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inventory

Spatial configuration of the occurrence of bat species (Mammalia: Chiroptera) in eastern Mato Grosso, Brazil

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Abstract: Given the substantial lacunas in the understanding of the occurrence and distribution of bat species in the eastern portion of the Brazilian state of Mato Grosso (Araguaia basin), this study presents an inventory of the species known to occur in the region, highlighting the areas sampled adequately and the species known to occur in conservation units. Georeferenced records of the occurrence of bat species in the region were obtained from published studies, scientific collections, through either the *Species*Link network or directly from the curator, as well as the capture of specimens by our research group between 2008 and 2013. A 0.5° x 0.5° (latitude/longitude) grid was added to the map of the region for the quantification of the bat species richness of each grid cell. A total of 63 chiropteran species were recorded for the study area. Only 10 of the 30 grid cells had records of bats, and just three contained more than 20 species, and were considered to be sampled adequately on a minimal level. Bat species have been recorded in three conservation units, two state and one municipal. The number of species recorded represents 82.7% of the total of chiropterans known to occur in Mato Grosso, although 12 species were recorded in the state for the first time, reinforcing the paucity of data available on the distribution of bats in the region. The high bat species richness recorded in the present study reinforces the importance of eastern Mato Grosso, a transition zone between the Amazon forest and the Cerrado savanna of central Brazil, for the conservation of Neotropical chiropterans.

Keywords: *Cerrado savanna, geographic distribution, conservation units, chiropterans.*

OLIVEIRA, S.L., SOUZA, L.A.S., SILVA, H.K., FARIA, K.C. **Configuração espacial da ocorrência de espécies de morcegos (Mammalia: Chiroptera) no leste de Mato Grosso, Brasil.** Biota Neotropica. 15(1): e20140122. http://dx.doi.org/10.1590/1676-06032014012214

Resumo: Frente à lacuna existente sobre a real ocorrência e distribuição das espécies de morcegos objetivamos listar as espécies registradas na região leste do estado de Mato Grosso, Brasil, apontando os locais minimamente amostrados e as espécies catalogadas dentro das Unidades de Conservação. Foram consideradas espécies com registros georrefenciados para a região disponibilizados por periódicos científicos, coleções científicas, por meio do sistema *Species*Link ou disponibilizados diretamente pela curadoria, além de capturas realizadas entre 2008 e 2013 pelo nosso grupo de pesquisa. Ao mapa da região leste do estado foi incorporado células de 0,5° latitudinais X 0,5° longitudinais e quantificadas sobre a riqueza de espécies de morcegos em cada célula. Foram registradas 63 espécies para a região. Das 30 células geradas 10 tiveram pelo menos uma espécie registrada e três tiveram mais de 20 espécies sendo consideradas minimamente amostradas. Três Unidades de Conservação tiveram espécies catalogadas, sendo duas estaduais e uma municipal. A região leste teve o registro de 82,7% do total de espécies conhecidas para o estado de Mato Grosso, sendo que 12 ainda não haviam sido assinaladas para o estado demonstrando que ainda pouco se conhece sobre a real distribuição dos morcegos na região. Considerando a alta riqueza encontrada enfatizamos a importância da região leste de Mato Grosso, zona de transição entre Cerrado e Amazônia, e também o potencial do estado na conservação dos morcegos neotropicais.

Palavras-chave: *Cerrado, distribuição geográfica, unidades de conservação, quirópteros.*

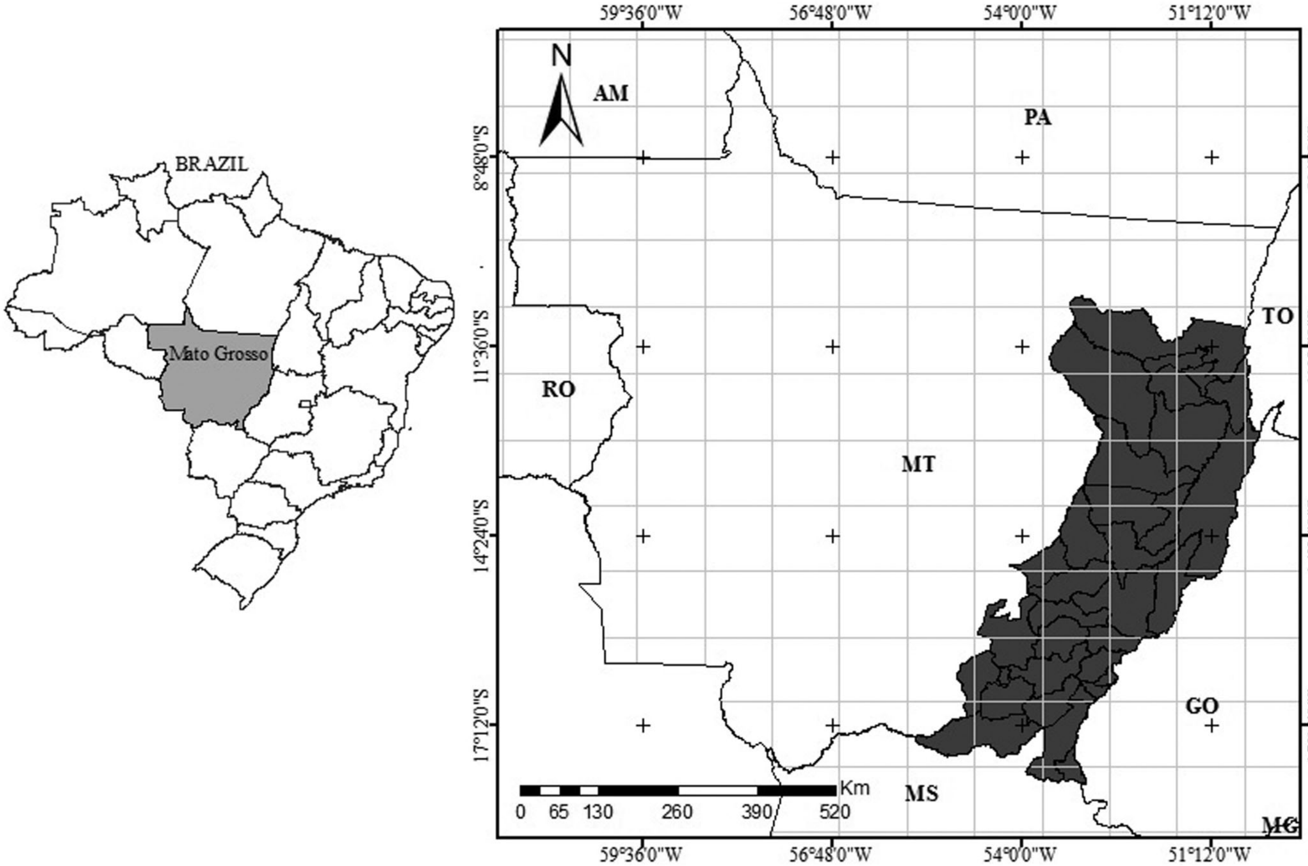

Figure 1. Map of Brazil, showing the state of Mato Grosso and in the inset, the study area in the east of the state and the 0.5° x 0.5° (latitude x longitude) cells established for the present study.

Introduction

The Brazilian state of Mato Grosso encompasses part of three of the country's terrestrial biomes – the Amazon forest, the Cerrado savanna, and the Pantanal wetlands – and thus plays an important role in the conservation of Neotropical biodiversity. The Cerrado, Brazil's second-largest biome, is characterized by a unique configuration of vegetation types with an ample variety of habitats and considerable biodiversity, which is not only poorly-known, but also seriously threatened by the ongoing fragmentation of habitat (Oliveira et al. 2008). This biome, considered to be a hotspot for biodiversity conservation (Myers et al. 2000) has 32 endemic mammal species, of which one is a bat (Ribeiro & Walter 2008; Paglia et al. 2012). Bats are highly mobile, which contributes to their effectiveness as pollinators and seed dispersers, providing important ecological services for dozens of plant species (Mikich & Bianconi 2005).

Despite their ecological importance, the distribution of most bat species in Brazil is still poorly defined. The number of surveys and inventories has increased considerably in recent years, although most of this research has focused on the Atlantic Forest of southeastern Brazil (Bernard et al. 2011). Most research in the Cerrado has been conducted in the states of Goiás, Minas Gerais, and Distrito Federal (Aguiar & Zortéa 2008). Of the 178 bat species known to occur in Brazil, 101 have been recorded in the Cerrado (Paglia et al. 2012; Reis et al. 2013; Nogueira et al. 2014).

While almost half of Brazilian species (81) are known to occur in Mato Grosso, most of the studies have focused on sites in the vicinity of the state capital, Cuiabá, while major lacunas still exist in the north and east of the state (Aguiar & Zortéa, 2008, Bernard et al. 2011, Reis et al. 2013). The areas of Cerrado in eastern Mato Grosso are among those considered to be of the highest priority for the conservation of species, and have been identified by some authors (Horta et al. 2002; Bernard et al. 2011) as extremely important for the maintenance of bat species. Given this interest, the region's biodiversity has been the focus of numerous studies (e.g. Pine et al. 1970, Silva & Anacleto 2011, Sousa et al. 2011, 2013a, b, Oliveira et al. 2013), although its bat fauna is still relatively poorly studied.

Considering the need for new data and the updating of the inventory of the state's bat fauna, the present study compiled the data available on the occurrence of bat species in its eastern region. The study emphasizes the areas considered to be most adequately sampled, and the species recorded in three of the region's conservation units.

Material and Methods

The present study focused on eastern Mato Grosso (Brazil), within an area delimited to the south by the municipalities of Alto Araguaia, Alto Taquari, and Itiquira, and to the north by São Félix do Araguaia, including the basins of the Araguaia and das Mortes rivers (Figure 1). The region is characterized by

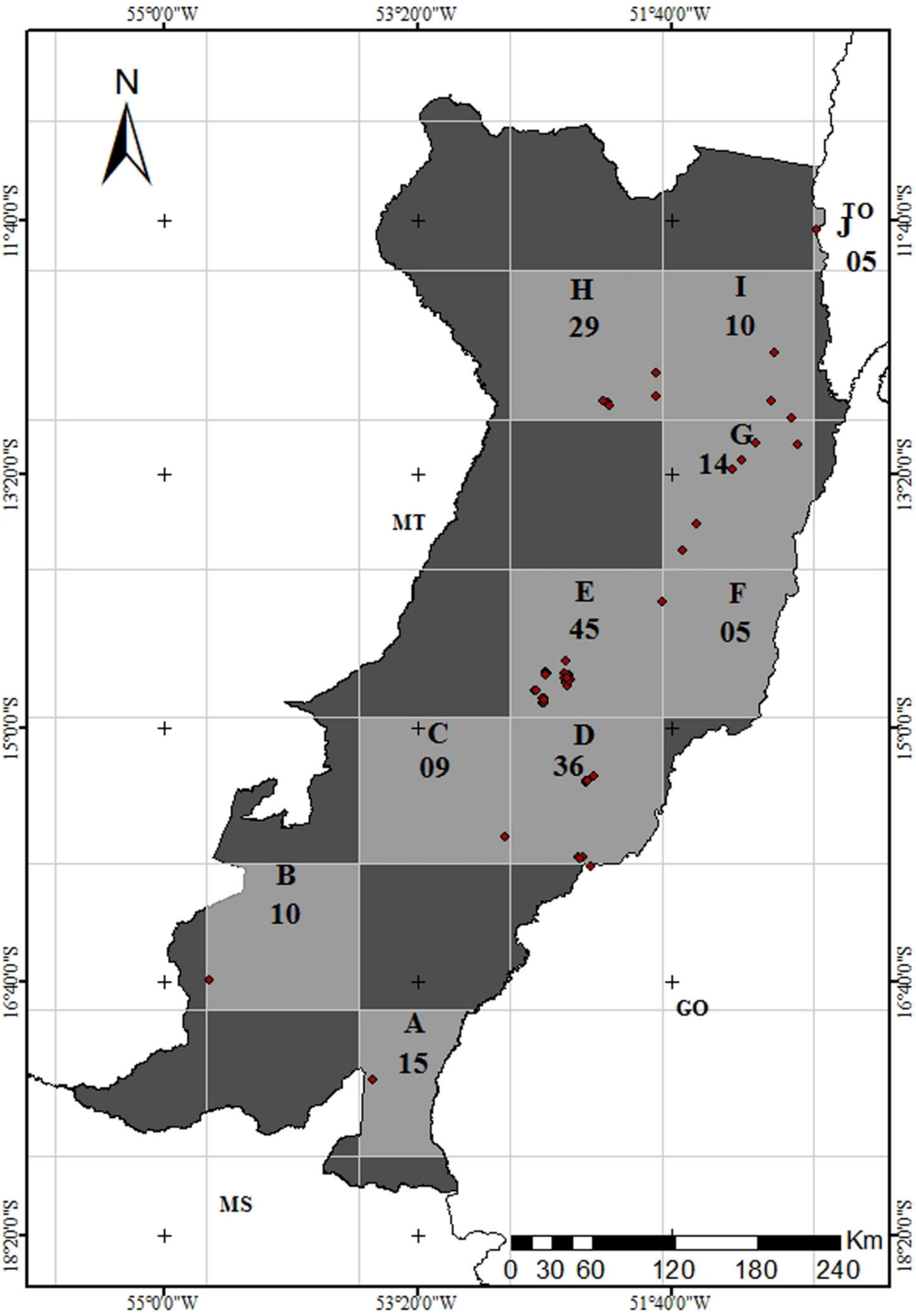

Figure 2. Map of eastern Mato Grosso showing the 0.5° x 0.5° cells in which at least one bat species has been recorded, identified by the letters A–J. The numbers refer to the species richness recorded in each cell. ◆ = sites at which specimens were captured.

the diverse habitats typical of the Cerrado biome, which suffers the influence of the neighboring areas of the Amazon forest in the north. The region's climate is of the AW in the Köppen classification systems, and is characterized by distinct dry and rainy season, with mean annual temperatures of between 23°C and 25°C (Silva et al. 2008). It also includes conservation units, such as the Araguaia and Serra Azul state parks, which provide important infrastructure for research.

Georeferenced records of the occurrence of bats within this region were obtained from published studies (Pine et al. 1970, Silva & Anacleto 2011, Sousa et al. 2011, 2013a, b; Oliveira et al. 2013), scientific collections with records available on the *Species*Link network: (CM–UNEMAT, ZUEC-MAM - UNICAMP and MCP-Mammals – PUC/RS), or made available by their curators (CCMZ-UFPR), and the capture of specimens by the authors of the present study within the region between 2008 and 2013. The voucher specimens resulting from these captures were deposited at the Nova Xavantina campus of the Mato Grosso State University (UNEMAT).

The spatial distribution of bat species in the region was mapped using procedures adapted from Bernard et al. (2011), which included the incorporation of a 0.5° x 0.5° (latitude/

Table 1. List of the bat species recorded in eastern Mato Grosso, Brazil. The letters refer to the respective grid cells (see Figure 2). The species not recorded previously for Mato Grosso (Reis *et al.* 2013) are indicated by an asterisk (*). Sources are: (1) present study (specimens collected between 2008 and 2013); (2) Oliveira *et al.* (2013); 3 – Sousa *et al.* (2013a); 4 – Sousa *et al.* (2013b); 5 – Silva & Anacleto (2011); 6 – Sousa *et al.* (2011); 7 - Pine *et al.* (1970); 8 – CM - UNEMAT; 9 – MCP-Mammals – PUC/RS; 10 – ZUEC-MAM - UNICAMP; 11 – CCMZ-UFPR.

Family/ Subfamily / Species	**Grid cells**									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
EMBALLONURIDAE										
Emballonurinae										
Centronycteris maximiliani (J. Fisher, 1829) *	-	-	-	-	-	-	8	-	-	-
Peropteryx macrotis (Wagner, 1843)	-	-	-	1	1	-	-	-	-	-
Saccopteryx bilineata (Temminck, 1838)	-	-	-	10	-	-	-	7	-	-
Saccopteryx leptura (Schreber, 1774)	-	-	-	-	1	-	1	7	-	-
Rhynchonycteris naso (Wied-Neuwied, 1820)	-	-	-	10	1, 4	-	-	7	-	-
PHYLLOSTOMIDAE										
Desmodontinae										
Desmodus rotundus (E. Geoffroy, 1810)	-	11	9	1	1, 4, 8	-	-	-	-	-
Glossophaginae										
Anoura caudifer (E. Geoffroy, 1818)	-	-	-	1	1, 4, 5	-	-	-	-	-
Anoura geoffroyi Gray, 1838	11	-	9	1	-	-	-	-	-	-
Glossophaga soricina (Pallas, 1766)	11	-	9	1, 8	1, 4, 5, 8	-	1, 8	7	1	1
Lonchophylla dekeyseri (Taddei, Vizotto & Sazima, 1983)	11	11	-	1	1	-	-	-	-	-
Phyllostominae										
Chrotopterus auritus (Peters, 1856)	-	-	-	1	-	-	-	-	-	-
Lampronycteris brachyotis (Dobson, 1879) *	-	-	-	1	1	-	-	-	-	-
Lonchorhina aurita Tomes, 1863 *	-	-	-	-	8	-	-	-	-	-
Lophostoma brasiliense Peters, 1867	11	-	-	1	1, 4, 8	-	-	-	-	-
Lophostoma silvicolum d'Orbigny, 1836	-	11	-	1	1, 4	-	1	-	-	-
Micronycteris microtis Miller, 1898 *	-	11	-	-	-	-	-	-	-	-
Micronycteris minuta (Gervais, 1856)	-	-	-	1	-	-	-	-	-	-
Micronycteris schmidtorum Sanborn, 1935 *	11	11	-	-	-	-	-	-	-	-
Mimon benettii (Gray, 1838)	-	-	-	1	-	-	-	-	-	-
Mimon crenulatum (E. Geoffroy, 1803)	11	-	-	-	1, 2	-	-	7	1	-
Phylloderma stenops Peters, 1865	-	-	-	-	1	-	-	-	-	-
Phyllostomus discolor Wagner, 1843	11	11	-	-	1, 4, 8	-	-	-	-	-
Phyllostomus elongatus (E. Geoffroy, 1810)	-	-	-	-	1, 4, 5	-	-	-	-	-
Phyllostomus hastatus (Pallas, 1767)	-	-	-	-	1, 4, 5, 8	-	-	-	-	-
Tonatia bidens (Spix, 1823)	-	11	-	1	-	-	-	-	-	-
Tonatia saurophila Koopman & Wiliiams, 1951 *	-	-	-	1	-	-	-	-	-	-
Trachops cirrhosus (Spix, 1823) *	-	-	-	1	1, 3, 4, 8	-	-	-	-	-
Vampyrum spectrum (Linnaeus, 1758)	-	-	-	-	4, 6	-	-	-	-	-
Carolliinae										
Carollia perspicillata (Linnaeus, 1758)	11	11	9	1, 10	1, 4, 5, 8	1, 8	1, 8	7	1	1
Rhinophylla pumilio Peters, 1865	-	-	-	1	1	-	-	7	-	-
Stenodermatinae										
Ametrida centurio Gray, 1847	-	-	-	-	-	-	-	7	-	-
Artibeus concolor Peters, 1865 *	-	-	9	-	-	-	-	-	-	-
Artibeus lituratus (Olfers, 1818)	-	-	-	1, 10	1, 4, 5	1	1	7	1	1
Artibeus obscurus (Schinz, 1821)	-	-	-	-	1	-	-	-	-	-
Artibeus planirostris (Spix, 1823)	11	11	-	1, 10	1, 4, 5, 8	1, 8	1	7	1	1
Chiroderma trinitatum Goodwin, 1958	-	-	-	-	-	-	-	7	-	-
Chiroderma villosum Peters, 1860	-	-	-	1	1, 4, 5	-	-	7	-	-
Dermanura cinerea (Gervais, 1856)	11	11	-	1	1	-	-	7	-	-
Dermanura gnoma (Handley, 1987)	-	-	-	1	1	-	1	-	-	-
Mesophylla macconnelli Thomas, 1901	-	-	-	-	-	-	-	7	-	-
Platyrrhinus brachycephalus (Rouk & Carter, 1972)*	-	-	-	10	-	-	-	-	-	-
Platyrrhinus incarum (Thomas, 1912)	-	-	-	1	1, 4, 5	1	1	7	1	1
Platyrrhinus lineatus (E. Geoffroy, 1810)	11	-	-	1	1, 4, 5, 8	-	1	7	-	-
Sturnira lilium (E. Geoffroy, 1810)	11	-	-	1	1, 4, 5, 8	-	-	-	-	-
Sturnira tildae de la Torre, 1959	-	-	-	-	-	-	-	7	-	-

Continued on next page

Table 1. Continued.

