, as well as their associated lower (LCL) and upper 95% confidence limits (UCL), and coefficients of variation (pdCV).

Results

In total, considering the 10 transect replicates, we obtained 105 records for the White-shouldered Antshrike, with perpendicular distances varying from 2.1 to 70 m (25.33 ± 18.01); 110 records for the Brown-winged Mourner, with perpendicular distances varying from

Table 1. Results of the model selection procedures used to estimate population densities (D) for the White-shouldered Antshrike (*Thamnophilus aetiops distans*), the Brown-winged Mourner (*Schiffornis turdina intermedia*), and the White-bellied Tody-tyrant (*Hemitriccus griseipectus naumburgae*) using distance sampling approach. Models were selected based on AIC Criteria, and the ΔAIC indicated their relative importance. Estimates of lower (LCL) and upper 95% confidence limits (UCL), coefficient of variation (dCV), and probability of the Kolmogorov-Smirnov goodness-of-fit test (P) are provided for the density estimates, which were calculated by pooling 10 transect replicates together. The Probabilities of Detection (PD) of the individuals of the different taxa, as well as their associated lower (LCL) and upper 95% confidence limits (UCL), and coefficients of variation (pdCV) were also estimated.

	AIC	ΔAIC	D (LCL–UCL)	dCV	P	PD (LCL–UCL)	pdCV
White-shouldered Antshrike							
Uniform Cosine	862.41	0.00	2.39 (1.90–3.01)	0.12	0.008	0.49 (0.39–0.62)	0.12
Half-Normal Cosine	868.79	6.38	1.95 (1.69–2.24)	0.07	0.009	0.61 (0.53–0.70)	0.07
Hazard-Rate Cosine	**863.13**	**0.72**	**2.06 (1.60–2.64)**	**1.28**	**0.070**	**0.57 (0.45–0.74)**	**0.13**
Neg. Exponential Cosine	864.41	2.00	2.39 (1.90–3.01)	0.12	0.008	0.49 (0.39–0.62)	0.12
Brown-winged Mourner							
Uniform Cosine	**930.24**	**0.00**	**1.30 (0.90–1.88)**	**0.19**	**0.098**	**0.83 (0.57–1.00)**	**0.19**
Half-Normal Cosine	937.07	6.83	1.49 (0.83–2.65)	0.30	0.027	0.73 (0.41–1.00)	0.30
Hazard-Rate Cosine	932.20	1.96	1.36 (1.28–1.46)	0.03	0.085	0.79 (0.74–0.85)	0.03
Neg. Exponential Cosine	937.45	7.21	1.48 (0.95–2.29)	0.22	0.030	0.73(0.47–1.00)	0.22
White-bellied Tody-tyrant							
Uniform Cosine	2572.44	7.40	7.33 (6.19–8.68)	0.09	0.023	0.51 (0.43–0.60)	0.09
Half-Normal Cosine	2571.80	6.76	7.45 (6.24–8.89)	0.09	0.045	0.50 (0.42–0.59)	0.09
Hazard-Rate Cosine	**2565.04**	**0.00**	**7.26 (6.69–7.87)**	**0.04**	**0.231**	**0.51 (0.47–0.55)**	**0.04**
Neg. Exponential Cosine	2574.44	9.40	7.33 (6.19–8.68)	0.09	0.023	0.51 (0.43–0.60)	0.09

0.5 to 80 m (32.37 ± 16.57), and 330 records for the White-bellied Tody-tyrant, with perpendicular distances varying from 1.0 to 70 m (20.16 ± 13.07).

Because cosine, hermite polynomial, and simple polynomial adjustments resulted in only slight variations in modeling results, only the results of each key detection function with cosine adjustments were used for population density estimates and were shown in Table 1. For the White-shouldered Antshrike, although the key detection function with the lower ΔAIC value was Uniform Cosine, the Kolmogorov-Sminov goodness-of-fit test was significant for this model, indicating a poor model fit, which was corroborated by a relatively high CV (Table 1). On the other hand, the Hazard-Rate detection function was the only presenting non-significant goodness-of-fit test and had only slightly bigger AIC value compared to the best model based on ΔAIC (Uniform Cosine) (Table 1). Further, the plot of detection probabilities across perpendicular distances, and the Q-q plots demonstrated no relevant deviations (Figures S1A and S1B).

For the Brown-winged Mourner, the key detection function with lower ΔAIC was Uniform Cosine, and its adherence to the data was confirmed by the non-significant goodness-of-fit test (Table 1). Although the Hazard-Rate model also had non-significant goodness-of-fit test, the graphic depicting the detection probabilities distributed according to perpendicular distances and the Q-q plots visually evidenced the best fit of the Uniform Cosine model (Figures S1C and S1D).