Family/ Subfamily / Species	**Grid cells**									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Uroderma bilobatum Peters, 1866	-	-	-	10	1, 4, 5, 8	-	1, 8	7	1	-
Uroderma magnirostrum Davis, 1968	-	-	-	-	1, 5	-	-	7	-	-
Vampyressa pusilla (Wagner, 1843) *	-	-	9	-	-	-	-	-	-	-
MORMOOPIDAE										
Pteronotus gymnonotus Natterer, 1843	-	-	-	1	8	-	-	-	-	-
Pteronotus parnellii (Gray. 1843)	11	-	9	1	1, 4, 5	1	-	7	-	-
NOCTILIONIDAE										
Noctilio albiventris Desmarest, 1818	-	-	-	-	1, 5	-	1, 8	-	-	-
MOLOSSIDAE										
Cynomops abrasus (Temminck, 1827)	-	-	-	-	4	-	-	7	-	-
Cynomops milleri (Osgood, 1914)	-	-	-	-	-	-	-	7	-	-
Eumops glaucinus (Wagner, 1843)	-	-	-	-	1	-	-	-	-	-
Molossops temminckii (Burmeister, 1854)	11	-	-	1	1, 4, 5	-	1, 8	7	1	-
Molossus molossus (Pallas, 1766)	-	-	9	-	1, 4, 5	-	-	7	1	-
Molossus rufus E. Geoffroy, 1805	-	-	-	10	1, 5	-	-	7	-	-
Nyctinomops laticaudatus (E. Geoffroy, 1805)	-	-	-	1	-	-	-	-	-	-
VESPERTILIONIDAE										
Eptesicus andinus J. A. Allen, 1914	-	-	-	-	-	-	-	7	-	-
Eptesicus brasiliensis (Desmarest, 1819)	-	-	-	8	8	-	-	-	-	-
Eptesicus diminutus Osgood, 1915 *	-	-	-	8	4	-	-	-	-	-
Eptesicus furinalis (d'Orbigny & Gervais, 1847)	-	-	-	-	1	-	-	-	-	-
Lasiurus blossevillii (Lesson & Garnot, 1826)	-	-	-	-	-	-	-	7	-	-
*Lasiurus ega (*Gervais, 1856)	-	-	-	-	-	-	-	7	-	-
Myotis nigricans (Schinz, 1821)	-	-	9	-	1, 4, 5	-	8	-	8	-
Myotis riparius Handey, 1960 *	11	-	-	-	1	-	-	-	-	-
Rhogeessa io Thomas, 1903	-	-	-	-	1	-	-	7	-	-

longitude) grid using ArcGis 9.2 in the Environmental Analysis Laboratory (LANA) at UNEMAT, Nova Xavantina. The grid cells were scored according to the number of bat species recorded, and those with at least 20 species were considered to be adequately sampled on a minimal level, as established by Bernard et al. (2011). The outlines of the local federal, state, and municipal conservation units – provided by the Mato Grosso State Environment Secretariat (SEMA/MT) – were then added to the map in order to quantify the number of bat species recorded in each of these protected areas.

Results

Ten of the 30 cells demarcated for the present study returned at least one record of a bat species (Figure 2), and in three of these (D, E, and H), more than 20 species have been recorded. These cells were thus considered to have been adequately sampled on a minimal level. No records of bats were found for the other 20 cells.

A total of 67 bat species were recorded, representing 40 genera and five families (Table 1), including 12 species not included in the most recent inventory published for the state (Reis et al. 2013). Cells D, E, and H were the most diverse, with 36, 45, and 29 species, respectively (Figure 2), whereas cells F and J presented the lowest number of species, with five each.

Three of the conservation units found within the study area were sampled, providing the first data on their bat faunas. Two of these – the Serra Azul State Park and the Araguaian Chelonians State Wildlife Refuge – are administered by the Mato Grosso state government, while the other, the Bacaba Municipal Park, is run by the municipality of Nova Xavantina. A total of 25 bat species were recorded in both the Serra Azul and Bacaba parks, while only eight species were registered for the Araguaian Chelonians State Wildlife Refuge (Figure 3; Table 2).

Discussion

The number of bat species recorded in eastern Mato Grosso corresponded to 82.7% of the total known to occur in the state as a whole (Reis et al. 2013). While a number of recent studies (e.g. Sousa et al. 2013a, Carrijo et al. 2013) have confirmed the occurrence of some species, many are known only in scientific collections. This is reinforced by the fact that 12 of the species had not been recorded previously in the state of Mato Grosso.

The low number of cells considered to be adequately sampled in this analysis also emphasizes the paucity of the data available on the occurrence and distribution of bat species in the region. The configuration of the cells also reflects the highly asymmetric distribution of the available knowledge of the region's bat fauna, a problem identified almost 20 years ago by Uieda & Pedro (1996).

Bernard et al. (2011) noted that, while the number of inventories of bat populations has grown considerably in recent years, most studies have tended to be concentrated in areas adjacent to universities that have active research groups. In fact, two of the cells considered to adequately sampled in this analysis (D and E) coincide with the region's two major

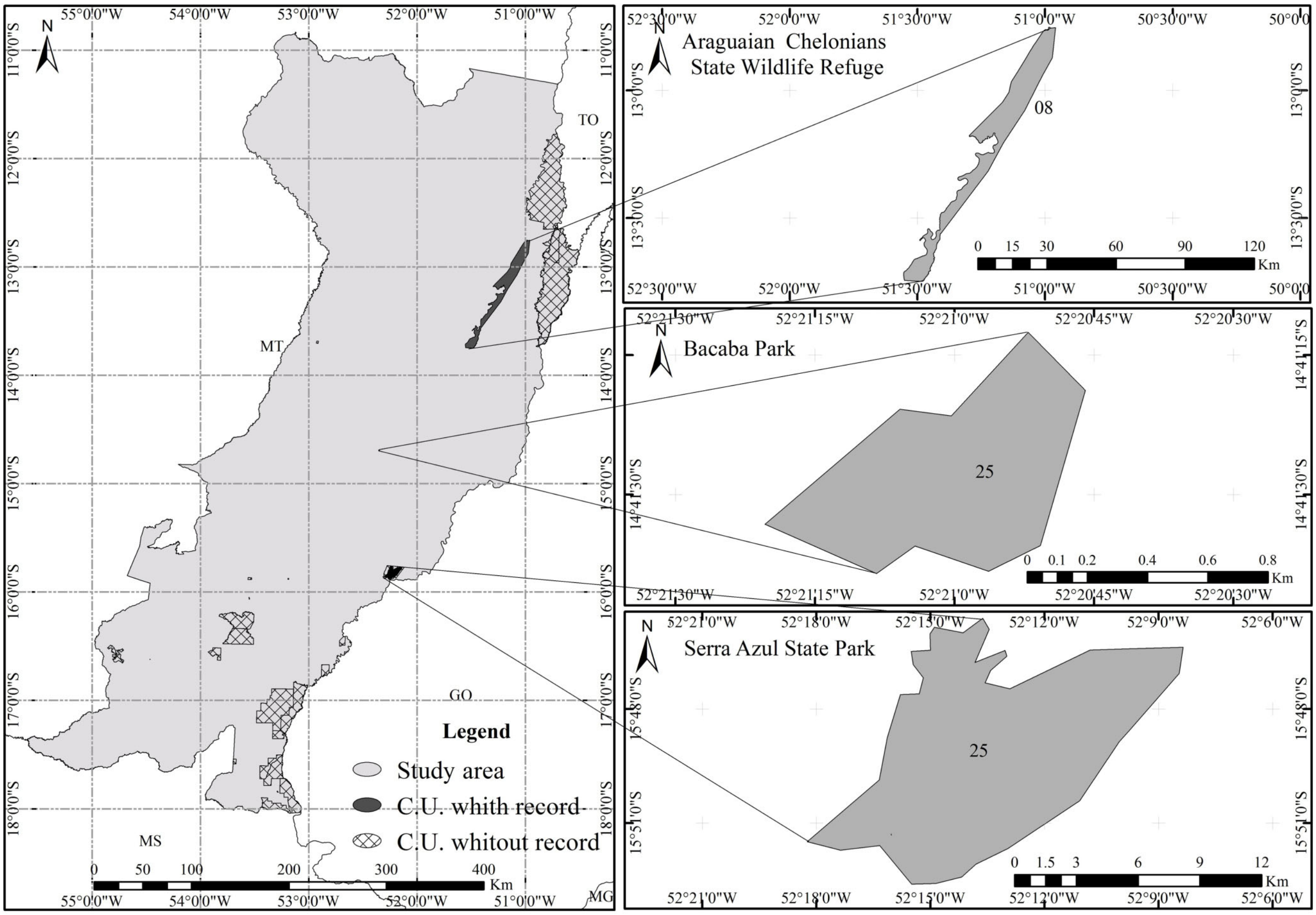

Figure 3. Conservation units found within the study area, highlighting the three areas in which at least one bat species has been recorded. The numbers refer to the species richness recorded in each unit.

university centers, the Araguaia campus of the Federal University of Mato Grosso, and the Nova Xavantina campus of UNEMAT, respectively, reinforcing the importance of such research groups, as well as the need for further fieldwork in areas that have been the focus of little or no investigation.

The ongoing expansion of agricultural and energetic (hydroelectric dams) frontiers in the state should be accompanied by new studies of environmental impacts and the monitoring of fauna (Brasil 2000). Systematic species inventories (including Chiroptera) are legally required for the concession of licenses for the implementation of any project that may potentially cause environmental degradation (Brasil 1986, 1997). However, the available data on the occurrence of bat species in Mato Grosso do not correspond to the ongoing advances in major development projects, in both the public and private sectors, and there is a clear need for better access to the records and specimens produced by these projects, in order to consolidate the scientific understanding of the state's chiropteran fauna.

Eastern Mato Grosso is considered to be of major importance for the conservation of the biological diversity of the Neotropical region (e.g. Myers et al. 2000, Horta et al. 2002, Bernard et al. 2011) and is located within the Cerrado's principal agricultural frontier, in the Arc of Deforestation on the southern rim of the Amazon basin (Nogueira et al. 2008). The conservation units already established in this region will obviously play a fundamental role in the investigation of its biodiversity, and this will demand concerted actions between research institutions (on local and regional scales) and local administrators, given the intrinsic interest of researchers and the need for inventories, which are an integral component of the management plan of any conservation unit (Brasil 2000).

The occurrence of species restricted to specific types of habitat, such as *L. dekeyseri*, which is endemic to the Cerrado (Reis et al. 2013), and *L. brachyotis*, *T. bidens*, *T. cirrhosus*, and *M. crenulatum*, which are considered to be sensitive to habitat disturbance (Mendellin 2000), reinforce the important of integral protected areas, even those associated with human activities, such as the Serra Azul State Park, in which all these species were recorded. This type of information provides material for projects in environmental education, which are essential for the effective creation of parks at any level, whether federal, state or municipal (Brasil 2000).

A reliable understanding of the distribution of species is essential for the demarcation of new protected areas, as well as the evaluation of any new development projects to be established in the region. The results of the present study, which highlight the diversity of bats in the Brazilian state of Mato Grosso, reinforce its importance, and especially that of

Table 2. List of the bat species recorded in each of the three conservation units. The occurrence of a given species in a unit is indicated by an "x". PESA: Serra Azul State Park; PMB: Bacaba Municipal Park; RVSQA: Araguaian Chelonians State Wildlife Refuge.

Family/ Subfamily / Specie	PESA	PMB	RVSQA
EMBALLONURIDAE			
Emballonurinae			
Saccopteryx leptura	-	x	-
PHYLLOSTOMIDAE			
Desmodontinae			
Desmodus rotundus	x	x	-
Glossophaginae			
Anoura caudifer	x	x	-
Anoura geoffroyi	x	-	-
Glossophaga soricina	x	x	x
Lonchophylla dekeyseri	x	-	-
Phyllostominae			
Lampronycteris brachyotis	x	-	-
Lophostoma brasiliense	-	x	-
Lophostoma silvicolum	x	x	x
Micronycteris minuta	x	-	-
Mimon crenulatum	x	x	x
Phyllostomus discolor	-	x	-
Phyllostomus elongatus	-	x	-
Phyllostomus hastatus	-	x	-
Tonatia bidens	x	-	-
Trachops cirrhosus	x	x	-
Carolliinae			
Carollia perspicillata	x	x	x
Rhinophylla pumilio	x	x	-
Stenodermatinae			
Artibeus lituratus	x	x	x
Artibeus planirostris	x	x	x
Chiroderma villosum	x	x	-
Dermanura cinerea	x	x	-
Dermanura gnoma	x	x	-
Platyrrhinus incarum	x	x	x
Platyrrhinus lineatus	x	x	x
Uroderma bilobatum	-	x	-
MORMOOPIDAE			
Pteronotus gimnonotus	x	-	-
Pteronotus parnellii	x	x	-
MOLOSSIDAE			
Molossops temminckii	x	x	-
Molossus rufus	-	x	-
VESPERTILIONIDAE			
Eptesicus diminutus	x	-	-
Myotis sp.	x	-	-
Roghesia io	-	x	-
Total	**25**	**25**	**08**

the eastern region, for the preservation of Neotropical chiropterans.

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article

Influence of environmental quality of the tributaries of the Monjolinho River on the relative condition factor (Kn) of the local ichthyofauna

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Abstract: The relative condition factors (Kn) of the fishes *Astyanax paranae*, *Phalloceros harpagos* and *Poecilia reticulata* were used as a means of assessing the influence of environmental conditions on the well-being of sub - populations of these species, with the eventual aim of using them as bioindicators of disturbance in tributary streams of the Monjolinho River, in São Carlos - SP. The power-law curve generated by the length-weight relationship indicated a positive allometric growth for the three species studied. Overall, the canonical correspondence analysis (CCA) positively correlated average Kn of *A. paranae* with well oxygenated and oligotrophic environments, typical of conserved areas or near the natural state. For the average value of Kn obtained for *Phalloceros harpagos* species, there was no significant difference between natural and disturbed areas. However, the CCA positively correlated the mean Kn of the species *P. reticulata* from similar environments with higher trophic level, suggesting that this species is indicative of disturbance.
Keywords: *Biomonitoring, condition factor, length-weight relationship, degradation, bioindicators.*

BARRILLI, G.H.C, ROCHA, O., NEGREIROS, N.F., VERANI, J.R. **Influência da integridade ambiental dos afluentes do Rio Monjolinho sobre o fator de condição relativo (Kn) da ictiofauna local.** Biota Neotropica. 15(1): e20140107. http://dx.doi.org/10.1590/1676-06032015010714

Resumo: Os fatores de condição relativo (Kn) de *Astyanax paranae, Phalloceros harpagos* e *Poecilia reticulata* foram utilizados como ferramenta para avaliar a influência da qualidade ambiental sobre o bem estar de sub-populações destas espécies, visando utilizá-las como bioindicadoras de distúrbios em córregos afluentes do rio Monjolinho, no município de São Carlos – SP. A curva potencial gerada pela relação peso-comprimento indicou um crescimento do tipo alométrico positivo para as três espécies estudadas. No geral, a análise de correspondência canônica (CCA) correlacionou positivamente o Kn médio da espécie *A. paranae* com ambientes bem oxigenados e oligotróficos, característicos de áreas preservadas ou próximas do estado natural. Para o valor médio do Kn obtido para a espécie *Phalloceros harpagos,* não ocorreram diferenças significativas entre áreas naturais e perturbadas. Entretanto, a CCA correlacionou positivamente o Kn médio da espécie *Poecilia reticulata* a ambientes impactados, com maior grau de trofia, o que sugere que o fator de condição relativo desta espécie pode ser utilizado como indicador de distúrbios, neste caso, ocasionado pela poluição orgânica.
Palavras-chave: *Biomonitoramento, Fator de condição, relação peso-comprimento, degradação, bioindicadores.*

Introduction

Natural ecosystems have suffered heavily over the last years from the impact of the combined effects of urbanization and other anthropogenic activities resulting from population growth. Many aquatic environments, such as rivers, lakes and reservoirs, which provide essential services to humanity, have undergone a number of changes due to human interference (König et al., 2008). In this context, aquatic communities are constantly exposed to pollution by the large number of compounds released into water bodies from various emission sources, including industrial effluent discharge, domestic sewage, agricultural waste and others (Rashed, 2001). Thereby, the environmental quality or degradation level of these ecosystems may be reflected by their biological communities, which respond differently to the effects of the disturbing agents, providing an indicator to assess the effects of these disorders (Barbour et al., 1999).

The organisms most fequently used in the assessment of the impacts on aquatic ecosystems are the benthic macroinvertebrates, fish and periphyton (Goulart & Callisto, 2003). In ichthyofauna studies, for instance, the parameters usually analyzed in the study of populations are the size and weight of the organisms. The length-weight relationship of fish is an important tool to distinguish aspects of their biology, physiology and ecology, and combined with other quantitative features, such as growth, recruitment and mortality, it provides valuable information about the species structure in an environment (Lizama & Ambrósio, 1999).

Using the relationship between body weight and length, it is possible to derive a parameter that is a measure of wellness, providing information about how the animal takes advantage of the available resources. This parameter, known as the relative condition factor (Kn), is an important and powerful tool to demonstrate changes in the condition of fish over a certain period of time and can be used to indicate nutritional status, environmental changes, the reproductive period, the dietary changes period, the fat accumulation (Le Cren, 1951; Gomiero & Braga, 2003) and parasite infections (Lemos et al., 2007), making it possible to compare populations that are subjected to different climate conditions, water temperature, salinity and density, food availability and other conditions (Lizama & Ambrósio, 2002; Rocha et al., 2005; Rêgo et al., 2008). Under normal conditions, the theoretically expected value of Kn is 1, whereas any event that interferes with the health or welfare of the fish can produce variations in this value.

The improper use of land and natural resources, resulting from urban development without proper planning and agricultural activities in the catchment area of the Monjolinho River have caused large disturbances in the basin, especially in the area of headwaters in the city of São Carlos during the last few decades (Sé, 1992). The accelerated development occurring in areas where these headwaters are located interferes directly with the stability of aquatic ecosystems and, therefore, affects the water quality and aquatic biota across the whole river basin.

The aim of this study was to assess the conditions in the tributary streams of the upper portion of the Monjolinho River system, through chemical, physical and biological analysis, as well as to test the relative condition factor as an indicator of environmental influence on the physiological state of the fish species present in these streams, with a view to using them as indicators of disturbance.

Material and Methods

The Monjolinho River basin covers an area of approximately 275 km^2, at an elevation between 700 and 800 meters above sea level. The greater part of this basin is located in the district of São Carlos city, in the state of São Paulo. The city is located in an area of accelerating urban development and, therefore, of considerable anthropogenic impact. The length of the river is 43.25 km (Sé, 1992).

The stretches used as sampling sites were chosen to include a variety of environmental and anthropogenic influences (natural, rural and urban areas) in several tributaries belonging to the upper portion of the Monjolinho River catchment area. The study area is mapped in Figure 1, with stream names and sampling sites.

A brief description of each site follows:

- Espraiado 1 (21°58′17.5″ S; 47° 52′ 18″ W): Stream stretch in an area of dense and structured native vegetation, closed canopy, legally defined as a preserved area; a reference site for this study.
- Espraiado 2 (21° 58′ 52″ S; 47°52′26″ W). Stream stretch in an area with preserved riparian vegetation near a canalized portion. Both stretches (Espraiado 1 and 2) are located on Federal University of São Carlos land, enclosed in an area covered by cerrado *sensu stricto* and replanted *Eucalyptus* sp. forest.
- Belvedere (21°59′54.3″ S; 47°52′13.9″ W): stretch located in an area with a small fragment of riparian vegetation, but with signs of burning and household waste, as well as earthworks that indicate the expansion of the Belvedere Park neighborhood. The stream is located in an urban development.
- Ponte de Tábua 1 (22°00′32.1″S; 47°51′38.8″W): stretch located in an urban area, near the Sabara Park condominium, with fragments of riparian vegetation and domestic waste collected along the stretch.
- Ponte de Tábua 2 (21°59′35.1″ S; 47°51′43.2″W): stretch located in an urban area; Jardim Veneza and Jardim Munique neighborhoods close to it, without riparian vegetation, with pipe for sewage discharge and grazing animals nearby.
- Canchim stream (21°59′21.4″S; 47°51′14.2″W): stretch located inside Coqueiros Farm, with riparian vegetation and without evidence of household wastes.
- São Rafael (22°00′52″S; 47°51′9.4″W): stretch located close to Jardim Tangará and São Rafael residential neighborhoods and with evidence of disturbance.
- Douradinho (22°00′37″S; 47°50′28.3″W): stretch located inside Santa Joana Farm, characterized by a large forest fragment.

To analyze the sampling stretches, we used the Habitat Diversity Rapid Assessment Protocol described by Callisto et al. (2002), which assesses a set of variables and indicates the degree of conservation of the habitat as: natural (up 60 points), altered (41-60 points) or impacted (0-40 points).

Sampling was conducted in the months of July and August 2013: a metal wire sieve mesh (diameter = 0.75 m, mesh = 3 mm) and a net (0.50 m in diameter) were used to catch the fish fauna, with a sampling effort of one hour in each stretch (approximately 50 meters long). The specimens were fixed in 10% formalin and preserved in 70% alcohol for later identification and biometrics analysis. For taxonomic identification, the specialized bibliography, keys and descriptions available in the literature were used (Britski, 1972 Britski et al., 1999, modified by Casatti et al., 2001; Castro et al., 2004; Oliveira, 2006; Grace & Pavanelli, 2007; Lucinda, 2008), as well as the help of ichthyologists. Species with greater occurrence constancy were selected, according to the criteria of Dajoz (1983), as well as those with higher relative abundance at the collection sites, and the species that were present in the habitats of lowest and highest degradation were taken as references.

For each selected taxon, measurements of standard length (Ls) and fresh weight (Wo) were taken with digital calipers (King Tools) and a precision balance (Marte AS 2000c). These

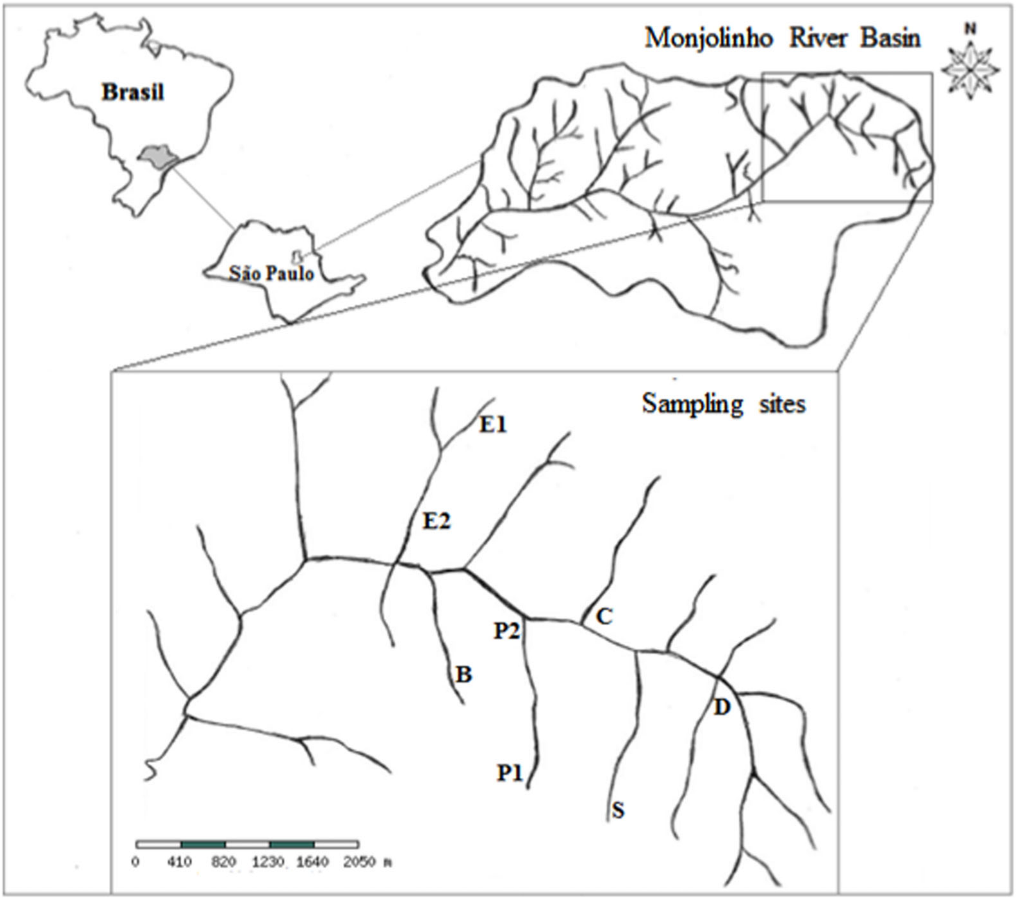

Figure 1. Map showing location of the Monjolinho River basin, São Carlos - SP, with tributary streams indicated. Espraiado (E1 and E2), Belvedere (B), Ponte de Tábua (P1 and P2), Canchim (C), São Rafael (S) and Douradinho.

data were used to fit an overall weight-length curve for each species, by adjusting a and b, the equation $W = a.Ls^b$ (Le Cren, 1951). With the estimated values of coefficients "a" and "b", the theoretical expected weights (We) for the respective values of standard length (Ls) were calculated. The values of the relative condition factor (Kn) calculated by the equation $Kn = Wo/We$ for individuals sampled in each environment, and the Kn data sets for each species and their habitats were compared by the nonparametric Kruskal-Wallis test (complemented by Dunn's test) at a significance level of 5%. Finally, each mean Kn was compared with the hypothetical average ($Kn = 1$) by student's *t*-test (Zar , 2010).

The physical and chemical data: pH, electrical conductivity, dissolved oxygen concentration and water temperature, were measured "*in situ*" with a HORIBA U-10 multiprobe, alongside the water sampling. The inorganic nutrients analyzed were: total phosphorus and nitrogen (Valderrama, 1981), nitrite (Bendchreider & Robinson, 1952, cited by Golterman et al., 1978), nitrate (Mackereth et al. 1978), ammonium (Koroleff 1976, cited by Mackereth et al. 1978) and dissolved total phosphate, organic phosphate and inorganic phosphate (Strickland & Parsons, 1960). Once the nutrient concentrations were established, the trophic state index (TSI) of Carlson (1977) modified by Lamparelli (2004) was calculated, using the total phosphorus concentration.

Canonical correspondence analysis (CCA), followed by a Monte Carlo test, with 999 random permutations, was used to test the existence of significant associations between environmental variables and the relative condition factor of each species, using the program CANOCO 3:12 (Šmilauer & Ter Braak, 2002).

Results

Fishes belonging to eight species, totaling 616 specimens, were collected in the sampled streams, of which *Astyanax paranae* (Eigenmann, 1914), *Phalloceros harpagos* (Lucinda, 2008) and *Poecilia reticulata* (Peters, 1859) were more numerous, both in occurrence (O) and relative abundance (A), than others: *Hypostomus ancistroides* (Ihering, 1911), *Geophagus brasiliensis* (Quoy & Gaimard, 1824), *Rhamdia quelen* (Quoy & Gaimard, 1824), *Gymnotus carapo* (Linnaeus, 1758) and *Hyphessobrycon anisitsi* (Eigenmann, 1907) Table 1. Therefore, the first three were selected for the length-weight relationship and relative condition factor.

The score obtained for the Rapid Assessment Protocol, trophic state index (TSI) and physical and chemical variables are presented in table 2. The highest values for the physical and chemical variables, with the exception of dissolved oxygen, pH and temperature, were recorded in Belvedere stream. The lowest dissolved oxygen concentration was found in this stream too.

The Habitat Diversity Rapid Assessment Protocol classified as natural habitats (N) the Espraiado stream (E1 and E2), as altered streams (A) the Douradinho (D), Canchim (C), Ponte

Table 1. Composition, occurrence (O) and relative abundance (A) of the species collected in tributary streams of the Monjolinho River in the district of São Carlos – SP. Streams: Espraiado (E1 and E2), Douradinho (D), Canchim (C), Belvedere (B), Ponte de Tábua (P) and São Rafael (S).

	Streams									
Species	**E1**	**E2**	**D**	**C**	**B**	**P1**	**P2**	**S**	**O (%)**	**A (%)**
Astyanax paranae	34	34	53	10	-	31	19	-	75	29.4
Poecilia reticulata	-	-	-	-	47	62	32	-	37.5	22.9
Phalloceros harpagos	-	52	40	15	-	61	19	34	75	36.0
Hypostomus ancistroides	-	-	-	1	-	13	21	-	37.5	5.7
Geophagus brasiliensis	-	-	3	-	-	-	5	-	25	1.3
Rhamdia quelen	-	-	-	-	-	-	4	-	12,5	0.6
Gymnotus carapo	-	-	-	-	-	1	5	-	25	1.0
Hyphessobrycon anisitsi	-	-	-	10	-	-	10	-		3.2

de Tábua (P1 and P2) and São Rafael (S), and as impacted stream (I) the Belvedere (B). The value of TSI characterized the Espraiado stream (E1 and E2) as oligotrophic (O), the Douradinho, Canchim, Ponte de Tábua (P1 and P2) and São Rafael streams as mesotrophic (M), and Belvedere stream as eutrophic (E) (Table 2).

The equations obtained for the length-weight relationship for *Astyanax paranae, Phalloceros harpagos* and *Poecilia reticulata* in the streams under study were, respectively, $W = 0.00001399\ Ls^{3.180}$, $W = 0.000003791\ Ls^{3.558}$ and $W = 0.000007636\ Ls^{3.4142}$. The values of the exponents of LS ($b>3$) characterize the growth of the species as positive allometric; therefore, there is a greater than expected increase in weight as the standard length grows (Figure 2).

The data shown in Figure 3 indicate that *Astyanax paranae* showed significantly lower values of the mean the relative condition factor (Kn) in the Ponte de Tábua stream (PT1 and PT2) than in other streams where the species occurred; both in PT1 and PT2, Kn was smaller than 1 (0.94 and 0.95, respectively). The Kn values for the species in Canchim (Kn = 1.05) and Douradinho streams (Kn = 1.03) were significantly higher than 1, suggesting significantly more suitable environmental conditions for this fish than those in sites PT1 and PT2.

In contrast, *Phalloceros harpagos* individuals collected in Douradinho stream were in poor body condition, shown by the low average value of Kn ($p<0.05$) relative to the other streams and the standard Kn (Kn = 1).

The specimens of *Poecilia reticulata* showed a higher Kn value in Belvedere stream than in all the other streams where this species was recorded. Besides being the highest value among all the streams, the average Kn of this species in this stream was significantly higher thant the standard value (Kn = 1) (Figure 3).

In the canonical correspondence analysis (CCA), the first two axes explained 98.5% of the total variability of the data (Figure 4). In general terms, the Belvedere stream (Bvd) was associated with higher nutrient concentrations, environmental disturbance, lower dissolved oxygen and higher abundance of *Poecilia reticulata* individuals. The species *Astyanax paranae* was correlated with natural habitat streams, with low nutrient concentrations and higher dissolved oxygen concentrations. In turn, *Phalloceros harpagos* individuals were associated with altered conditions, as in:

Table 2. Values related to chemical, physical, habitat diversity rapid assessment protocol and trophic state index (TSI) in tributary streams of Monjolinho River, in district of São Carlos – SP. Streams: Espraiado (E1 and E2), Douradinho (D), Canchim (C), Belvedere (B), Ponte de Tábua (P) and São Rafael (S). O – Oligotrophic, M – Mesotrophic, E – Eutrophic, N – Natural, A – Altered and I – Impacted.

Variables	**E1**	**E2**	**D**	**C**	**B**	**P1**	**P2**	**S**
Nitrite ($\mu g.L^{-1}$)	1.4	1.4	1.9	1.4	92.6	2.7	2.1	3.1
Nitrate ($\mu g.L^{-1}$)	11.9	39.3	249.7	18.8	961.4	337.1	163.3	961.4
Ammonium ($\mu g.L^{-1}$)	30.4	35.6	64.1	43.1	692.9	105.3	81.9	60.2
DIN ($mg.L^{-1}$)*	0.04	0.08	0.32	0.06	1.75	0.45	0.25	1.02
Total N ($\mu g.\ L^{-1}$)	206.2	221.2	414.5	134.7	1919.4	604.4	326.5	810.5
Inorganic phosphate ($\mu g.L^{-1}$)	13.3	12.2	11.2	15.3	98.3	11.8	16.5	11.5
Total dissolved P ($\mu g.L^{-1}$)	18.1	17.0	15.5	21.7	119.1	14.6	21.3	15.2
Organic P ($\mu g.L^{-1}$)	4.7	4.8	4.3	6.3	20.9	2.8	4.9	3.7
Total P ($\mu g.L^{-1}$)	19.7	20.2	47.7	36.6	164.8	42.8	41.5	53.6
pH	6.5	6.5	7.4	6.9	6.9	6.9	5.4	6.7
Dissolved Oxygen ($mg.L^{-1}$)	8.1	10.7	8.4	5.7	4.0	5.4	6.5	5.8
Conductivity ($\mu S.cm^{-1}$)	9.7	5.0	39.0	19.0	107.0	42.3	31.3	107.0
Temperature (°C)	17.5	16.5	17.8	20.3	19.4	18.3	18.2	21.7
TSI	49.4	49.6	54.0	52.6	60.5	53.5	53.3	54.6
Classification (TSI)	O	O	M	M	E	M	M	M
Assessment Protocol	83.0	80.0	58.0	59.0	38.0	45.0	46.0	42.0
Classification	N	N	A	A	I	A	A	A

* DIN – Dissolved inorganic Nitrogen

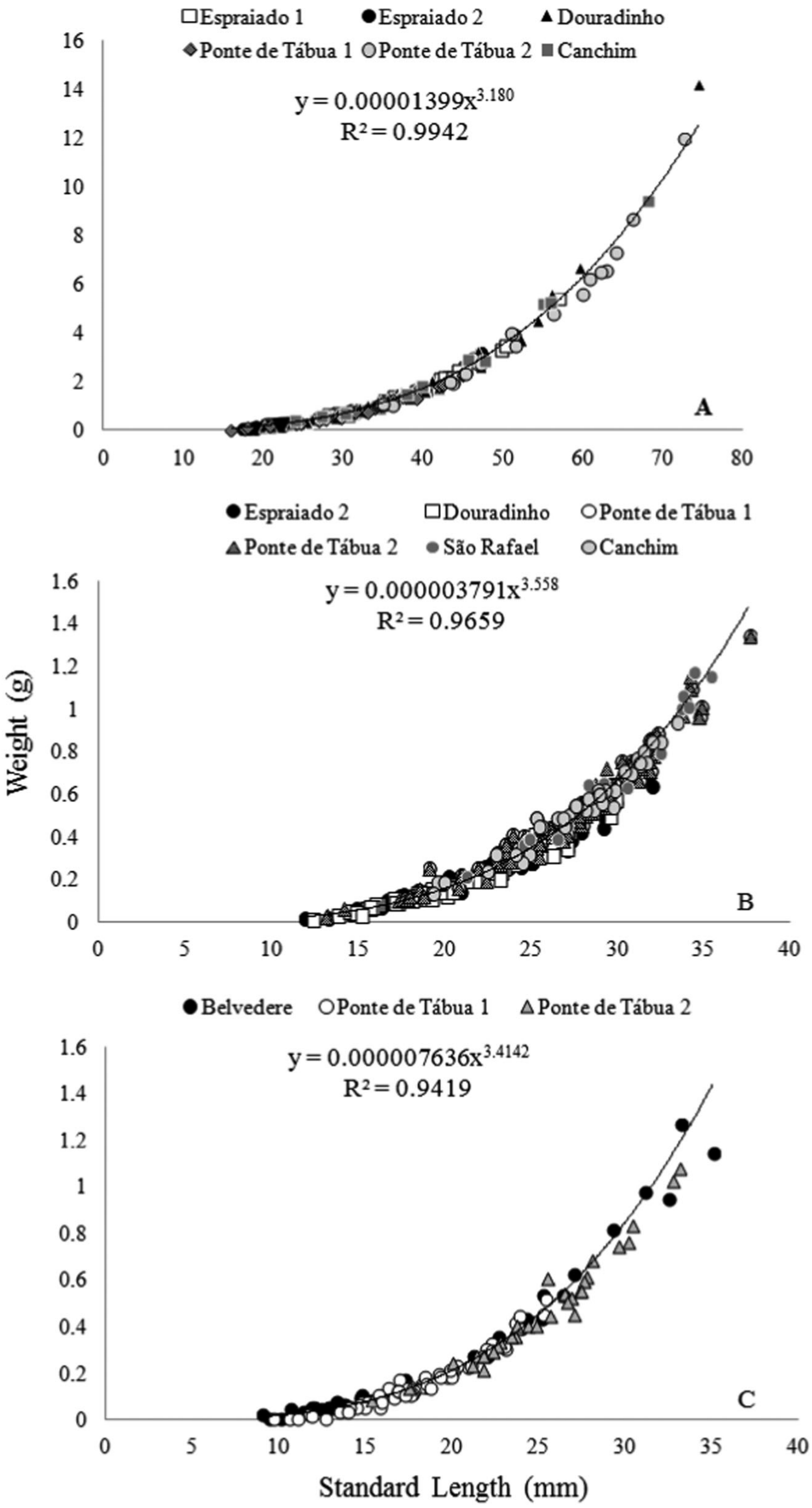

Figure 2. Length-weight relationship of the fish (A) *Astyanax paranae*, (B) *Phalloceros harpagos* and (C) *Poecilia reticulata* in the tributary streams of the upper Monjolinho river streams in São Carlos – SP.