For the White-bellied Tody-tyrant the Hazard-Rate Cosine detection function returned the lowest ΔAIC, and it was the only model with non-significant goodness-of-fit test (Table 1). The graphic of detection probability versus perpendicular distance and the Q-q plot did not evidence remarkable deviations and also provided a visual evidence that this model was well-fitted (Figures S1E and S1F).

In Table 1 we present population density estimates (D) obtained by pooling together the 10 transect replicates. After correcting the data (subdividing by 10), the resulted numbers of individuals per hectare estimated with the selected models were 0.21 for the White-shouldered Antshrike, 0.14 for the Brown-winged Mourner, and 0.73 for the White-bellied Tody-tyrant. Then, the expected numbers of individuals of the three taxa in our study area of 978 ha were 205, 137, and 714, respectively. The probabilities of detection (PD) were 0.57 for the White-shouldered Antshrike, 0.83 for the Brown-winged Mourner, and 0.51 for the White-bellied Tody-tyrant.

Discussion

1. *Population density estimates*

Distance-sampling population density data are scarce for Neotropical forest passerines. For the EN Black-cheeked Ant-tanager, *Habia atrimaxillaris* (Thraupidae), densities across Costa Rican populations varied from 0.24 to 0.27 individuals/ha (Cornils et al. 2015), and for the Near Threatened (NT) Atlantic Forest endemic Southern Bristle-Tyrant, *Phylloscartes eximius* (Tyrannidae) it was 0.13 individuals/ha (Tonetti & Pizo 2016). These data are close to our findings for the White-shouldered Antshrike (0.21 individuals/ha) and for the Brown-winged Mourner (0.14 individuals/ha), respectively, while for the White-bellied Tody-tyrant population density was much higher (0.73 individuals/ha).

An important assumption of the distance-sampling method is that all birds in the first perpendicular distance band should be detected (Bernardo et al. 2011, Cornils et al. 2015), and violations to this assumption could mean that birds are avoiding the trails, or that they have moved before being detected by the observer (Buckland et al. 1993, 2001, Thomas et al. 2010, Bernardo et al. 2011, Cornils et al. 2015). Our plots of detection probabilities across perpendicular distance bands indicated that this assumption was violated to some level for all of the analyzed taxa, an effect that was more drastic for the Brown-winged Mourner. A way to avoid this type of error is using point-counts instead of transect-based distance-sampling methods (see for instance Tonetti & Pizo 2016) because point-counting is independent of the use of trails, which reduces the effects of observer displacement. Here, point-counting was tested but it was inefficient due to the low number of records, which could compromise model fit (see also Buckland et al. 1993, 2001, Thomas et al. 2010). Despite the potential residual variances introduced in our estimates by this sampling artifact, other procedures used to address model fitting, i.e. the goodness-of-fit tests, the Q-q plots, density confidence limits and variation coefficients returned satisfactory results, suggesting that our estimates are still good proxies of the population densities of the analyzed taxa. Average probabilities of detection (PD) were high for the three studied taxa, when compared, for instance, with the Southern Bristle-Tyrant (0.08 to 0.14) (Tonetti & Pizo 2016). The values we obtained (all above 0.5) were comparable to those reported for large tropical forest game-birds, such as curassows (Alves et al. 2017), suggesting that the lower population density estimates found for the Brown-winged Mourner, for example, may not be associated with potential detectability problems.

Behavioral differences between sexes can be another important source of bias in distance-sampling analyses (Alves et al. 2017). For passerine birds, for instance, divergent vocalization patterns between males and females can affect detectability, misleading population density estimates, especially when males have louder territorial songs (Bibby et al. 2000). Among our study species, this seemed not to be a problem for the White-shouldered Antshrike and for the White-bellied Tody-tyrant, that were more often detected by visual cues or by their short calls likely emitted by both sexes. On the other hand, Brown-winged Mourners were rarely seen, and they were detected mainly when they displayed their main songs. We are unaware, however, if females also display the main songs; if males could vocalize more frequently, or even if sex biased densities can occur. Due to the lack of sexual dimorphism in this taxon, correct multipliers could be generated only by the observation of marked, molecularly-sexed individuals, which should be in the scope of future studies. It is worth noting that population densities of the studied taxa may vary across the studied fragment due to habitat heterogeneity. However, because our transects have covered large portions of the fragment we are confident that we have provided good overall estimates of population densities for the area.