Canchim (Cch), Ponte de Tábua (PT1 and PT2) and São Rafael (SR), but not Douradinho stream. The Monte Carlo test showed that the differences in dissolved oxygen, nitrite and total phosphorus concentrations were significant ($p < 0.05$).

Discussion

The physical and chemical analysis, the Habitat Rapid Assessment Protocol of habitats and the trophic state index indicated a range of sites, from very clean to very impacted.

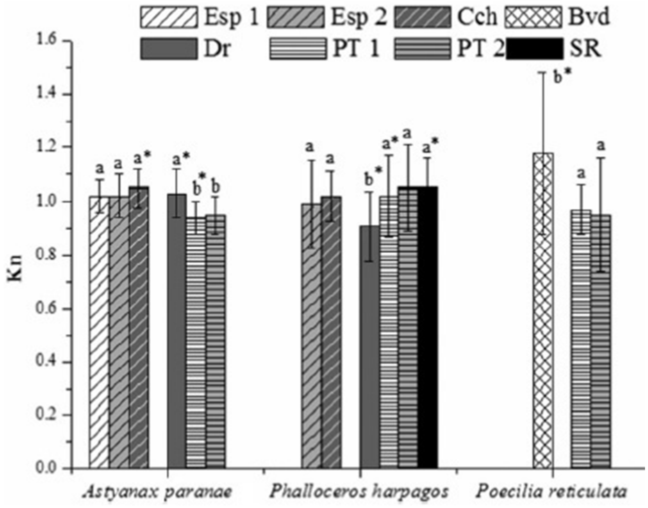

Figure 3. Relative Condition Factor (Kn) of each species in selected tributaries of Monjolinho River (São Carlos – SP) during the dry season: Espraiado (Esp1 and Esp2), Canchim (Cch), Belvedere (Bvd), Douradinho (Dr), Ponte de Tábua (PT1 and PT2) and São Rafael (SR). Different letters represent statistically significant differences between individuals of the same species caught in distinct streams (Kruskal-Wallis test, $p \leq 0.05$, followed by the Dunn multiple comparison test). Same letters correspond to the absence of statistical significance (Kruskal-Wallis, $p > 0.05$). * Statistically different from 1 (Student *t* test, $p \leq 0.05$) in the stream indicated.

Being located in conservation areas, with well structured vegetation and far from pollutant emission sources, Espraiado stream, 1 and 2, have a good environmental quality, with nutrient concentrations below the regional limits for natural systems, according to those described by Tundisi & Matsumura-Tundisi (2008). The Habitat Rapid Assessment Protocol and trophic state index corroborated the improved environmental quality of these stretches, classifying them as natural and oligotrophic environments, respectively. However, these instruments characterized the Canchim, Douradinho, Ponte de Tábua1 and 2 and São Rafael streams as mesotrophic and altered. In all streams except for Espraiado and Canchim streams, the dissolved inorganic nitrogen concentrations (ammonium, nitrite and nitrate) were higher than those found in natural habitats with low human intervention (around 0.12 $mg.L^{-1}$), according to Allan & Castillo (2007).

In Belvedere stream, high nutrient concentrations and electrical conductivity were recorded compared to the other streams. The trophic state index and the Habitat Rapid Assessment Protocol characterized the Belvedere stream as eutrophic and impacted, respectively. Furthermore, evidence of fires was found in the riparian vegetation. These results corroborate those of Souza (2011), who reported, at the same site, a stream that proved to be negatively impacted.

The values of exponent b values for the species studied were within the limits indicated by Vazzoler (1996), ranging from 2.4 to 4.0 for most fish species. According to Verani (1980),

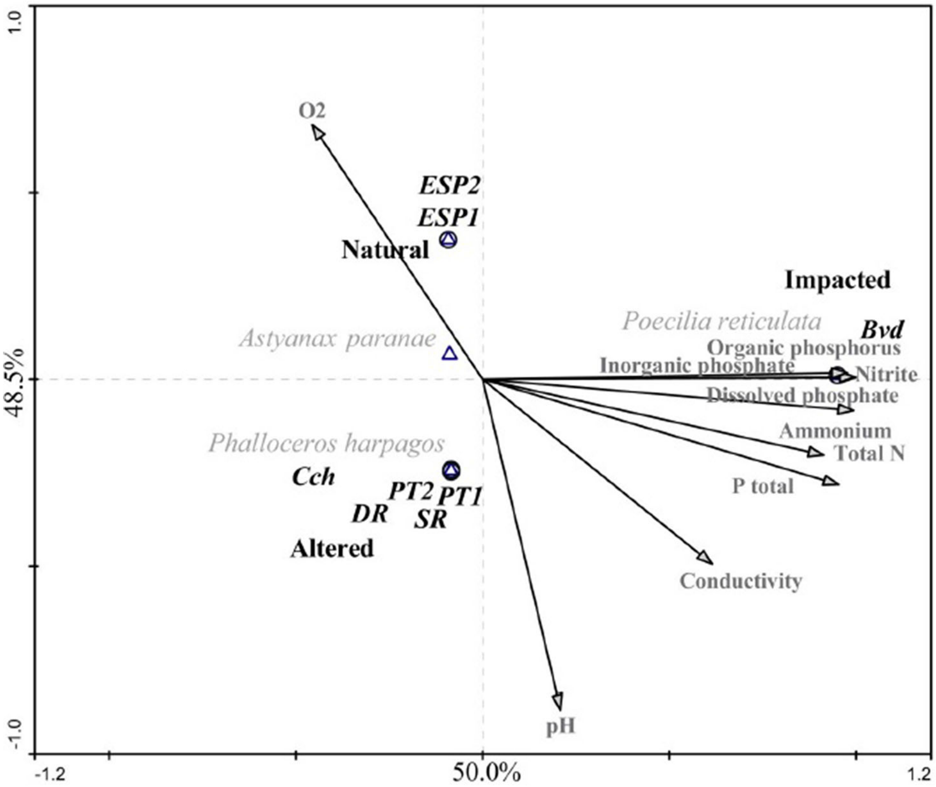

Figure 4. Canonical correspondence analysis (CCA) relating the environmental variables, the relative condition factor of the species *Astyanax paranae, Phalloceros harpagos* and *Poecilia reticulata* and scores in rapid assessment of habitats of tributaries of Monjolinho river (São Carlos – SP), during dry season. Streams: Espraiado (Esp1 and Esp2), Canchim (Cch), Belvedere (Bvd), Douradinho (Dr), Ponte de Tábua (PT1 and PT2) and São Rafael (SR).

variations in this allometric coefficient can be related to environmental conditions and inherent biogenetic features of each species. Thus, the fact that this exponent exceeded 3 indicates that all three species, *Astyanax paranae, Phalloceros harpagos* and *Poecilia reticulata* at the study sites, showed a greater weight gain than predicted during growth, featuring positive allometric growth (Wooton, 1991).

In the CCA the relative condition factor (Kn) showed that *Astyanax paranae* was in good condition in the well-oxygenated and less nutrient environments in Espraiado stream, as noted in stretches 1 and 2. However, there were no significant differences in the Kn values between the stretches classified as natural and oligotrophic and those classified as altered and mesotrophic, except for the Ponte de Tábua stream, stretches 1 and 2, where below average values of Kn were found for this species.

The results found by Lima-Junior (2004) and Orsi (2004) for the species *Astyanax altiparanae* demonstrated a fall in the condition factor at most degraded sites. In contrast, Junior-Martins & Schulz (2001) and Albert et al. (2005) found an increase in Kn for another species of lambari, *Astyanax fasciatus*, in polluted sites. One possible explanation for the higher values of Kn for *Astyanax paranae* found in the subpopulations in Canchim and Douradinho streams, classified as mesotrophic and altered in this study could be that, within certain limits, eutrophication can increase the productivity of an ecosystem (Toledo et al., 1983), in the short term, be beneficial to the species. However, an excessive level of productivity can be harmful because it adversely alters the water quality, causes profound changes in the biogeochemical cycles of aquatic ecosystems and also leads to changes in community structure, destroying the natural balance of the food web (Toledo et al.,1983).

The low Kn values found for the subpopulation in the Ponte de Tábua stream (stretch 1 and 2) may be related to exposure of *Astyanax paranae* to the high nitrite concentrations recorded when compared to those reported in other streams where this species occurred. According to Baldisseroto (2002), nitrite can be toxic to fish, even at low concentrations, because it combines with the blood's hemoglobin, hindering the transport of oxygen and resulting in tissue hypoxia (Jensen & Knudsen, 1997). Even at non-lethal levels, it can cause a weakening of the immune system of some species, leading to reduced growth and lower weight gain (Hanson & Grizzle, 1985).

For *Phalloceros harpagos,* the canonical correspondence analysis (CCA) related the species to environments with moderate levels of pollution, which suggests that it is tolerant to environments with moderate disturbance. The relative condition factor did not differ statistically between environments of different degrees of disturbances except for the subpopulation from Douradinho stream. A similar result was obtained by Araújo et al. (2009) for the population of *Phalloceros caudimaculatus* in the Paraiba do Sul River. The low condition factor obtained for the subpopulation of *P. harpagos* in Douradinho stream was possibly a result of competition with *A. paranae*, which occurs in the same stream and in greater numerical density, and the fact that these species have similar trophic niches and a degree of flexibility that allows them to occupy a range of environments, from moderately impacted areas to nearly natural ones (Orsi, 2004). Thus, according to this author, the fish of this genus (*Astyanax* spp.) can use available resources efficiently and can also compete well in moderately disturbed habitats, which can be seen from the higher Kn value of this species in Douradinho stream compared, to *Phalloceros harpagos*.

Poecilia reticulata was highly correlated with negatively impacted environments, characterized by higher contents of nutrients and low oxygenation of the water. This has already been observed for this species by Lemes & Garutti (2002), Dyer (2003) and Cunico et al. (2006) who reported a high density of this species in impacted streams. According to Oliveira & Bennemann (2005), *Poecilia reticulata* is an exotic species that shows resilience in environments disturbed by human activity, owing to its opportunistic habits and diversified diets. In the present study, the relative condition factor of *P. reticulata* was highest in Belvedere stream, where the most severe conditions of eutrophication were observed, confirming that this species is not affected by poor environmental quality. In general, the species of the order Cyprinodontiformes are more tolerant of environmental degradation and can remain in such sites long after all the other fish disappear (Araújo, 1998; Chapman & Chapman, 1992). According to the authors cited here, the flexibility in the diet and the ability to survive and reproduce in waters with low oxygen facilitate the exploration of the habitat by this fish.

In the streams of the Monjolinho river basin, the varying degrees of environmental quality influenced differently the relative condition factor of the species. *Astyanax paranae* was more sensitive to environments with higher nutrient and oxygen concentrations, while *Phalloceros harpagos* seems to be tolerant, since its condition factor did not differ between environments, with the exception of Douradinho stream, where the Kn value probably reflected the competition for food with *A. paranae*. On the other hand, *P. reticulata* had the highest Kn value in the environment with lowest oxygen and highest nutrient concentrations, suggesting that this species is resistant to disturbed environments. The relative condition factor of fishes, combined with the analysis of environmental conditions, can be a useful tool for studies assessing the environmental quality of streams.

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article

Acanthoceras and *Urosolenia* species (Diatomeae) in subtropical reservoirs from South Brazil: Ultrastructure, distribution and autoecology

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Abstract: *Acanthoceras* Honigmann and *Urosolenia* Round & Crawford *emend.* Rott, Kling & McGregor species were studied based on samples of 19 hydroelectric power plants reservoirs located in the State of Paraná, Southern Brazil. Autoecological informations of *Urosolenia* species complement the study. One *Acanthoceras* and four *Urosolenia* species were identified: *A. zachariasii* (Brun) Simonsen, *U. amazonica* Sala, Núñez-Avellaneda & Vouilloud, *U. eriensis* var. *morsa* (West & G.S.West) Bukhtiyarova, *U. longiseta* Zacharias and *U. obesa* Freire, Tremarin & Ludwig. Morphological variation of frustules was described and illustrated by optical and scanning electron microscopy, and compared with similar species such as *U. delicatissima* Sala, Núñez-Avellaneda & Vouilloud and *U. eriensis* var. *eriensis* (H.L.Smith) Round & Crawford. The pioneer record of *U. amazonica* to Brazil and unprecedent details of the ultrastructure of *A. zachariasii* and *U. longiseta* are included in this study. Cellular densities differed among evaluated reservoirs showing strong correlations with inorganic nitrogen concentrations, N/P ratio and temperature. The results suggested higher densities in periods of warmer temperatures and low availability of the nitrogen compounds and confirmed that species respond strongly to local environmental gradients.
Keywords: *centric diatom, lentic environments, State of Paraná, taxonomy.*

TREMARIN, P.I., FREIRE, E.G., ALGARTE, V.M., LUDWIG, T. **Espécies de *Acanthoceras e Urosolenia* (Diatomeae) em reservatórios subtropicais do sul do Brasil: ultraestrutura, distribuição e autoecologia.** Biota Neotropica. 15(1): e20140043. http://dx.doi.org/10.1590/1676-06032014004314

Resumo: Espécies de *Acanthoceras* Honigmann e *Urosolenia* Round & Crawford *emend.* Rott, Kling & McGregor foram estudadas com base em amostras provenientes de 19 reservatórios de usinas hidrelétricas do estado do Paraná, sul do Brasil. Informações sobre a autoecologia das espécies de *Urosolenia* complementam o estudo. Uma espécie de *Acanthoceras* e quatro de *Urosolenia* foram identificadas: *A. zachariasii* (Brun) Simonsen, *U. amazonica* Sala, Núñez-Avellaneda & Vouilloud, *U. eriensis* var. *morsa* (West & G.S.West) Bukhtiyarova, *U. longiseta* Zacharias e *U. obesa* Freire, Tremarin & Ludwig. A variação morfológica das frústulas foi descrita e ilustrada através de microscopia óptica e eletrônica de varredura e comparada com a de espécies similares, como *U. delicatissima* Sala, Núñez-Avellaneda & Vouilloud e *U. eriensis* var. *eriensis* (H.L.Smith) Round & Crawford. O registro pioneiro de *U. amazonica* para o Brasil e detalhes inéditos da ultraestrutura de *A. zachariasii* e *U. longiseta* estão contemplados neste estudo. As densidades celulares diferiram entre os reservatórios avaliados e mostraram forte correlação com concentrações de nitrogênio inorgânico, relação N/P e temperatura. Os resultados sugeriram densidades mais elevadas em períodos de temperaturas mais quentes e baixa disponibilidade de compostos nitrogenados e confirmaram que as espécies respondem fortemente aos gradientes ambientais locais.
Palavras-chave: *ambientes lênticos, diatomácea cêntrica, estado do Paraná, taxonomia.*

Introduction

Acanthoceras Honigmann and *Urosolenia* Round & Crawford *emend.* Rott, Kling & McGregor are centric diatoms worldwide distributed, occurring primarily in plankton of lentic environments (Rott et al. 2006). These genera are mainly characterized by having open girdle bands, cylindrical or sub-cylindrical frustules, conical to semi-conical valves ornamented or not, calyptra and the presence or not of the seta (Round et al. 1990, Rott et al. 2006). The valves of *Acanthoceras* presents two calyptra while *Urosolenia* have only one (Round et al. 1990).

Detailed research on *Acanthoceras* and *Urosolenia* taxa is difficult to realize due to weakly silicified frustules, which are often destroyed by the usual techniques of cleaning and preservation. This fact may be the reason of so scarce records of these genera. Scanning and transmission electron microscopies have been useful and often essential to distinguish among species, since they enable the visualization of structures indistinguishable in optical microscopy (Morales 2005). Accordingly, identifications of some species performed only with light microscopy should be reviewed (Rott et al. 2006).

Recent studies on *Acanthoceras* and *Urosolenia* were developed by Rott et al. (2006), Sala et al. (2008), Li et al. (2009), Karthick & Kociołek (2011) and Tremarin et al. (2013), with descriptions of eight new species and some new combinations.

Brazilian surveys have found *Acanthoceras zachariasii* (Brun) Simonsen and five taxa of *Urosolenia*: *U. brauni* (Hustedt) Rott & Kling, *U. longiseta* (Zacharias) Edlund & Stoermer, *U. eriensis* (H.L.Smith) Round & Crawford var. *eriensis*, *U. eriensis* var. *morsa* (West & G.S West) Bukhtiyarova and *U. obesa* Freire, Tremarin & Ludwig (Torgan et al. 1999, Rott et al. 2006, Melo et al. 2004, Raupp et al. 2009, Tremarin et al. 2009, Silva et al. 2011, Eskinazi-Leça et al. 2012, Tremarin et al. 2013). Informations about the ultrastructure of *Urosolenia* species found in Brazil are not routinely added to the studies, except for Torgan & Becker (1998) who described the morphology of *U. eriensis* var. *morsa*, and Tremarin et al. (2013) when proposed *U. obesa*.

According to Reynolds et al. (2002), *Urosolenia* are included within functional A-group (centric diatoms) characterized by preferring lakes with clear and often well-mixed water, tolerating nutrients deficiency. Representatives of the genus were detected in shallow Amazonian high-waters stages. In Brazilian subtropical reservoirs, *Urosolenia* species occurred in winter mixed waters (Silva et al. 2005). Ramberg (1987) found *A. zachariasii* and *U. eriensis* during stratification of water column, both disappearing in the mixing period. Edlund & Stoermer (1993) remark that *Acanthoceras* is largely distributed and may be found in alcalin, shallow and eutrophic lakes and rivers from Norh America. *Urosolenia* may occur in highly diverse habitats and in oligotrophic to eutrophic conditions.

Thus, this study aimed to describe the morphology and expand the geographic distribution of *Acanthoceras* and *Urosolenia* species that occurred in plankton from hydropower plants reservoirs in the State of Paraná, Southern Brazil. Also, we identified the environmental factors closer correlated with *Urosolenia* species densities.