2. *Importance for conservation*

Population densities can differ across fragments of habitats due to varying environmental conditions (Magrach et al. 2011, Kattan et al. 2014), meaning that our data, collected in only one area, could be used to generate only rough approximations of the global population sizes of the studied taxa. However, because no other demographic information exists for the addressed taxa, below we present preliminary inferences about their conservation status. During the elaboration of the Brazilian Red List of Endangered Bird Species, members of the assessment committee estimated the Area of Occupancy (AOO) for some of the taxa from the PEC, being AOO the area of suitable habitat effectively occupied by a taxon (IUCN 2019). For the White-shouldered Antshrike, AOO was calculated as the summation of 4 km^2 grids in which the species was known to occur, which resulted in an area of approximately 244 km^2. Then, this taxon was listed as EN based on the criteria B2ab(ii,iii) from IUCN (AOO is <500 km^2) (ICMBio 2018, IUCN 2019). The multiplication of the estimated AOO by the population density we found resulted in a global population of 5,124 individuals, which according to the IUCN population size criteria (criteria C) would place this taxon in the VU category (population of mature individuals between 2,500 and 10,000) (IUCN 2019), confirming that it is threatened, and evidencing that its current EN status based on its limited AOO must prevail.

For the Brown-winged Mourner AOO was not provided, but despite the lack of censuses data the global population was estimated to be about 10,000 individuals, with no subpopulations presenting more than 1,000 reproductive animals (ICMBio 2018). Then, this taxon was listed as VU based on criteria C2a(i), which means that the number of mature individuals in each subpopulation should be 250–1,000 (IUCN 2019). The Brown-winged Mourner presented the lowest population density estimate (0.14 individuals/ha). With such a low population density, an area of approximately 7,143 ha would be necessary for keeping a subpopulation of 1,000 individuals, but in a thorough mapping work, the biggest PEC fragment had approximately 3,500 ha (Pontes et al. 2016), which based on our data could retain ~490 individuals. These extrapolations are obviously problematic, but in the absence of further data we suggest that the decision of the Brazilian Red List committee to include this taxon in the VU category due to the limited sizes of the individual subpopulations should be maintained.

The White-bellied Tody-tyrant, on the other hand, was considered by the Red List committee as a frequent taxon, for which AOO was assumed to be an approximation of the total amount of Atlantic Forest from the PEC fragments (~2,000 km^2). Then, the latter was listed as VU based on the IUCN criteria B2ab(iii), i.e. AOO is less than 2,000 km^2, with areas that are fragmented and still declining (ICMBio 2018, IUCN 2019). Of the three addressed taxa, the White-bellied Tody-tyrant was the one of least conservation concern under a demographic perspective. Considering the C2a(i) criteria, the number of 1,000 birds per subpopulation needed to reach the Least Concern (LC) category could be reached in areas above 1,370 ha, which are scarce, but still occur in the PEC. Further, if the AOO estimate of 2,000 km^2 presented in Brazilian Red List for this taxon is true, the global population of the White-bellied Tody-tyrant could be around 146,000 individuals, which is highly above the 10,000 individuals necessary to reach the LC category based on the population size criteria of IUCN (C criteria) (IUCN 2019).

Our findings corroborated the premise that demographic information is important to indicate conservation priorities and to optimize the investments in conservation (Rodrigues et al. 2006, Bennun et al. 2018), as taxa listed in the same categories based on habitat parameters only, proved to have highly variable population densities and likely divergent risks of extinction. Future studies may address population densities in other areas to improve censuses estimates, and may focus on the generation of more precise habitat availability data for each of the taxa. It is surprising that red lists in the country with the higher concentration of endangered bird taxa are almost entirely devoid of demographic information, providing only rough information to direct the use of the scarce resources available for the implementation of conservation actions. It is worth noting that the taxa we studied are among the most frequent passerines from PEC fragments (Lobo-Araújo et al. 2013), and our preliminary population size extrapolations confirmed that two of these taxa are facing some level of threat also under a demographic perspective. It means that demographic studies on many other less frequent taxa, i.e. large frugivorous and birds of prey, are urgently needed.

Supplementary Material

The following online material is available for this article:

Figure S1 – Detection probabilities at different perpendicular distances, and Q-q plots obtained respectively for the White-shouldered Antshrike (A and B), the Brown-winged Mourner (C and D), and the White-bellied Tody-tyrant (E and F).

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Author Contributions

Luiza Carvalho Prado: work delineation; data collection; data analyses; manuscript preparation.

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Lahert Willian Lobo-Araújo: work delineation; data analyses.

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Mercival R. Francisco: work delineation; data analyses; manuscript preparation.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available at: https://doi.org/10.48331/scielodata.T3U4P5

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Article

A new species of *Phanerothecium* (Monogenea, Oogyrodactylidae), in *Hypostomus regani* (Loricariidae) from southeast Brazil

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Abstract: A new species of *Phanerothecium* Kritsky & Thatcher, 1977 (Oogyrodactylidae Harris, 1983) is described from locariid fish from southeast Brazil. *Phanerothecium macrosomum* n. sp. (Oogyrodactylidae) is described from the body surface of *Hypostomus regani* (Ihering, 1905) (Loricariidae). It is characterized by an armed male copulatory organ containing spines of different size from proximal to distal extremity, short peduncle and robust haptor.