Material and methods

For the taxonomic analysis, samplings were carried out quarterly at 19 hydroelectric power plants reservoirs from the State of Paraná, Southern Brazil (Figure 1, Table 1), over four consecutive years (2007–2010), at subsurface (≈ 30 cm depth) and at the limit of the photic zone. A total of 768 phytoplanktonic samples were collected with a van Dorn sampler and were preserved with Lugol's iodine acetic solution (1%) (Bicudo & Menezes 2006). The material was washed with distilled water to prepare permanent slides mounted with Naphrax® (R.I. = 1.74). The specimens found were measured and photographed under Olympus BX40 light microscopy (LM) equipped with Olympus DP71 image capture, using phase contrast (1000x). Some of the material was dried on aluminum stubs and covered with gold and studied using a JEOL JSM 6360LV scanning electron microscopy (SEM), operated at 15 kV and 8 mm working distance, at the Electron Microscopy Center of the Universidade Federal do Paraná. Analyzed

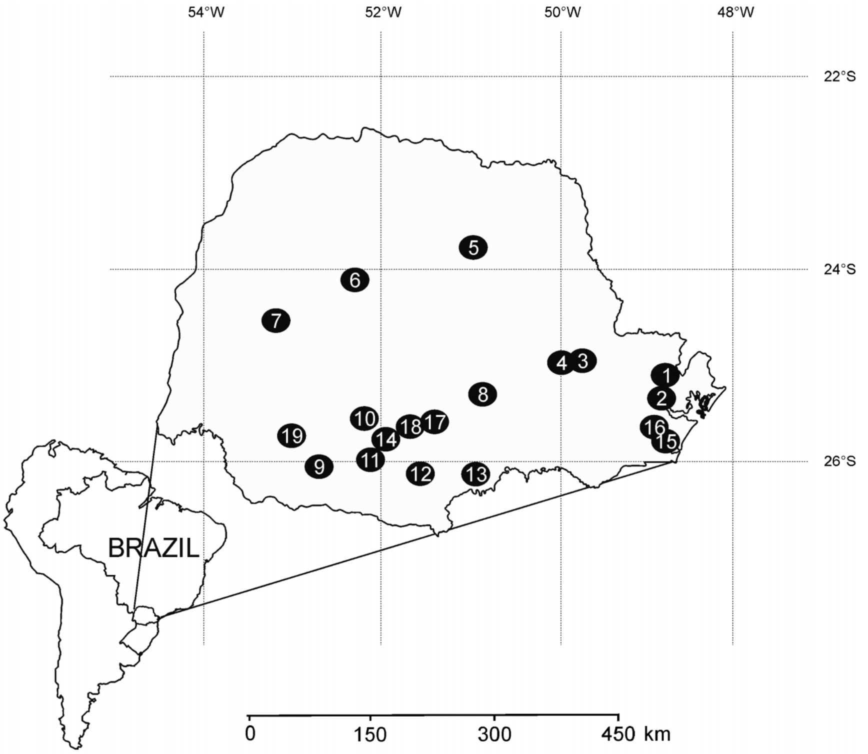


Figure 1. Sampling locations in the State of Paraná, Brazil. Hydroelectric power plants reservoirs: 01– Capivari, 02– Marumbi, 03– São Jorge, 04– Pitangui, 05– Apucaraninha, 06– Mourão, 07– Melissa, 08– Rio dos Patos, 09– Chopim, 10– Cavernoso, 11– Segredo, 12– Foz do Areia, 13– Salto do Vau, 14– Jordão, 15– Chaminé, 16– Guaricana, 17– Fundão, 18– Santa Clara, 19– Salto Caxias.

Table 1. Data of the sampling sites in the State of Paraná and register number in the herbarium of Universidade Federal do Paraná (UPCB).

Reservoir	Station	UPCB/Date	Municipality	Geographic coordinates
Apucaraninha	E2	69524–2007; 60508–2008; 68842–2009; 68866–2010	Tamarana	23°44′56″S/50°56′33″W
Capivari	E2	59525–2007; 60509–2008; 68843–2009; 68867–2010	Antonina	24°59′10″S/48°47′20″W
Cavernoso	E2	59526–2007; 60510–2008; 68844–2009; 68868–2010	Virmond	25°23′49″S/52°11′24″W
Chaminé	E2	59527–2007; 60511–2008; 68845–2009; 68869–2010	São José dos Pinhais	25°41′36″S/49°01′14″W
	E4	59528–2007; 60512–2008; 68846–2009; 68870–2010		
Chopim	E2	59529–2007; 60513–2008; 68847–2009; 68871–2010	Itapejara d'Oeste	25°53′26″S/52°43′05″W
Foz do Areia	E2	59530–2007; 60514–2008; 68848–2009; 68872–2010	Pinhão	26°03′39″S/51°30′09″W
	E3	59531–2007; 60515–2008; 68849–2009; 68873–2010		
	E5	59532–2007; 60516–2008; 68850–2009; 68874–2010		
Fundão	E3	65977–2008; 68864–2009; 68888–2010	Candói	25°32′04″S/51°48′55″W
Guaricana	E2	59533–2007; 60517–2008; 68851–2009; 68875–2010	Guaratuba	25°42′31″S/48°58′18″W
Jordão	E2	59534–2007; 60518–2008; 68852–2009; 68876–2010	Reserva do Iguaçu	25°45′14″S/52°04′54″W
Marumbi	E2	68865–2009; 68889–2010	Morretes	25°25′35″S/48°55′44″W
Melissa	E2	59535–2007; 60519–2008; 68853–2009; 68877–2010	Corbélia	24°32′12"S/53°12′28"W
Mourão	E2	59536–2007; 60520–2008; 68854–2009; 68878–2010	Campo Mourão	24°06′20"S/52°19′42"W
Pitangui	E2	59537–2007; 60521–2008; 68855–2009; 68879–2010	Ponta Grossa	25°01′41"S/50°06′06"W
Rio dos Patos	E2	59538–2007; 60522–2008; 68856–2009; 68880–2010	Prudentópolis	25°10′37"S/50°56′29"W
Salto Caxias	E3	59539–2007; 60523–2008; 68857–2009; 68881–2010	Capitão Leônidas Marques	25°32′43"S/ 53°06′05"W
	E5	59540–2007; 60524–2008; 68858–2009; 68882–2010		
Salto do Vau	E2	59541–2007; 60525–2008; 68859–2009; 68883–2010	União da Vitória	25°58′50"S/51°43′14"W
Santa Clara	E3	65976–2008; 68863–2009; 68887–2010	Candói	25°39′14"S/51°54′26"W
São Jorge	E2	59542–2007; 60526–2008; 68860–2009; 68884–2010	Ponta Grossa	24°59′45″S/49°59′39″W
Segredo	E2	59543–2007; 60527–2008; 68861–2009; 68885–2010	Mangueirinha	26°00′47″S/51°52′43″W
	E3	59544–2007; 60528–2008; 68862–2009; 68886–2010		

Source: Ribeiro et al. (2006).

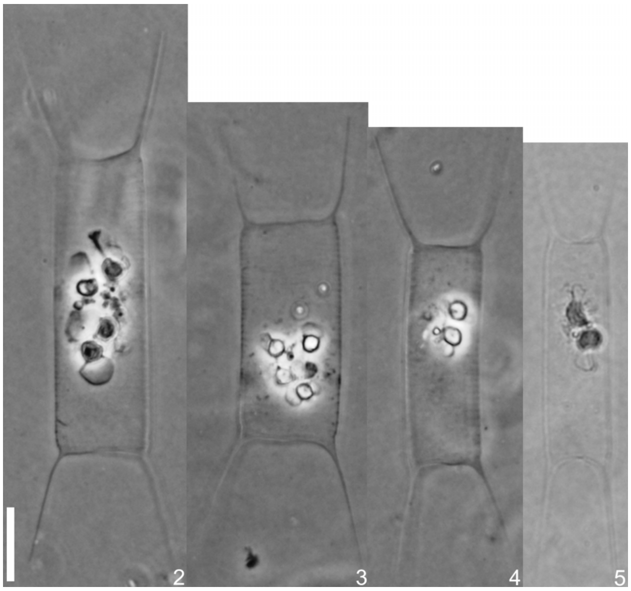
samples (2007–2010) were stored in the Herbarium of the Universidade Federal do Paraná (UPCB). The terminology used in the description of species was based on Round et al. (1990) and Rott et al. (2006).

For the quantitative and ecological analysis, samplings were carried out quarterly over six consecutive years (2007–2012). *Urosolenia* quantification was performed in Ütermohl' chambers (1958) under Olympus IX70 inverted microscope at a magnification of 600 x, enumerated in random fields (Uhelinger 1964) and followed the stabilization curve of the number of species. Sedimentation time of the samples was carried out according to Lund et al. (1958). The physical and chemical analyses (Table 2) were performed by the technical staff of the Instituto de Tecnologia para o Desenvolvimento (LACTEC) following the Standard Methods (APHA 1989).

Environmental data were summarized by a principal component analysis (PCA, Legendre & Legendre 1998) with log transformed and standardized variables. The selection of the axes for the interpretation of the results followed the Broken Stick criteria (Jackson 1993). Spearman rank correlation coefficients were used to measure the degree of association between the densities of *Urosolenia amazonica*, *U. longiseta* and

Table 2. Physical and chemical characteristics of the sampling stations (mean values among sampling periods).

	Apucaraninha (n=4)	**Capivari (n=3)**	**Chaminé (n=20)**	**Fundão (n=4)**	**Guaricana (n=20)**	**Jordão (n=10)**	**Mourão (n=9)**	**Pitangui (n=18)**	**Rio dos Patos (n=6)**	**Salto Caxias (n=2)**	**Santa Clara (n=6)**	**Segredo (n=14)**	**São Jorge (n=14)**
Dam depth	9.75	13	13.5	38.5	8.06	58.6	12.11	2.86	3.5	56.5	43.83	46.25	7.6
Secchi (m)	1.66	2.36	1.84	1.37	1.41	1.52	1.37	0.74	0.41	2.1	1.47	1.44	0.84
Water temperature (°C)	20.1	19.13	20.99	23.68	20.58	22.06	22.66	19.25	17.75	20.25	24.06	20.65	20.88
Dissolved oxygen ($mg.L^{-1}$)	7.6	5.16	6.9	7.9	8.19	6.68	6.49	7.47	7.21	7.8	7.67	6.58	7.24
pH	7.32	7.4	7.66	7.25	7.52	6.89	7.37	7.52	7.13	7.35	7.25	7.17	7.89
Conductivity ($\mu S.cm^{-1}$)	31.75	70.33	43.12	28.75	25.75	26.7	26.88	48.05	51.5	44.5	31.16	49.14	51.5
Total phosphorus ($mg.L^{-1}$)	0.015	0.013	0.017	0.02	0.024	0.015	0.015	0.043	0.061	0.015	0.018	0.024	0.034
$N\text{-}NO3^{-}(mg.L^{-1})$	0.097	0.263	0.091	0.37	0.088	0.414	0.186	0.157	0.575	0.67	0.355	0.745	0.097
Total inorganic nitrogen ($mg.L^{-1}$)	0.2	0.393	0.21	0.482	0.189	0.525	0.295	0.31	0.763	0.78	0.468	0.858	0.192
Total Nitrogen ($mg.L^{-1}$)	0.762	1.45	0.875	0.662	0.82	0.99	0.916	0.816	1.52	2.3	0.825	1.182	0.73
Turbidity (NTU)	6.25	3	3.25	6.75	4.4	5.9	9.44	9.61	26.16	6.5	5.5	7.57	10.65
N/P Ratio	129.6	231.7	146.9	94.7	98.07	171.8	185.3	46.19	56.8	463.5	128.7	120.5	58
Water retention time	14	107	121	4	12	10	53	2	2	31	48	45	43
Classification	lentic-lotic	lentic	lentic	lotic	lentic-lotic	lentic-lotic	lentic	lotic	lotic	lentic-lotic	lentic	lentic	lentic



Figures 2–5. *Acanthoceras zachariasii*. LM. Scale: 10 µm.

U. obesa and abiotic variables. The relationship between the environmental variables and the density of three species of *Urosolenia* was evaluated by means of stepwise multiple regression analysis. The method consists of starting with a single predictor variable and then adding variables one at a time until the addition of further variables does not produce an appreciable increase in the coefficient of determination (Sokal & Rohlf 1981). Except for pH, other variables were log–transformed. Data distribution and multicollinearity among the abiotic factors were checked before performing the analysis (Zar 2010). The principal component analysis (PCA), Spearman correlations and multiple regressions were carried out respectively using PC-ORD (McCune & Mefford 1999) and STATISTICA (StatSoft 2005).

The autoecology of *Urosolenia* species was performed with the taxa that present densities >3 cells.mL^{-1} in the quantitative analysis (*U. amazonica, U. longiseta* and *U. obesa*) and only with reservoirs that have had regular sampling of physical and chemical data.

Results and discussion

Five taxa were identified in the qualitative analysis: *A. zachariasii, U. amazonica, U. eriensis* var. *morsa*, *U. longiseta* and *U. obesa*. The taxa occurred in 15 of the 19 reservoirs (except for Cavernoso, Chopim, Marumbi and Melissa reservoirs). Specimens of *Acanthoceras* and *Urosolenia* were registered in 12% of analyzed samples, being *Urosolenia amazonica* present in 87% of these samples, followed by *U. obesa* (80%), *U. longiseta* (60%), *U. eriensis* var. *morsa* (16%) and *A. zachariasii* (10%).

Acanthoceras zachariasii (Brun) Simonsen, Bacillaria 2: 55, 1979.

Basionym: *Attheya zachariasii* Brun, Forschungsberichte aus der Biologischen Station zu Plön 2: 53, pl. 1, fig. 11, 1894.

Synonyms: *Acanthoceras magdeburgense* Honigmann, Archiv für Hydrobiologie und Planktonkunde 5: 77, pl. 2, fig. a, 1910.

Acanthoceras magdeburgense var. *lata* Honigmann, Archiv für Hydrobiologie und Planktonkunde 5: 78, pl. 2, fig. b, 1910.

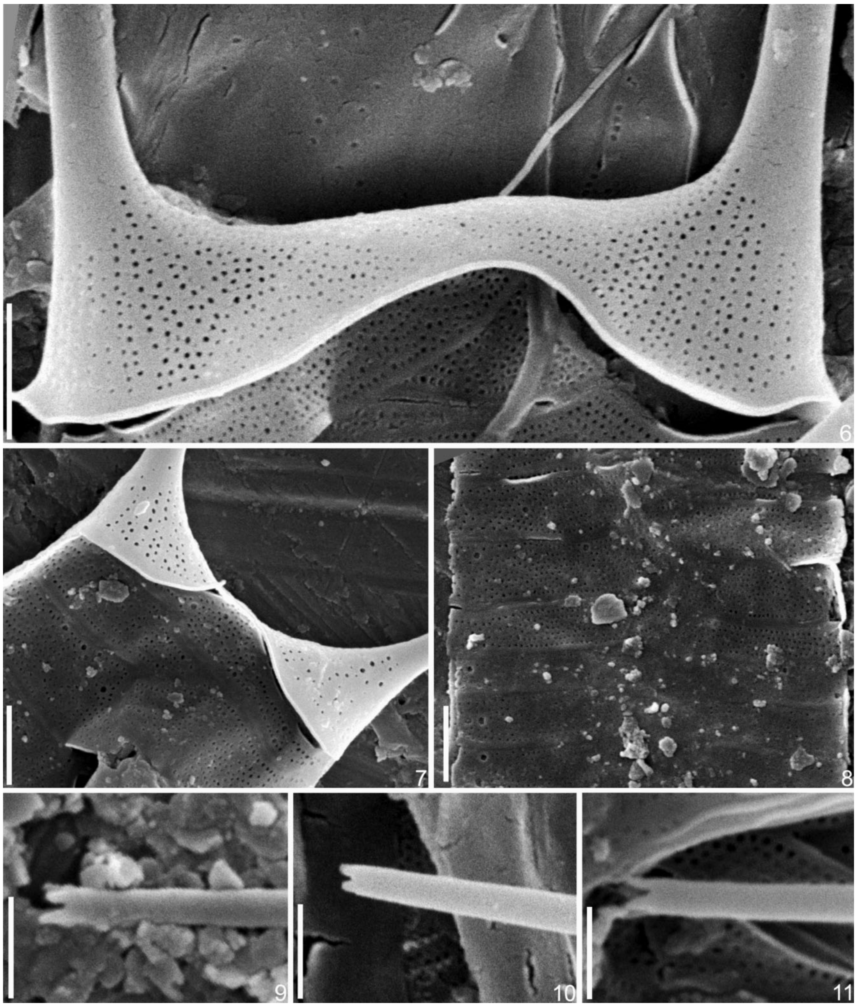
Rhizosolenia eriensis var. *zachariasii* (Brun) Playfair, Proceedings of the Linnean Society of New South Wales 37(3): p. 538; pl. 56, fig. 33–35, 1913.

Frustules solitary, subcylindrical, straight, 56.5–73.4 µm total long, 6.1–13.5 µm width (Figures 2–5). Valve face straight with conical apices, ornamented with round to irregular areolae, 50–55 in 10 µm, arranged in rows and extending onto the calyptra base (Figures 6, 7). Valve mantle edge surrounded by a thin hyaline margin (Figure 7). Calyptra straight, positioned in the valve apices, 14.9–17.8 µm long, positioned at right to strongly oblique angle with the pervalvar axis. Tip of spine-like extension with four small teeth (Figures 9–11). Terminal seta not observed. Cingulum with several semi-circular open and narrow bands, 9–14 in 10 µm, perforated by round poroids, ca. 7 in 1 µm (Figure 8). Bands of the median region of frustule perforated by a few poroids, scarcely distributed. Coarser rounded pores, varying in size and number, present on the girdle bands (Figure 8). Two to four discoid to plate-like chloroplasts per cell (Figures 2–5).

The genus *Acanthoceras* was proposed by Honigmann (1910) when describing *A. magdeburgense* Honigmann, a later synonym of *Attheya zachariasii* Brun. The name *Acanthoceras* had already been proposed by Kützing (1842) for a red alga genus currently considered a later homonym of *Ceramium* Roth (Edlund & Wynne 1996). Since the name *Acanthoceras* Kützing was not in use and that *Acanthoceras* Honigmann was reported for a diatom, Edlund & Wynne (1996) suggested the conservation of the name *Acanthoceras* that was recommended by the Committee for Algae (see Compère 1999).

Although the ultrastructure of *Acanthoceras zachariasii* has been illustrated and described by Round et al. (1990) and the morphology of its resting spores analyzed by Edlund & Stoermer (1993), some taxonomically important details on the frustule morphology of this species remained unknown. The number of calyptra teeth and density of poroids in the girdle bands are recorded for the first time in this study.

The specimens of *Acanthoceras zachariasii* from Brazilian reservoirs showed smaller individuals than the type material of the species, but they were similar to other studied specimens, with intermediate sizes, as can be seen on Table 3. The Brazilian material has smaller calyptra length and higher number of girdle bands when compared with materials analyzed by Huber-Pestalozzi (1942), Rivera (1974), Shirata & Valente-Moreira (1987) and Ferrario et al. (1992) (Table 3). There are few records of the metric variation of *A. zachariasii.* Rivera (1974) remarked that the number of bands is not a constant feature in *A. zachariasii*, so we believe that the specimens analyzed in our study represent an extreme of the population and would not justify the proposition of a new taxon. Anyway, it is necessary to analyze the type material of *A. zachariasii*, especially in SEM, to study the fine ornamentation of the frustules (ex. calyptra teeth, details of the valve, calyptra and bands), for comparison among different populations. However, we advise on this difficult task, given the frequent and fast disappearing of *Acanthoceras* individuals in the stored samples. The low silicified frustules of *Acanthoceras*, as well as *Urosolenia*, do not resist long time in chemical preserved samples (Tremarin et al. 2013).