Keywords: *Brazilian siluriforms; freshwater fish; Oogyrodactylidae; Batalha River; Neotropical region.*

Uma nova espécie de *Phanerothecium* (Monogenea, Oogyrodactylidae), de *Hypostomus regani* (Loricariidae) do sudeste do Brasil

Resumo: Uma nova espécie de *Phanerothecium* Kritsky & Thatcher, 1977 (Oogyrodactylidae Harris, 1983) é descrita em peixes locariídeos do sudeste do Brasil. *Phanerothecium macrosomum* sp. n. (Oogyrodactylidae) é descrito da superfície corporal de *Hypostomus regani* (Ihering, 1905) (Loricariidae) e é caracterizado pela presença de órgão copulador masculino armado contendo espinhos de diferentes tamanhos da extremidade proximal à distal, pedúnculo curto e haptor robusto.

Palavras-chave: *Siluriformes brasileiros; peixe de água doce; Oogyrodactylidae; rio Batalha; Região Neotropical.*

Introduction

Siluriformes Cuvier, 1816 is the most diverse group of fishes in South America and mainly in Brazil. Loricariidae Rafinesque, 1815 is one of the families included in this order and the second richest with 1192 valid species (Fricke et al. 2021). Loricariids usually harbor oogyrodactylids (Harris 1983, Boeger et al. 2021), although they can also concomitantly harbor species of gyrodactylids (Vianna & Boeger 2019).

There are 23 known species of oogyrodactylids all restricted to the Neotropical region and parasitizing loricariid and pimelodid fishes (Siluriformes). Oogyrodactylids were reported parasitizing pimelodid fishes, considered an accidental infestation, as *Phanerothecioides agostinhoi* Kritsky, Vianna & Boeger, 2007 found in *Pseudoplatystoma fasciatum* (Linnaeus) (Kritsky et al. 2007), and *Phanerothecium caballeroi* Kritsky & Thatcher, 1977 on *Zungaro zungaro* (Humboldt, 1821) (Kritsky & Thatcher 1977).

Eight genera of oogyrodactylids are known: *Aglaiogyrodactylus* Kritsky, Vianna & Boeger, 2007 (8 species); *Atopogyrodactylus* Kritsky, Boeger & Patella, 2020 (1); *Hyperopletes* Boeger, Kritsky & Belmont-Jégu, 1994 (1); *Nothogyrodactylus* Kritsky & Boeger, 1991 (3); *Onychogyrodactylus* Kritsky, Vianna & Boeger, 2007 (2); *Oogyrodactylus* Harris, 1983 (1); *Phanerothecioides* Kritsky, Vianna & Boeger, 2007 (1); and *Phanerothecium* Kritsky & Thatcher, 1977 (6) (Kritsky & Thatcher 1977, Harris 1983, Kritsky & Boeger 1991, Boeger et al. 1994, Kritsky et al. 2007, 2020).

Phanerothecium is characterized mainly for possessing vitelline follicles and ducts in reversed h-shaped, both absent in dextral pregermarial field; coiled, twisted copulatory organ spined (or not) inside of copulatory sac, eversible or with distal non-eversible sclerotized tube; uterus with heavy wall, containing from one-to-many eggs (sometimes empty) (Kritsky et al. 2007). *Phanerothecium caballeroi* Kritsky & Thatcher, 1977 was described in *Z. zungaro* (Pimelodidae) from Colombia, while the remaining species are from Brazil: *Phanerothecium deiropedeum* Kritsky, Vianna & Boeger, 2007 in *Hypostomus* sp.; *Phanerothecium harrisi* Kritsky & Boeger, 1991 in *Hypostomus plecostomus* (Linnaeus, 1758) (= *Plecostomus plecostomus* Linnaeus, 1758); *Phanerothecium spinatus* Boeger, Kritsky & Belmont-Jégu, 1994 (= *P. spinatum*, see Kritsky et al., 2007) in *Hypostomus punctatus* Valenciennes, 1840; *Phanerothecium spinatoides* Kritsky, Vianna & Boeger, 2007 in *Hypostomus* sp. 7 and sp. 9.; and *Phanerothecium spinulatum* Kritsky, Vianna & Boeger, 2007 in *Hypostomus* sp. (Kritsky & Boeger 1991, Boeger et al. 1994, Kritsky et al. 2007).

In this study a new species of *Phanerothecium* is described from the body surface of *Hypostomus regani* (Ihering, 1905) (Loricariidae) from southern Brazil.