Figures 6–11. *Acanthoceras zachariasii*. SEM. Figs 6–7. Valve surface. Scales: 2 µm. Fig. 8. Girdle bands in the median region of frustule. Scale: 2 µm. Figs 9–11. Teeth of the calyptra. Scales: 1 µm.

Table 3. Morphometric features of *Acanthoceras zachariasii* var. *zachariasii* and *A. zachariasii* var. *curvata.*

	A. zachariasii* var. *zachariasii						***A. zachariasii* var. *curvata***
Reference	this study	Brun (1874)	Huber-Pestalozzi (1942)	Rivera (1974)	Shirata & Valente-Moreira (1987)	Ferrario et al. (1992)	Rivera (1974)
Total frustule length (µm)	56.5–73.4	...	12–100	...	...	...	...
Frustule length (µm)	29.1–39.7	60–100	...	42–86	31–45.6	20–36	43–90
Frustule width (µm)	6.1–13.5	15–20	15–25	8.5–17	9.7–18.1	11–12	8–11
Calyptra length (µm)	14.9–17.8	...	40–70	24–32	18.6–30.1	20–25	20–30
Girdle bands (in 10 µm)	9–14	...	3.4–4	4–6	...	4–4.5	4.5–5
Porous of the bands (in 1 µm)	7	...	...	...	...	...	...
Teeth of the calyptra	4	...	...	...	...	...	...
Country	Brazil	Germany	Switzerland and Germany	Chile	Brazil	Argentina	Chile

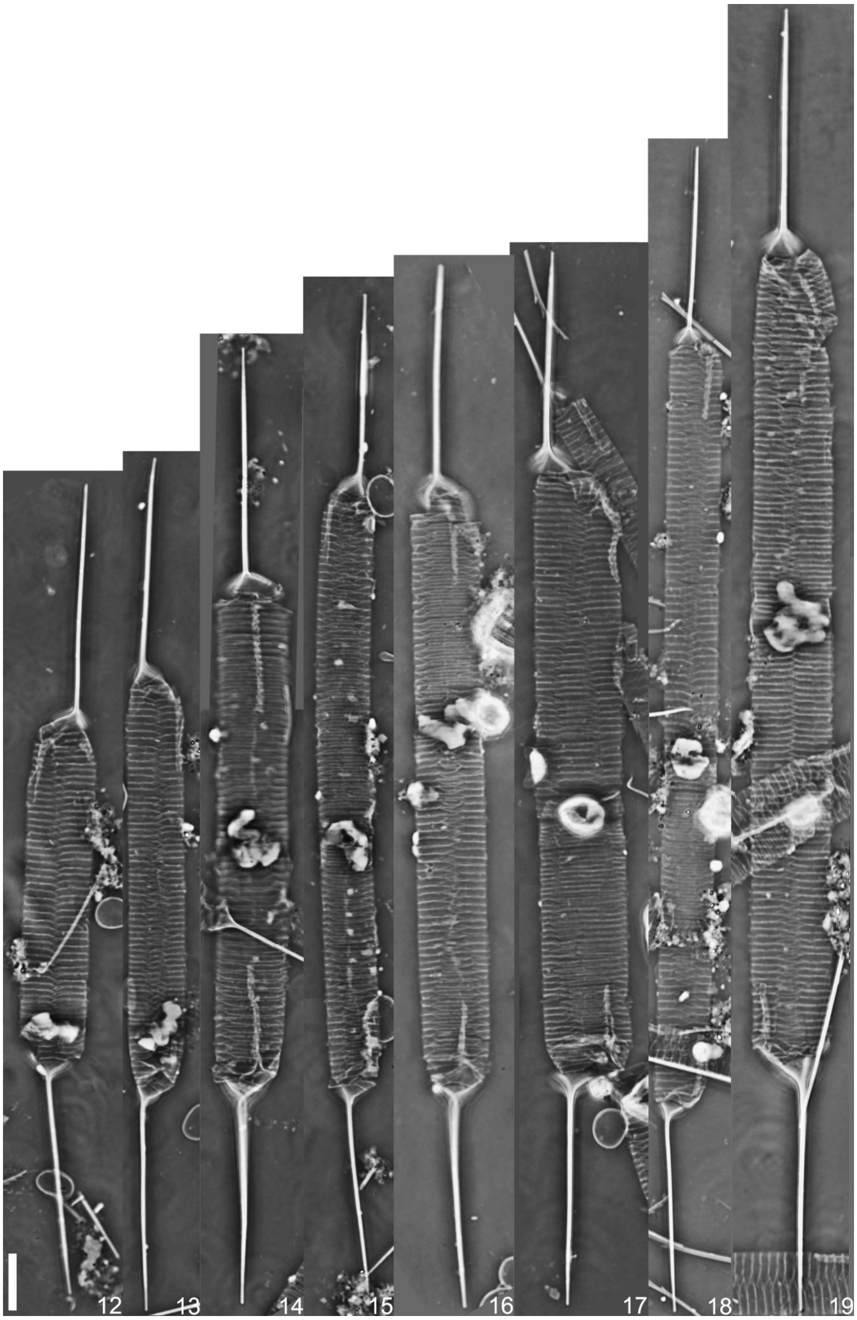
The species has only one variety, *Acanthoceras zachariasii* var. *curvata* Rivera, proposed by Rivera (1974) based on the frustule curvature in relation to the pervalvar axis.

Acanthoceras zachariasii is a freshwater taxon, worldwide distributed, recorded to Germany, Australia, Switzerland, Sweden, Finland, Russia, United States, Chile, Argentina and Brazil (Brun 1874, Hustedt 1930, Cleve-Euler 1951, Rivera 1974, Shirata & Valente-Moreira 1987, Ferrario et al. 1992, Edlund & Stoermer 1993, Medvedeva et al. 2009).

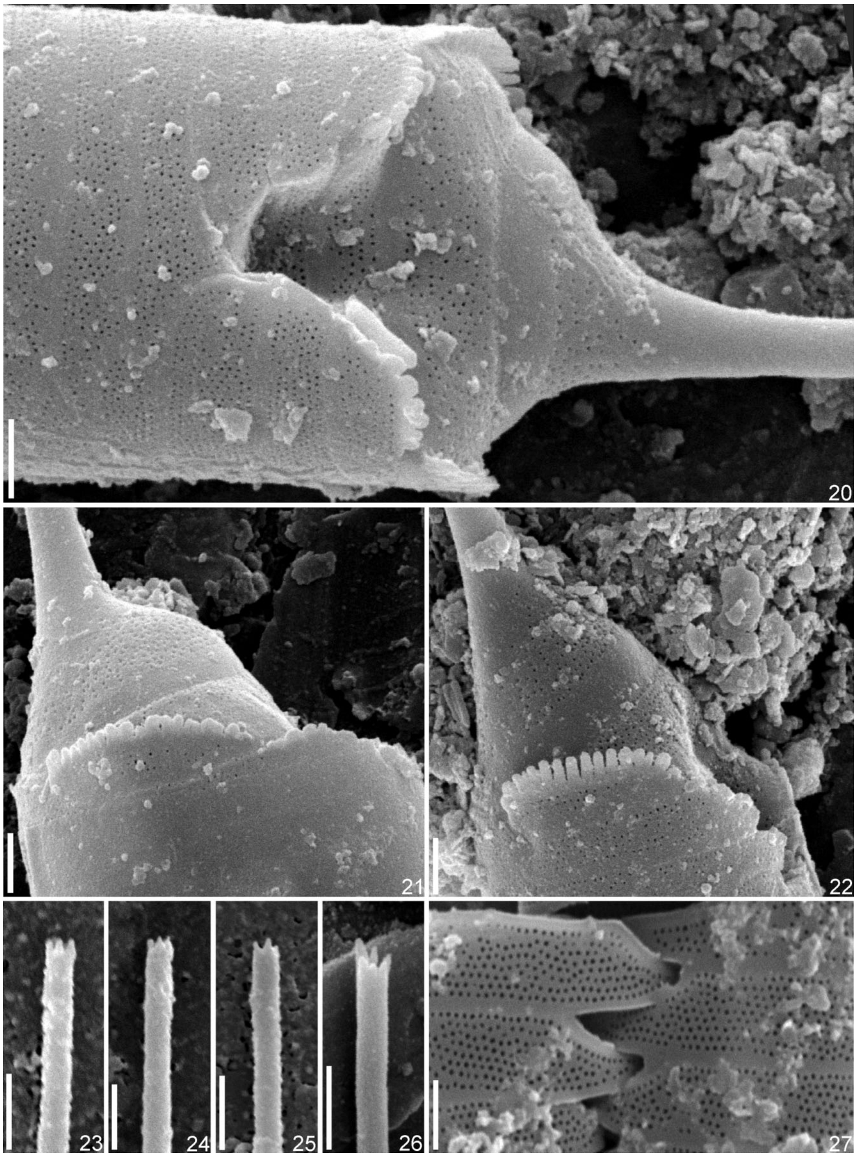
Occurrence in samples (UPCB) – São Jorge reservoir 68884; Pitangui reservoir 68879.

Urosolenia amazonica Sala, Núñez-Avellaneda & Vouilloud, Diatom Research 23(1): 164, pl. 1, figs 1–9, 2008.

Frustules solitary or in pairs, cylindrical, straight, 78–194 µm total long, 7.2–12.8 µm width (Figures 12–19). Valve face conical, 2.4–5.4 length, ornamented with rounded areolae 7–9 in 1 µm, randomly arranged and extending onto the calyptra base (Figures 20-22). Valve mantle edge surrounded by a thin hyaline margin (Figures 21, 22). Calyptra straight and eccentric, 24.8–38.2 µm long, positioned at right to slightly oblique angle with the pervalvar axis. Tip of spine-like extension with 4–6 small teeth (Figures 23–26). Terminal seta not observed. Cingulum with several semi-circular open and narrow bands, 8–11 in 10 µm, perforated by round poroids, ca. 7–10 in 1 µm (Figure 27). Valvocopula wider than the other bands, with poroids irregularly distributed and serrated margin (Figures 20, 22).



Figures 12–19. *Urosolenia amazonica*, LM. Scale: 10 µm.



Figures 20–27. *Urosolenia amazonica*, SEM, external view. Fig. 20. Aspect of valve and the insertion site of the calyptra of adjacent cell. Scale: 1 μm. Figs 21, 22. Overview of valve. Note the serrated valvocopulae. Scales: 1 μm. Figs 23–26. Detail of calyptra teeth. Scales: 1 μm. Fig. 27. Detail of girdle bands showing the poroids and imbrication line in the median region of frustule. Scale: 1 μm.

Urosolenia amazonica is similar to *U. eriensis* var. *eriensis*, mainly by the dimensions and shape of frustules, but differs by higher number of girdle bands and valvocopula with serrate margin (Table 4) (Huber-Pestalozzi 1942, Krammer & Lange-Bertalot 1991, Sala et al. 2008). The absence of more detailed features of *U. eriensis* var. *eriensis*, as number of calyptra teeth, calyptra length and density of poroids in the bands, difficult a more precise comparison between the two species.

Urosolenia eriensis var. *morsa* is very similar to *U. amazonica* in light microscopy. However, the former may have larger valves and valvocopulae with smooth edge (Huber-Pestalozzi 1942, Krammer & Lange-Bertalot 1991, Torgan & Becker 1998). Furthermore, *Urosolenia eriensis* var. *morsa* have three teeth in the calyptra as documented by Torgan & Becker (1998) (Table 4). We believe that some Brazilian exemplars recorded as *U. eriensis* var. *morsa* in previous studies may be *U. amazonica*, due to the similarities between the species in light microscopy.

We found some exemplars of *U. amazonica* with longer total length of frustule and smaller valve length than that reported by Sala et al. (2008) (Table 4), but the valvocopulae serrate and calyptra teeth were always present in the observed specimens.

Urosolenia amazonica was proposed based on material from the Colombian and Peruvian Amazon (Sala et al. 2008), with no subsequent records. Thus, this is the first citation of the species in Brazil.

Occurrence in samples (UPCB) – Apucaraninha reservoir 59524, 60508, 68842; Guaricana reservoir 59533, 60517, 68875, 68875; São Jorge reservoir 59542, 60526, 68860, 68884; Pitangui reservoir 59537, 60521, 68855, 68879; Fundão reservoir 68864, 68888; Foz do Areia reservoir 60515, 60516, 60517, 68872, 68874; Santa Clara reservoir 68863, 68887; Jordão reservoir 59520, 68852, 68876; Segredo reservoir 59543, 59544, 60527, 60528, 68861, 68862, 68885, 68886; Salto Caxias reservoir 68857, 68858, 68881, 68882; Mourão reservoir 59536, 60520,

Table 4. Morphometric and morphological variation of *Urosolenia amazonica* and related taxa.

	U. amazonica		***U. erienses* var. *eriensis***		***U. eriensis* var. *morsa***	
Reference	this study	Sala et al. (2008)	Krammer & Lange- Bertalot (1991)	Huber-Pestalozzi (1942)	Huber-Pestalozzi (1942), Krammer & Lange-Bertalot (1991)	Torgan & Becker (1998)
Total frustule length (µm)	78–194	76–120	40-150	40–150	80–135*	…
Frustule width (µm)	7.2–12.8	6–18	6–15	6–15	5–20	6.0–12.0
Frustule length (µm)	32.8–118.8	…	…	…	40–68	40–84
Girdle bands (in 10 µm)	8–11	8–16	3–4	3–4	6–9	5–10(12)
Porous in the bands (in 1 µm)	7–10	7–14	…	…	…	7–9
Calyptra length (µm)	24.8–38.2	27–48	…	28–38	22–36	22–45
Valve length (µm)	2.4–5.4	3–9.5	…	2–15	5–20	6–12
Teeth in the calyptra	4–6	4–6	…	…	…	2+ligula*
Valvocopula	serrate	serrate	…	…	…	smooth*

* data measured or observed in the illustrations.

68854; Chaminé reservoir 59527, 59528, 60511, 60512, 68845, 68846, 68869, 68870; Rio dos Patos reservoir 68856, 68880.

Urosolenia eriensis* var. *morsa (West & G. S. West) Bukhtiyarova, Algologia 5(4): 417, 1995.

Basionym: *Rhizosolenia eriensis* var. *morsa* W. & G. S. West, Transactions of the Royal Society of Edinburgh 41(3): 509, pl. 6, fig. 23, 1905.

Synonyms: *Rhizosolenia morsa* (W. & G. S. West) W. & G.S. West, Transactions of the Royal Irish Academy 33: 109, pl. 11, fig. 5, 1906.

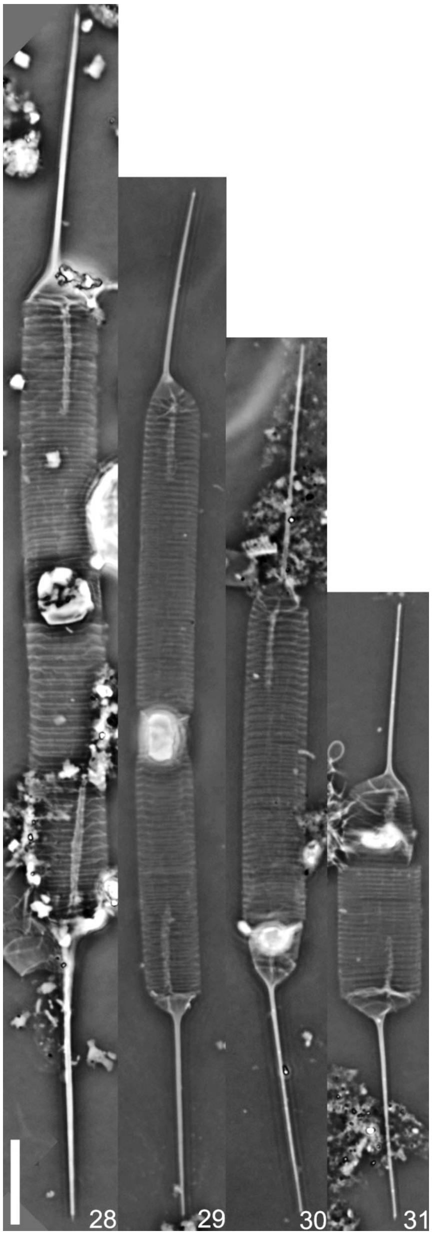
Urosolenia eriensis var. *morsa* (W. West & G. S. West) Torgan in Torgan & Becker, Iheringia, Série Botânica 50: 90; figs 2–9, 1998.

Frustules solitary or in pairs, cylindrical, straight, 73.1–143.4 µm total long, 6.9–20.3 µm width (Figures 28–31). Valve face conical, 3.8–7.6 length, ornamented with rounded areolae 7–10 in 1 µm, randomly arranged and extending onto the calyptra base (Figures 32–34). Valve mantle edge surrounded by a thin hyaline margin (Figure 33, 34). Calyptra straight and eccentric, 22.4–35.5 µm long, positioned at right to slightly oblique angle with the pervalvar axis. Tip of calyptra with 2-3 small teeth and one ligula (Figures 36–38). Terminal seta not observed. Cingulum with several semi-circular open and narrow bands, 7–11(18) in 10 µm, perforated by round poroids, ca. 8–9 in 1 µm (Figure 35). Valvocopula wider than the other bands, with poroids irregularly distributed and smooth margin (Figures 32, 34).