Materials and Methods

Sixty specimens of the armored-catfish, *Hypostomus regani* (Loricariidae) (mean weight = 165.45 ± 77.75g and mean standard length = 17.72 ± 2.85cm), were collected from February 2014 to February 2016 in the Batalha River, Reginópolis municipality, State of São Paulo.

Fish were captured using nylon monofilament gillnets with different mesh sizes (sizes ranging from 20 to 100 mm internodes). The gillnets were placed on the slopes or near the river bottom at night and removed before dawn (10 hours exposure). Fish were removed from nets, anesthetized with eugenol solution (clove oil), and submitted to euthanasia through the physical method of medullary section, being immediately individualized in plastic bags and frozen for laboratory analysis. We observed that storing fish in plastic bags might have damaged the shape of some adults' parasites, flattening the bodies of the specimens. Even so, it was possible to observe the anatomy and represent it.

Sampling was carried out according to guidelines of the scientific fishing license under the authorization of the Chico Mendes Institute of Biodiversity through the System of Authorization and Information on Biodiversity (authorization nº 40998-2). The research project was submitted to the Ethical Committee on Animal Use of the Centro Universitário Sagrado Coração (UNISAGRADO) (authorization nº 3353050417).

Specimens of oogyrodactylids were collected under a dissecting microscope, preserved individually in 70% ethanol, and mounted on a slide prepared with Gray & Wess mounting medium; others were stained with Gomori's trichrome and mounted in Canada balsam (Humason 1979). Drawings were prepared with the aid of camera lucida on an Olympus BX51 microscope, equipped with phase contrast. Adult specimens were drawn from the side, as due to the size of the parasites and the form of conservation they were damaged. However, it is possible to identify and interpret the parasite anatomy. Measurements were made with ImageJ (NIH, Inc.) and are reported in micrometers (µm); the mean is followed by the range and sample size in parentheses (n). Measurements were taken by straight-line distances.

Type specimens were deposited in the helminthological collection of Museu de Zoologia da Universidade de São Paulo, São Paulo (MZUSP), Brazil, as presented in the respective descriptions.

Results

Phanerothecium Kritsky & Thatcher, 1977

Phanerothecium macrosomum n. sp.

(Figures 1, 2)

Type host: *Hypostomus regani* (Ihering, 1905) (Loricariidae).

Site of infection: Body surface.

Type locality: Batalha River (22° 06′ 35.2″S, 47° 49′ 12. 5″W), Reginópolis, São Paulo, Brazil, February 2014.

Prevalence and intensity: 11.7% and 3.3 ± 2.2 (7 parasitized hosts out of 60 analyzed).

Specimens deposited: MZUSP 8042-e (holotype), MZUSP 8042-a, MZUSP 8042-b, MZUSP 8042-c, MZUSP 8042-d, MZUSP 8042-f, MZUSP 8042-g, MZUSP 8042-h, MZUSP 8042-i, MZUSP 8042-j (paratypes).

Etymology**:** The specific name originates from Greek and refers to the strong and big body (*macro* = big; *soma* = body).

Description**:** Body 1509 (796–2098, n = 7) long, greatest body width at level of Mehlis' gland 309 (125–422, n = 7) (Figure 1a); peduncle short in pre-adult and matures adult specimens (Figure 1a, 2h). Unicellular cephalic glands, head organ conspicuous. Anterior pharyngeal bulb 96 (92–100, n = 2) diameter, from ovate to circular; posterior pharyngeal bulb 129 (120–137, n = 2) diameter, from ovate to circular. Testis observed only in immature specimens