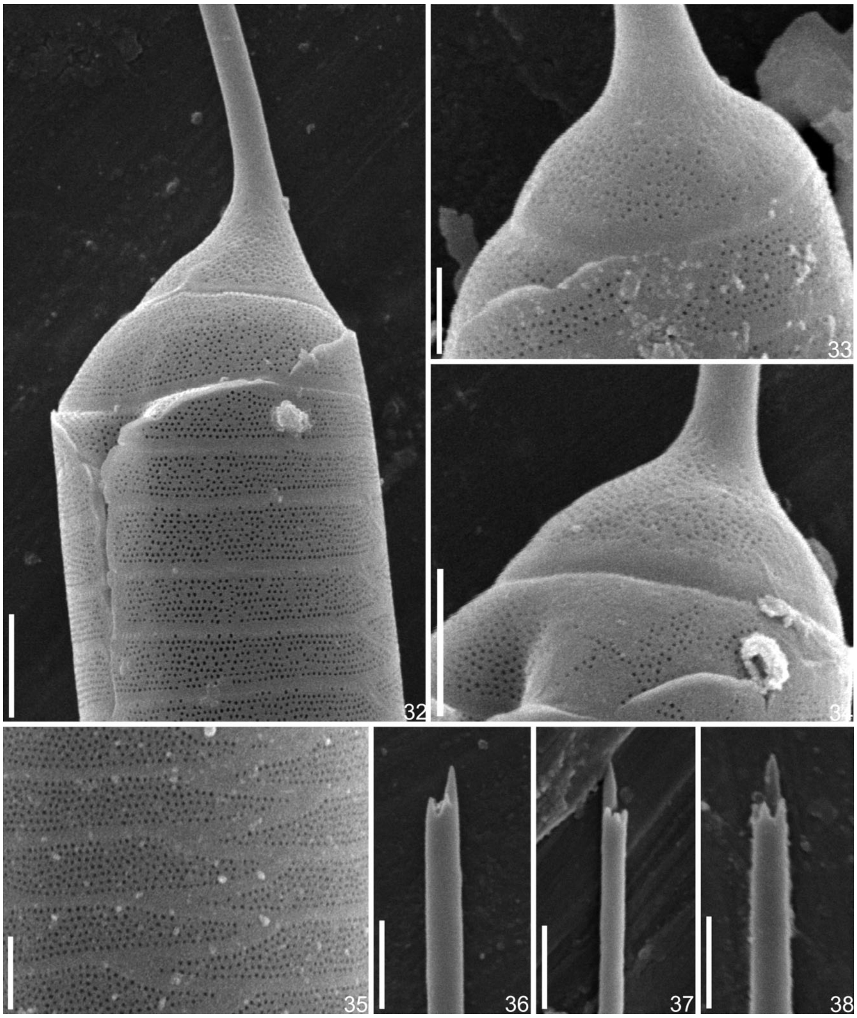
The ultrastructure of *U. eriensis* var. *morsa* was documented by Torgan & Becker (1998), based on samples from Patos lagoon, Southern Brazil. The illustrations show the similarities with the material from the State of Paraná, except by the number of teeth in the calyptra apex. We found exemplars with 2 or 3 teeth and one ligula, while Torgan & Becker (1998) recorded only 2 teeth and the ligula.

Urosolenia eriensis var. *morsa* differs from the typical variety of species by higher number of girdle bands (Table 4) (Huber-Pestalozzi 1942, Krammer & Lange-Bertalot 1991, Torgan & Becker 1998). *Urosolenia eriensis* var. *morsa* was found in countries such as Britain, New Zealand, Russia and Brazil (Medvedeva et al. 2009, Tremarin et al. 2009, Guiry & Guiry 2014).

Few specimens of *U. eriensis* var. *morsa* were found in Brazilian reservoirs samples, and occur together with *U. amazonica*.



Figures 28–31. *Urosolenia eriensis* var. *morsa*, LM. Scale: 10 µm.



Figures 32–38. *Urosolenia eriensis* var. *morsa*, SEM. Fig. 32. External view of frustule showing the insertion site of the calyptra of adjacent cell. Scale: 2 µm. Figs 33, 34. Aspect of valve in external view and valvocopulae. Scales: 1 µm and 2 µm, respectively. Fig. 35. Detail of girdle bands showing the poroids and imbrication line. Scale: 1 µm. Figs 36–38. Detail of calyptra teeth. Scales: 1 µm.

Occurrence in samples (UPCB) – Chaminé reservoir 68845, 68846; Guaricana reservoir 59533; São Jorge reservoir 60526.

Urosolenia longiseta (Zacharias) Edlund & Stoermer, Journal of Paleolimnology 9(1): 59, pl. 1, figs 5–6, 1993.

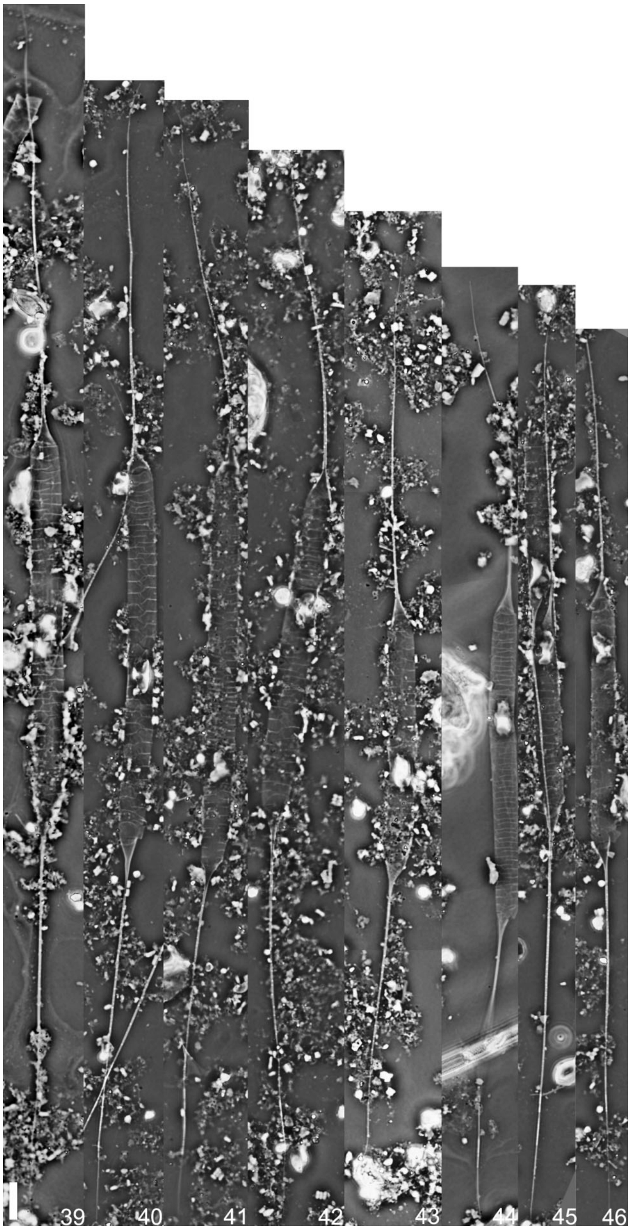
Basionym: *Rhizosolenia longiseta* Zacharias, Forschungsberichte aus der Biologischen Station zu Plön 1: 38; fig. 7, 1893.

Synonym: *Urosolenia longiseta* (Zacharias) Bukhtiyarova, Algologia 5(4): 417, 1995.

Frustules solitary, cylindrical, straight to slightly curved, 216–273 µm total long, 5.8–8.5 µm width (Figures 39–46). Valve face conical, 2.4–5.4 µm length, ornamented with rounded to elongate areolae, 6–8 in 1 µm, arranged in almost linear pattern and extending onto the calyptra base (Figures 47, 48). Valve mantle edge surrounded by a thin hyaline margin (Figure 47). Calyptra straight and central, 64–100 µm long, positioned at right to slightly oblique angle with the pervalvar axis. Tip of calyptra with 3–4 small teeth (Figures 51–55). Terminal seta long (Figure 56). Cingulum with several semi-circular open and large bands, 3–4 in 10 µm, perforated by elongate poroids, ca. 7–8 in 1 µm (Figures 49, 50).

When proposed *Rhizosolenia longiseta*, Zacharias (1893) provided only the length of frustule and calyptra (Table 5). Additional, but limited to light microscopy information on the morphology and metric limits was subsequently reported for this species (ex. Krammer & Lange-Bertalot 1991; Huber-Pestalozzi 1942). The failure to record the frustules details of *U. longiseta* type material has hampered the comparison of this species with populations from different regions of the world and similar taxa. Attempts to analyze a sample of *Rhizosolenia longiseta* studied by Zacharias from Schleswig-Holstein, Germany (material number E4347–Hustedt Diatom Collection) failed, because complete frustules were not found. Valves poorly preserved and the lack of integrity of the calyptra did not allow to observe the number and morphology of apical teeth.

Our specimens of *Urosolenia longiseta* had smaller frustules and shorter calyptra than those described by Zacharias (1893), Huber-Pestalozzi (1942) and Krammer & Lange-Bertalot (1991) (Table 5). The metric variation recorded was more related to that cited by Zacharias (1898) and Cleve-Euler (1951).



Figures 39-46. *Urosolenia longiseta*, LM. Scale: 10 µm.

The ultrastructure of *Urosolenia longiseta* is still poorly known. Only the morphology of its resting spores was well studied by Edlund & Stoermer (1993). Thus, the number and morphology of the calyptra teeth and the areolation pattern of the valves and girdle bands of *U. longiseta* are recorded for the first time in this study.

The frustules of *U. delicatissima* Sala, Núñez-Avellaneda & Vouilloud and *U. extensa* Karthick & Kociolek are very similar to *U. longiseta*. However, *U. delicatissima* differs mainly by having a bottom, a large labiate-shaped perforation on the valve (Sala et al. 2008). Furthermore, this species may have longer frustules and higher number of bands (Table 5) (Sala et al. 2008, Li et al. 2009). *Urosolenia extensa* have elongate openings in the valve, greater number of girdle bands, longer valves, higher density of areolae (8–9 in 1 µm) and shorter calyptra than that *U. longiseta* (Table 5) (Karthick & Kociolek 2011).

Urosolenia longiseta have a worldwide distribution, recorded in Britain, Ireland, North America, New Zealand, Russia, Germany and Brazil (Krammer & Lange-Bertalot 1991, Medvedeva et al. 2009, Tremarin et al. 2009, Guiry & Guiry 2014).

Occurrence in samples (UPCB) – Guaricana reservoir 59533, 60517, 68851, 68875; São Jorge reservoir 59534, 60526, 68852, 68884; Pitangui reservoir 68855, 68879; Fundão reservoir 68864; Foz do Areia reservoir 59530, 60514, 60515, 60516, 68872; Segredo reservoir 59543, 60527, 68861, 68862, 68885; Salto Caxias reservoir 68857; Chaminé reservoir 59527, 60511, 60512, 68845, 68846; Jordão reservoir 59520, 68852; Santa Clara reservoir 68863.

Urosolenia obesa Freire, Tremarin & Ludwig, Phytotaxa 125(1): 1–9, figs 2–27, 2013.

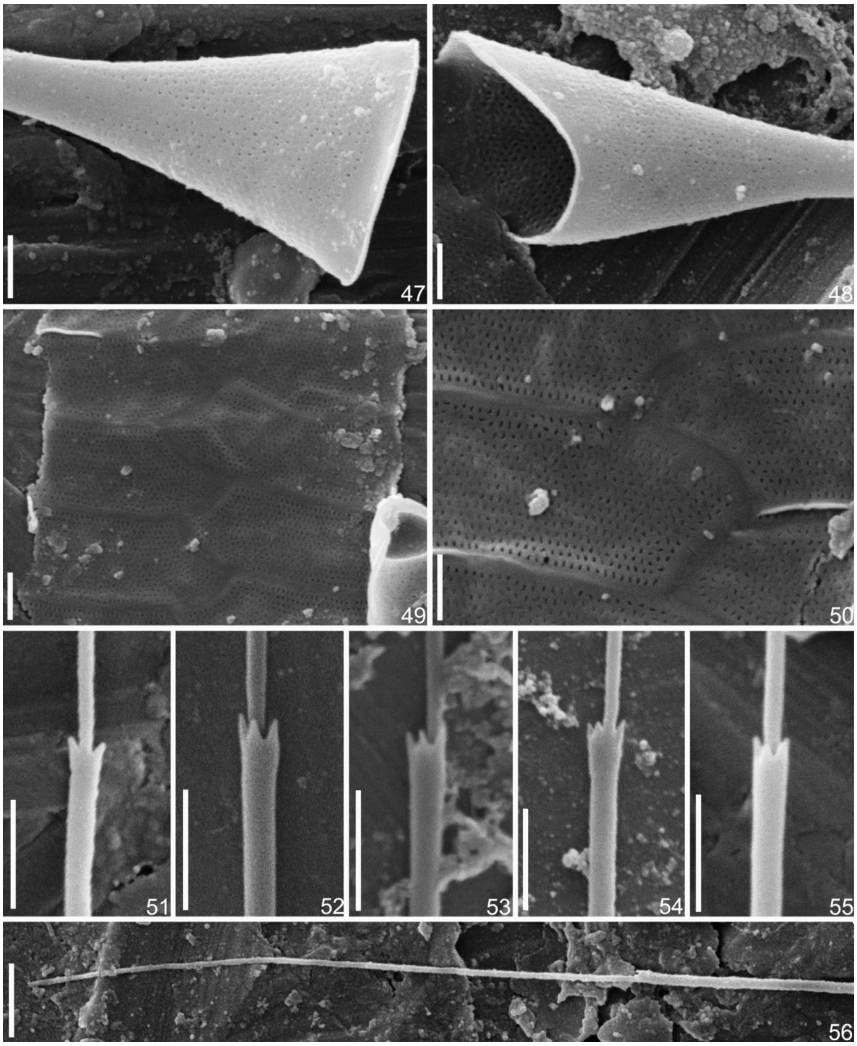
Frustules solitary, subcylindrical, straight to slightly curved, 27.6–55.2 µm total long, 6.8–14.2 µm width (Figures 57–61). Valve face conical ornamented with rounded to irregular areolae, 8–10 in 1 µm, randomly arranged and extending onto the calyptra base (Figure 62). Valve mantle edge surrounded by a thin hyaline margin. Calyptra straight and eccentric, 9.7–15.9 µm long, positioned at right to strongly oblique angle with the pervalvar axis. Calyptra in variable position to the frustules (Figures 57–61). Calyptra ornamented by irregular rib-like structures that extend from base until the median portion of this valve projection (Figure 62). Tip of calyptra with 2 small teeth and a central ligula (Figure 63). Terminal seta not observed. Cingulum with several semi-circular open and narrow bands, 13–16 in 10 µm, perforated by round poroids, ca. 10–11 in 1 µm. Coarser rounded pores, varying in size and number, present on both sides of the cingulum (Figure 62). Resting spore subcylindrical, with convex/concave wall, smooth, 5.4–6.5 µm long and 10.1–13.5 µm width (Figure 57).

Urosolenia obesa is a small and delicate taxa recently proposed to South Brazil. Details of frustule morphology and some ecological data of this species were reported by Tremarin et al. (2013) that proposed this taxon. At present, the species was only found in reservoirs of State of Paraná.

Occurrence in samples (UPCB) – Capivari reservoir 59525, 60509, 68843, 68867; Guaricana reservoir 59533, 60517, 68851, 68875; São Jorge reservoir 59523, 60526, 68860, 68884; Pitangui reservoir 59537, 60521, 68855, 68879; Salto do Vau reservoir 59541, 60525, 68859, 68883; Fundão reservoir 68864, 68888; Foz do Areia reservoir 59530, 59531, 59532, 60514, 60515, 60516, 68848, 68849, 68850, 68872, 68873, 68874; Santa Clara reservoir 68863, 68887; Jordão reservoir 59520, 60518, 68852, 68876; Segredo reservoir 59543, 59544, 60527, 60528, 68861, 68862, 68885, 68886; Salto Caxias reservoir 59539, 59540, 60523, 60524, 68857, 68858, 68881, 68882; Mourão reservoir 59536, 60520, 68854, 68878.

Ecology

The ecological preferences of *Acanthoceras* and *Urosolenia* species are poorly known. *Acanthoceras zachariasii* was reported as occasionally abundant and ephemeral in several alkaline and eutrophic environments in Europe, North and South America (Rivera 1974, Beaver 1981, Edlund & Stoermer 1993). In fact, this species was only found at low densities in two studied eutrophic reservoirs in April/2010, (São Jorge reservoir: 37 cells.mL^{-1} and Pitangui reservoir: 99 cells.mL^{-1}), co-occurring with *Urosolenia* species. Ramberg (1987), when



Figures 47-56. *Urosolenia longiseta*, SEM. Figs 47, 48. External and internal view of valve, respectively. Scales: 1 µm. Fig. 49. Girdle bands in the median region of frustule. Scale: 1 µm. Fig. 50. Detail of bands showing the poroids and imbrication line. Scale: 1 µm. Figs 51–55. Detail of calyptra teeth. Scales: 1 µm. Fig. 56. Seta in the calyptra. Scale: 1 µm.

study of phytoplankton of Lake Kariba, observed that *A. zachariasii* occurred in low density in the end of the rainy season and disappeared with the mixing of water column. According to Edlund & Stoermer (1993), the record of *Urosolenia* species for several environments with different physical and chemical conditions can be a result of the erroneous determination of taxa. Thus, we emphasize the importance of taxonomic studies to better define the differences between species and their geographical distribution, aiding subsequent ecological studies.

The first two axes from Principal Component Analysis (PCA) exceed expectations from the broken-stick distribution, suggesting these axes are significant and explained 52.52% of total variance from environmental variables considering 2007–2012. The first axis (27.66%) showed positive correlations with reservoir depth (r=0.83) and to molar N/P (r=0.83) and negative correlations with total phosphorous (r=-0.56) and pH (r=-0.51). Water column turbidity (r=0.76) and total inorganic nitrogen (r=0.68) had a significantly positive correlation and water transparency was negatively correlated (r=-0.60) with the second axis (24.86%).

In general, the Jordão reservoir was characterized by greater depth, and São Jorge, Pitangui, Guaricana and Chaminé were more alkaline environments. Rio dos Patos and Segredo reservoirs present higher turbidity and nutrient concentrations, but higher transparency characterizes Jordão and Chaminé reservoirs (Figure 64).

Urosolenia amazonica showed occurrence frequency of 78.7%, and despite the density values varied markedly, higher average values were recorded at São Jorge, Pitangui and Chaminé. Spearman rank correlation results revealed positive associations between density and pH, but total inorganic nitrogen, nitrate and reservoir depth were negatively correlated (Table 6). A multiple linear regression model was performed and revealed that total inorganic nitrogen was the main factor influencing *U. amazonica* cellular densities. Along with conductivity, water temperature and molar N/P ratio the model explained 12% of variance. According to this model, the conductivity was positively associated with *U. amazonica* density, and negatively correlated to total inorganic nitrogen, water temperature and the molar N/P ratio (Table 7).

Table 5. Metric and morphological variation of *Urosolenia longiseta* and related species.