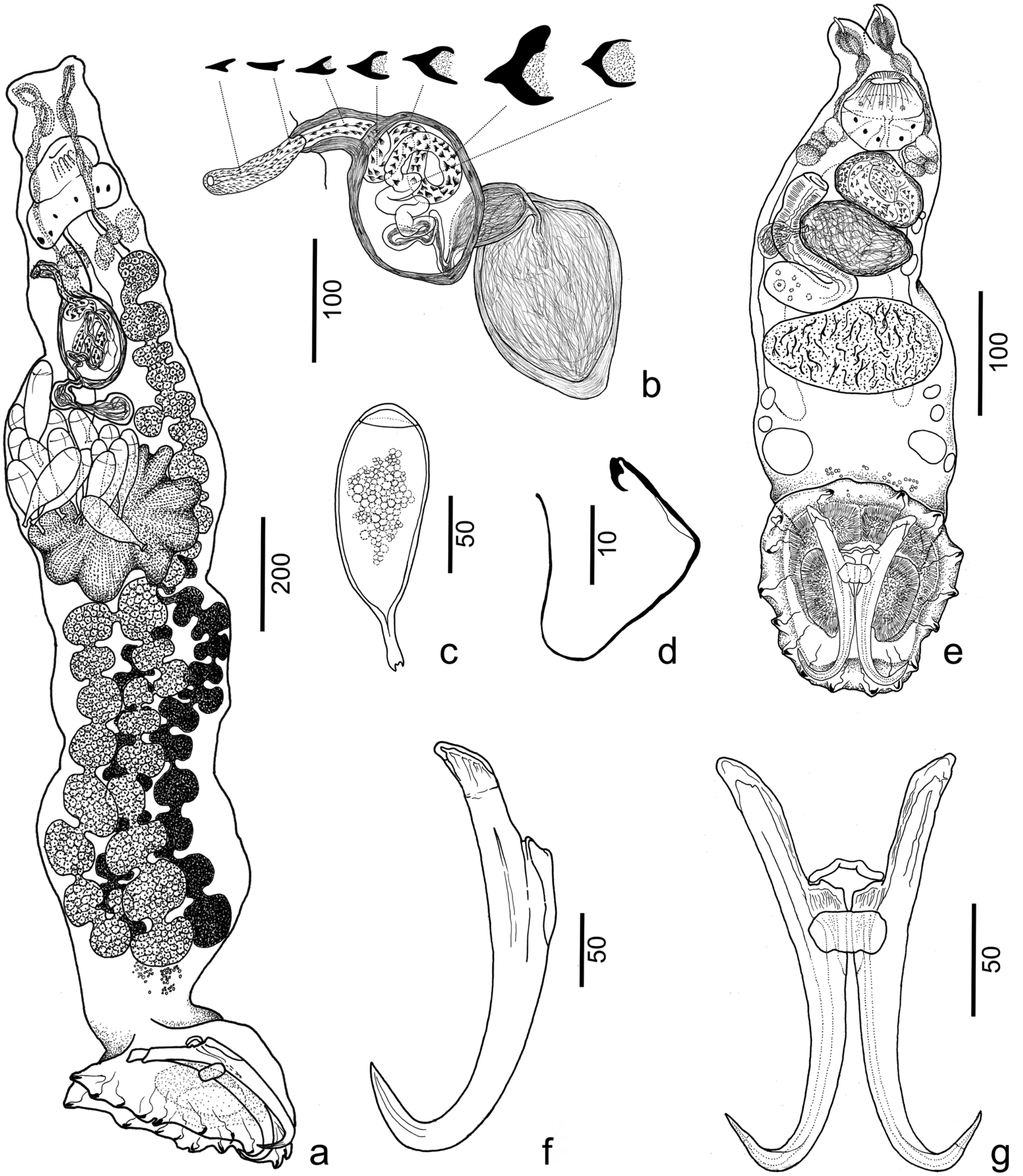

Figure 1. *Phanerothecium macrosomum* n. sp. (Oogyrodactylidae) on the body surface of *Hypostomus regani* (Loricariidae), holotype. a. Wholemount mature adult, lateral view. b. MCO (male copulatory organ). showing larger spines in the proximal portion and smaller spines in the distal portion. c. Egg. d. Hook. e. Wholemount immature specimen, ventral view, flattened. f. Anchor. g. Complex of anchors, superficial bar.

(Figure 1e, 2h), ovate, variable in size according to maturation; anterior seminal vesicle, elliptical, with thin wall; posterior seminal vesicle subspherical, bigger than anterior in pre-adults, with thick wall, reduced in adults (Figure 1b, 2l). Copulatory sac (Figure 2l) ovate, thick wall; male copulatory organ (MCO) tubular, muscular, inverted or everted (Figure 1b, 2l). MCO with spines of different sizes from proximal to distal portion (Figure 1b). Germarium not observed. Mehlis' gland well developed; uterus containing up to 19–40 eggs; uterine pore dextroventral, a transverse or diagonal slit with thickened rim. Egg 183 (170–213, n = 4) long, egg filament about 1/6 total egg length, with slight proximal bilobate flare (Figure 1c, 2i); egg droplets not observed. Haptor 368 (249–439, n = 7) long, 370 (276–447, n = 4) wide, subrectangular (young specimens) (Figure 1e, 2j) to circular (pre-adults and adults) (Figure 1a, 2k), with a thick edge formed by dorsal layer and hooklets (Figure 1d, 2j, 2k). Ventral portion containing two very conspicuous muscular

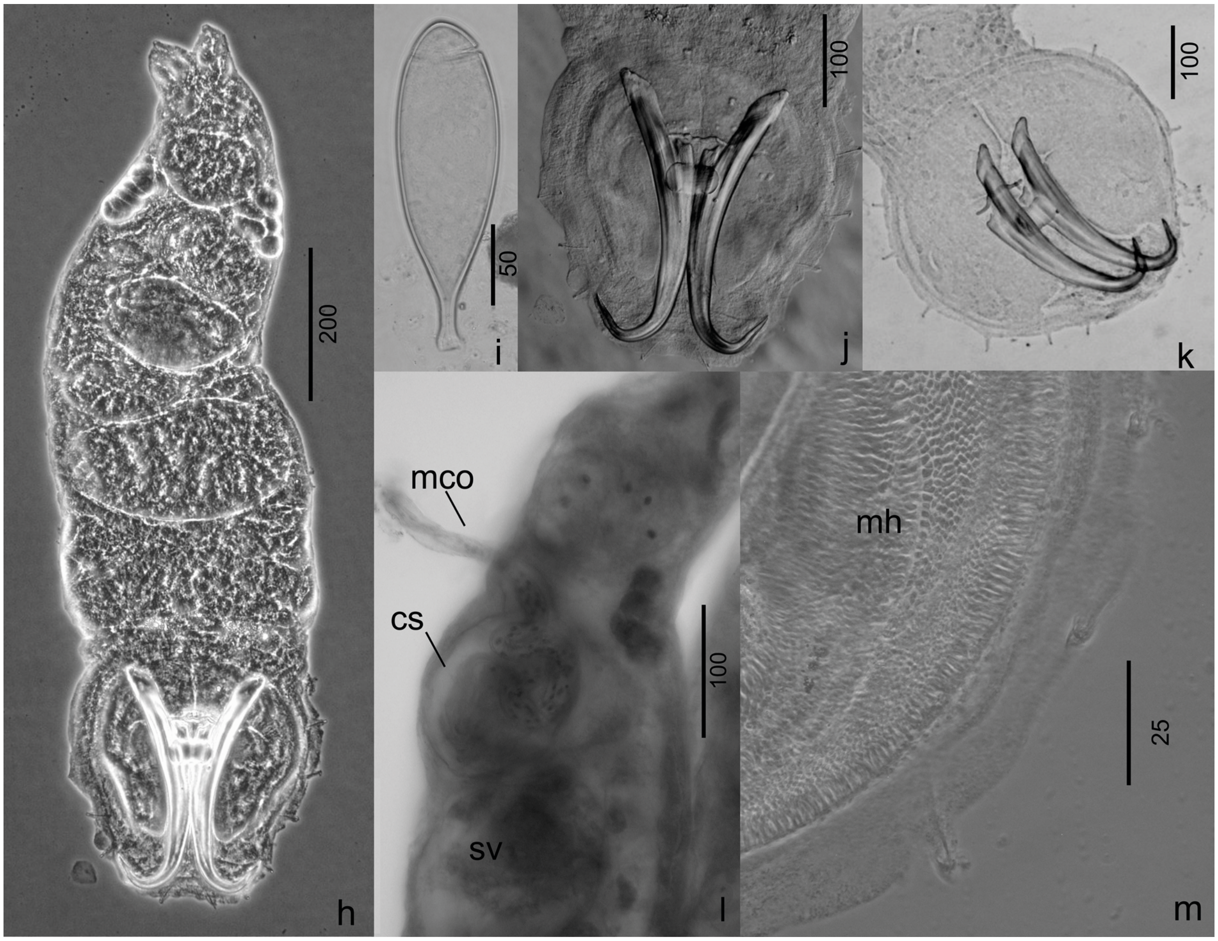

Figure 2. *Phanerothecium macrosomum* n. sp. (Oogyrodactylidae) on the body surface of *Hypostomus regani* (Loricariidae). h. Wholemount immature specimen, ventral view. i. Egg. j-k. Haptor. l. Male copulatory organ complex. mco – male copulatory organ, cs – copulatory sac, sv – seminal vesicle. m. Partial view of haptor. mh - musculature of haptor.

regions, lateral to anchor/bar complex, and due to striation appear to contain multiple papillae (Figure 2m). Anchor 385 (358–433, n = 3) long, with elongate superficial root, triangular and elongate deep root, slightly curved shaft and recurved point (Figure 1f, 1g, 2j, 2k). Superficial bar subrectangular 59 (51–66, n = 3) long; deep bar rod-shaped (Figure 1g, 2j). Hooks similar in shape and size, holocentric 34 (23–45, n = 2) long; hooklet 4 (n = 2) long, usually flexed ventrally, with short slightly recurved point, ventrally leaning shaft, globose heel and upright toe; shank tapers proximally to fine filament, with ventral keel near mid-length; FH (filament of hook) loop about 1/3 of shank length (Figure 1d).

Remarks**.** A comparison with other species of genus allows indicate *P. macrosomum* n. sp. as a new and the biggest species among all *Phanerothecium* species (Table 1). The new species is differentiated from the other congeneric species by presence of short peduncle; haptor subrectangular, containing strongly muscularized regions, antero-lateral to anchors; MCO armed with spines of different sizes from proximal to distal portion. Others three species of *Phanerothecium* presents armed MCO, *P. spinatus*, *P. spinatoides* and *P. spinulatum* and differ from *P. macrosomum* n. sp. by presence of spines of similar sizes and shapes.

Discussion

Oogyrodactylidae was proposed by Harris (1983) to accommodate *Oogyrodacytlus farlowellae* Harris, 1983 parasitic of *Farlowella amazonum* (Günther, 1864) (Loricariidae) and *Phanerothecium caballeroi* Kritsky & Thatcher, 1977, in *Zungaro zungaro* (Pimelodidae). Subsequently, Boeger & Kritsky (1993) consider Oogyrodactylidae synonymy of Gyrodactylidae due to the absence of synapomorphic features, thus uniting oviparous and viviparous species. Recently, through the use molecular data of 18S rDNA and COII (cytochrome oxidase II - mtDNA) Oogyrodactylidae (oviparous species) was reconsidered valid, separating this from species of Gyrodactylidae (viviparous species), thus both families were considered monophyletic and sister-groups (Boeger et al. 2021).

Phanerothecium Kritsky & Thatcher, 1977 was considered monophyletic (Boeger et al. 2021) and contains six species. In Brazil species of *Phanerothecium* were described only in *Hypostomus* Lacépède, 1803 hosts (Kritsky & Boeger 1991, Boeger, Kritsky & Belmont-Jégu 1994, Kritsky, Vianna & Boeger 2007).

Neither species of them *Phanerothecium* presents spines with different sizes on MCO as *P. macrosomum* n. sp. and the tubular MCO, muscular or sclerotized and unarmed was observed in *P. caballeroi*,

Table 1. Comparison of the measurements of *Phanerothecium* species. Values to *P. caballeroi* (forma minor/ forma major); values to *P. harrisi* (Kritsky et al. (2007)/ Kritsky & Boeger (1991)); values to *P. spinatoides* (from *Hypostomus* sp. 7/ from Hypostomus sp. 9). The values presented to measeruments gived are average.

	***P. caballeroi* forma minor**	***Phanerothecium* sp. (= *P. caballeroi* forma major)**	***P. deiropedeum***	***P. harrisi***	***P. macrosomum* n. sp.**	***P. spinatus***	***P. spinatoides***	***P. spinulatum***
Body								
Length	913	1094	1405	1107/ 1203	1509	1124	1376/ 1326	1362
Width	140	202	257	170/ 189	309	175	218/ 212	180
Wide (or diameter) pharyngeal bulb								
Proximal/ posterior	76	87	120	70/ 66	128	69	89/ 89	70
Distal/ anterior	48	46	85	50/ 83	96	69	63/ 64	51
Germarium		63						
Length/ Diameter	61/62	-	75/-	83/ 87	-	70/-	85/ 86	76/-
Width	-	-	-	-	-	75	89/ 88	78
Egg								
Length	-	-	224	-	183	162	155/ 158	161
Maximum number of eggs	-	-	12	22	40	10	>20	>7
Rate egg filament/ egg length	-	-	-	-	~1/6	-	~ 1/4	~ 1/4
Haptor								
Length	112	178	68	88/ 108	368	87	94/ 94	106
Width	115	184	102	113/ 104	370	95	111/ 117	143
Length of anchor	95	159	40	61/ 70	385	59	66/ 65	78
Superficial bar								
Length	29	46	17	23/ 25	59	48	25/ 24	25
Hook and hooklet								
Total length	47	48	46	37/ 33	34	35	40/ 40	44
Length of hooklet	6-7	6-7	8-9	5/ 5-6	4	6	5-6/ 5-6	6
Rate FH loop/ shank length	-	-	~1/3	-		~1/4	~1/5	~ 1/4
Keel of shank	Yes	Yes	No	No	Yes	Yes	Yes	Yes
MCO								
Eversible	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Spines present/ shape	No/-	No/-	No/-	No/ -	Yes/ different	Yes/ similar	Yes/ similar	Yes/ similar

P. harrisi and *P. deiropedeum*, while the muscular MCO, armed with diminutes spines and of the same size, were founded in *P. spinatoides*, *P. spinulatum* and *P. spinatus*.

The morphological features of *P. macrosomum* n. sp. as short peduncle, haptor and spines of MCO support the new species.

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Rogério Tubino Vianna: substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

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Rodney Kozlowiski de Azevedo: substantial contribution in the concept and design of the study; contribution to critical revision, adding intelectual content.

Vanessa Doro Abdallah: substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to critical revision, adding intelectual content.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Data Availability

The work qualifies as an exception according to the instructions for "Data Availability" (https://www.scielo.br/journal/bn/about/#instructions).

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