	U. longiseta						***U. delicatissima***		***U. extensa***
Reference	this study	Zacharias (1893)	Zacharias (1898)	Huber-Pestalozzi (1942)	Krammer & Lange-Bertalot (1991)	Cleve-Euler (1951)	Sala et al. (2008)	Li et al. (2009)	Karthick & Kociolek (2011)
Total frustule length (μm)	216–273	…	…	70–200	40–200	134–280	>179	200–400	…
Frustule width (μm)	5.8–8.5	…	…	4–10	4–10	5–14	3–10	3–10	3,2–5,1
Frustule length (μm)	59–103	160	77–176	…	…	…	…	…	…
Girdle bands (in 10 μm)	3–4	…	…	…	2–3	2.3–4.5	(3)4–7	5–7	5–7
Porous in the bands (in 1 μm)	7–8	…	…	…	…	…	6–9	…	
Calyptra length (μm)	64–100	180–200	58–154	…	…	90–170	44–99	55–115	15.4–44.4
Valve length (μm)	2.4–5.4	…	…	…	…	…	2.3–7.5	3–8	5–7
Teeth in the calyptra	3–4	…	…	…	…	…	…	…	…

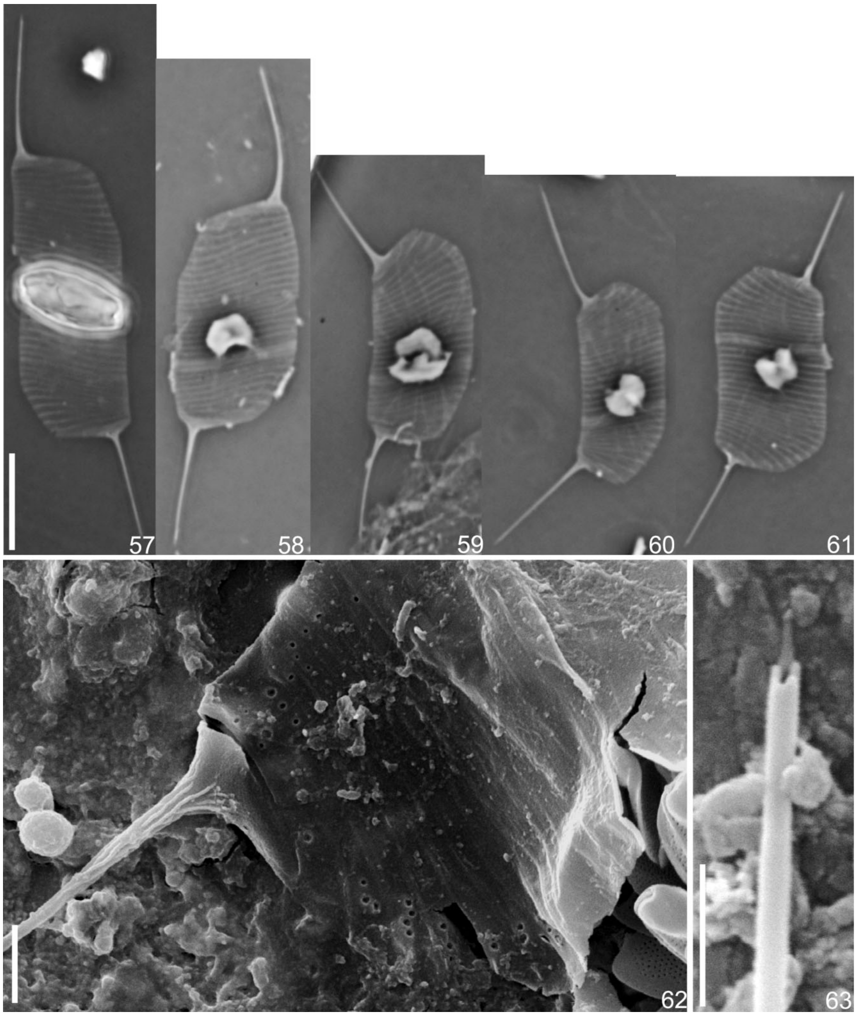
The frequency of *U. longiseta* occurrence was 34.5%. The density values had higher densities in winter season and in the São Jorge and Guaricana reservoirs. The maximum value registered was 486 ind.mL^{-1} in São Jorge, during the winter of 2008. *Urosolenia longiseta* density was negatively correlated with depth, molar N/P ratio and water temperature (Table 6). The multiple linear regression model showed that the water temperature and the N/P molar influenced significantly the density of *U. longiseta* in the studied reservoirs. These variables along with depth of the water column, inorganic nitrogen, conductivity and turbidity explained 28% of *U. longiseta* density between environments and established temporal interval. The water body depth was the only variable positively correlated with the density of this species and all the others were negatively correlated (Table 7).

Frequency occurrence of *Urosolenia obesa* was 17.8% during 2007–2012 and the density values were generally lower compared to *U. amazonica* and *U. longiseta.* Higher cell concentrations were achieved at São Jorge and Fundão reservoirs, and greater frequency occurred during fall and winter. *Urosolenia obesa* was negatively associated with total nitrogen, N/P molar ratio and inorganic total nitrogen (Table 6). Multiple linear regression supported that limnological variables were related to *U. obesa* density. Accordingly, N/P molar ratio was the main variable related to species density variation, along with water temperature and turbidity, the model explained 36% of data (Table 7).

The three *Urosolenia* species showed distinct frequencies of occurrence and wide density variation among different studied reservoirs, in the period 2007–2012. Statistical analysis showed that such variation was correlated with limnological factors associated with particular characters from each reservoir, influencing the distribution pattern of species. Generally, higher densities of *Urosolenia* were registered in shallower reservoirs (ex., São Jorge, Pitangui and Guaricana), except for Fundão (38 meters). Residence time (which favors nutrients mixing and resuspension) and hydrodynamics are important determinants of phytoplankton densities in shallow reservoirs (Silva et al. 2005; Reynolds 2006; Lopes et al. 2009; Nogueira et al. 2010).

Higher densities of *U. amazonica* were detected in more alkaline waters and in low inorganic nitrogen and nitrate concentrations, and shallow waters. *U. longiseta* were also recorded in shallower environments (São Jorge and Guaricana), in cooler temperatures. The species is less restricted by phosphorus (lowest N/P ratio). Finally, more elevated densities of *U. obesa* were related to lower concentrations of the nitrogenated forms. Higher densities of *U. amazonica* and *U. longiseta* were recorded by Silva et al. (2005), in two deep reservoirs from Iguaçu River basin (Foz do Areia and Salto Santiago), during lower temperatures and nitrogen forms minor concentrations, besides greater turbulence of the water column. Reported as r-strategists (Reynolds 2006), these centric diatoms thrive in conditions of turbulent water column and low nutrient concentrations, corroborating the general pattern observed in this study.

The performed model selected inorganic nitrogen as the primary determinant of *U. amazonica* density, with a negative coefficient. *Urosolenia longiseta* showed a negative correlation with temperature and N/P molar ratio, both variables were cited as the main determinants with that species density. N/P molar ratio was selected as the most important variable negatively correlated with *U. obesa*. These results suggest the occurrence of higher densities in periods of warmer tempera-



Figures 57–61. *Urosolenia obesa*, LM. Scale: 10 µm. Figures 62–63. *Urosolenia obesa*, SEM. Fig. 62. External view of frustule showing the ornamentation of the valve and girdle bands. Scale: 2 µm. Fig. 63. Detail of calyptra teeth. Scale: 1 µm.

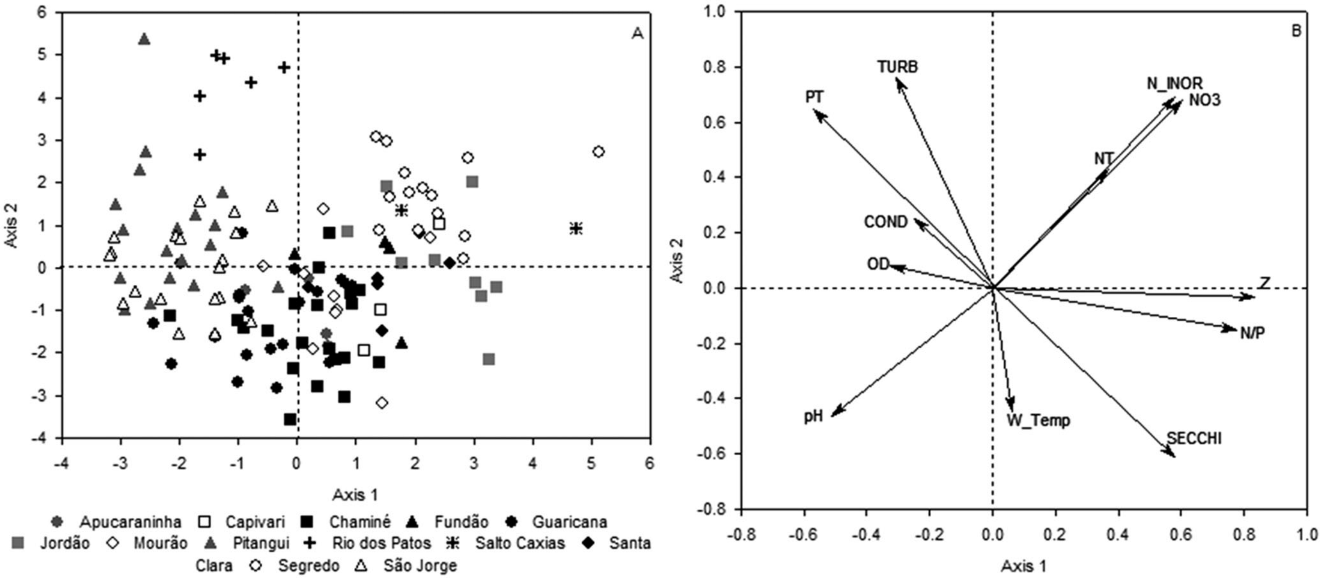


Figure 64. Reservoirs scores (A) derived from principal component analysis and Pearson correlation (B) between the original variables and ordination scores [COND (conductivity); N_INOR (total inorganic nitrogen), NO3 (nitrate), NT (total nitrogen), N/P ratio (N/P molar), DO (dissolved oxygen), PT (total phosphorus), Z (depth reservoir), Secchi (water column transparency); W_temp (water temperature); TURB (turbidity)].

Table 6. Values of Spearman's correlations between species density and environmental variables of the reservoirs. Values in bold = significant correlations.

	U. amazonica	*U. longiseta*	*U. obesa*
pH	**0.224**	0.179	0.144
Log Depth	**-0.200**	**-0.341**	-0.260
Log Conductivity	0.136	-0.123	-0.025
Log Water temperature	-0.081	**-0.292**	0.087
Log N/P ratio	-0.145	**-0.300**	**-0.475**
Log Inorganic nitrogen	**-0.266**	-0.148	**-0.314**
Log Nitrate	**-0.234**	-0.165	-0.268
Log Total nitrogen	-0.093	-0.225	**-0.500**
Log Turbidity	-0.094	0.019	0.223

Table 7. Results of a multiple regression analysis of species densities against environmental variables.

	Predictor variables	B	t	F	p
U. amazonica	Intercept	3.077	(96) 1.751	3.540	0.009
	Log Nitrogen inorganic	-2.516	-2.765		0.006
	Log Conductivity	0.892	1.636		0.105
	Log Water temperature	-1.411	-1.514		0.133
	Log N/P ratio	-0.263	-1.127		0.262
U. longiseta	Intercept	8.214	(40) 3.999	2.699	0.000
	Log Water temperature	-2.977	-2.591		0.013
	Log N/P ratio	-0.689	-2.403		0.020
	Log Conductivity	-0.653	-1.324		0.192
	Log turbidity	-0.334	-1.142		0.259
	Log Nitrogen inorganic	-1.326	-0.928		0.358
	Log depth	0.04	0.140		0.888
U. obesa	Intercept	-0.035	(38) -0.018	7.242	0.000
	Log N/P ratio	-0.039	-3.925		0.000
	Log Water temperature	2.485	1.889		0.066
	Log turbidity	0.366	1.030		0.309

tures and low levels of nitrogenated forms (inorganic nitrogen and N/P molar ratio), corroborating the results reported by Flynn (2001) for the phytoplanktonic diatoms community.

As shown, *Urosolenia* species respond more strongly to local environmental gradients, which are highly influenced by particular local characters (as depth and hydrodynamics of the system). Also, the extent of their ecological amplitude determines the distribution and occurrence pattern of these species in the reservoirs of State of Paraná.

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Ecological assessment of a southeastern Brazil reservoir

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MARTINS, I., SANCHES, B., KAUFMANN, P.R., HUGHES, R.M., SANTOS, G.B., MOLOZZI, J., CALLISTO, M. **Ecological assessment of a southeastern Brazil reservoir.** Biota Neotropica. 15(1): e20140061. http://dx.doi.org/10.1590/1676-06032015006114

Abstract: Reservoirs are artificial ecosystems with multiple functions having direct and indirect benefits to humans; however, they also cause ecological changes and influence the composition and structure of aquatic biota. Our objectives were to: (1) assess the environmental condition of Nova Ponte Reservoir, Minas Gerais state, southeastern Brazil; and (2) determine how the aquatic biota respond to disturbances. A total of 40 sites in the littoral zone of the reservoir were sampled to characterize physical and chemical habitat, land use, and benthic macroinvertebrate and fish assemblages. The predominant type of land cover near the reservoir was natural vegetation. A total of 29 fish species and 39 macroinvertebrate taxa were collected, including eight alien species. Most sites had intermediate levels of human disturbance, however, high levels of degradation were associated with high proportions of alien species. Disturbances at multiple scales may alter natural patterns and processes, leading to environmental changes and damaging biological communities. Our results reinforce the importance of assessing reservoir ecological conditions at several scales. The study of land use, littoral zone physical habitat characteristics, water quality, and assemblage structure set the ground for proposing actions to rehabilitate and conserve aquatic ecosystems.
Keywords: *reservoirs, water quality, bioindicators, physical habitat, environmental quality.*

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Resumo: Reservatórios são ecossistemas artificiais com múltiplas funções e que oferecem benefícios diretos e indiretos ao homem; no entanto, também causam mudanças ecológicas e influenciam a composição e estrutura da biota aquática. Os objetivos deste estudo foram: (1) avaliar a condição ambiental do reservatório de Nova Ponte, Estado de Minas Gerais, sudeste do Brasil; e (2) verificar se a biota aquática responde aos distúrbios. No total, 40 sítios amostrais na região litorânea do reservatório foram amostrados para caracterizar os habitats físicos e químicos, cobertura e uso do solo, assembleias de macroinvertebrados e peixes. Vegetação natural de cerrado foi o tipo predominante de cobertura do solo no entorno do reservatório. 29 espécies de peixes e 39 taxa de macroinvertebrados bentônicos foram coletadas, incluindo oito espécies exóticas. A maioria dos sítios amostrais possui níveis intermediários de distúrbio antrópico, porém o aumento de alterações antrópicas foi associado ao aumento do número e abundância de espécies exóticas. Distúrbios em múltiplas escalas podem alterar os padrões e processos naturais, levando a mudanças ambientais e nas comunidades biológicas. Nossos resultados reforçam a importância de avaliar as condições ecológicas do reservatório em várias escalas. O estudo do uso e cobertura do solo, características de habitats físicos na zona litorânea, características limnológicas e estrutura das assembléias fornecem bases para a proposição de ações para reabilitação e conservação de ecossistemas aquáticos.
Palavras-chave: *Reservatórios, bioindicadores de qualidade de água, habitats físicos, qualidade ambiental.*

Introduction

Reservoirs are artificial ecosystems with multiple functions, such as water storage, flood control, and electricity generation (Tundisi & Matsumura-Tundisi 2008). Their multiple uses bring indirect benefits to society, including economic development, employment, and income generation (Tundisi & Matsumura-Tundisi 2008). Reservoirs have become one of the most common types of human alteration in Brazilian river basins, where nearly all large rivers are dammed (von Sperling 2012). Dams produce several changes in rivers, including altered flow regimes, substrate composition, riparian flooding patterns, and riparian plant cover (Franklin et al. 1995). Those changes in turn influence fish and macroinvertebrate assemblage structure and composition (Agostinho et al., 2008, Borges et al. 2010), and may interfere with aquatic food web functions (Maroneze et al. 2011).

Aquatic species in reservoirs may be affected by human impacts at local and landscape scales (Luiz et al. 2003). Land use near reservoirs directly affects water quality (Beavan et al. 2001), which affects the density, distribution, and richness of biological communities. Therefore, it is necessary to assess the surrounding land use to evaluate ecological conditions of aquatic ecosystems in a meaningful manner (Meyer & Turner 1994). In urban reservoirs, for example, there are intensive human modifications in adjacent areas resulting from roads, housing, and commercial/industrial development (Hughes et al. 2014). Physical habitat modifications directly influence the composition and structure of aquatic communities (Kaufmann et al. 2014), and alter organism diets, reproduction, and growth (Benedito-Cecílio et al. 1997). As a result of all these influences, and because of the dam itself, aquatic communities undergo changes (Gehrke et al. 2002, Agostinho et al. 2008) that favor biological invasion (Rocha et al. 2011).

Information about land use and cover, littoral zone physical and chemical habitat characteristics, and aquatic assemblage structure facilitate ecological condition assessments and actions for rehabilitating and conserving aquatic ecosystems (Hughes et al. 2014, Kaufmann et al. 2014). This approach is particularly important in river basins with hydroelectric power plants (Macedo et al. 2012).

Our objective was to assess the ecological condition of Nova Ponte Reservoir in terms of its surrounding land use, littoral physical and chemical habitat, and fish and benthic macroinvertebrate assemblage structure. We hypothesized that reservoir macroinvertebrate and fish assemblages would respond to habitat disturbance and water characteristics.

Methods

1. Study area

Nova Ponte Reservoir (19°09'09''S and 47°40'29''W) is located on the Araguari and Quebra-Anzol Rivers in the state of Minas Gerais, southeastern Brazil, in the Paraná River basin, and was built to generate electricity (Figure 1). The local climate is tropical with temperatures between 14 °C and 30 °C and average annual rainfall of ca. 1,700 mm (Durães et al. 2001). There is a dry season from April to September (minimum rainfall of 11 mm/month) and a rainy season from October to March (maximum rainfall of 280 mm/month) (Climatempo 2013). The predominant vegetation is neotropical savanna (cerrado). Nova Ponte Reservoir is the largest of a series of reservoirs on the Araguari River, with a depth of 120 m close to the dam, a length of 115 km, and a volume of 12.8 billion m^3 (Vono 2002). Its hydroelectric power plant has a capacity of 510 Mw, three generating units, and its dam is 141 m high and 1,600 m long. The floodgates closed in 1993 and operations began in 1994 (CEMIG 2013).

1.1 Study design. The sampling sites were defined according to the concept of spatially balanced sampling (Stevens & Olsen 2004) adapted to large reservoirs (Macedo et al. 2014). The reservoir's perimeter was divided into 40 equidistant sections based on a randomly defined first point. Each site was located at the beginning of each section and each site was 200 m long. In each of the 40 sites, we assessed physical and chemical habitat, and sampled benthos and fish at the end of the rainy season, in April 2010. We did not conduct any temporal replication because of financial limits and a focus on spatial patterns.

2. Habitat characterization

2.1. Land use. We assessed land use via satellite images (TM sensor onboard Landsat 5 and images from Google Earth 6.0) that were obtained during the sampling period. We determined buffer areas of 500 m around each sampling site. Within each buffer, polygons were delimited and used to quantify the cover percentage of each land use and cover category. To visualize and determine the different types of land uses, we employed Kosmo 2.0 (Open Geographic Information System).

2.2 Physical habitat structure. In each of the 40 sites, we recorded cover percentage of aquatic macrophytes and types of substrates in the littoral zone, riparian vegetation features, and type and intensity of human impacts in the riparian zone (USEPA 2011). In each of the sites, we applied the physical habitat protocol along 200 m of the reservoir margin, in 10 consecutive, equidistant sample units (plots). Each plot comprised parts of the littoral (15 × 10 m), riparian (15 × 15 m), and exposed littoral zones (15 m wide and variable depth).

2.3. Water and sediment character. We used a multiparameter meter (model YSI 6600) to measure temperature (°C), pH, electrical conductivity (μS cm^{-1}), and total dissolved solids (g L^{-1}). We measured total depth with a SONAR gauge, euphotic zone depth with a Secchi disk, and turbidity (NTU) with a Digimed turbidimeter. We analyzed chlorophyll-a content (μg L^{-1}) following Golterman et al. (1978), dissolved oxygen content (mg L^{-1} and percent saturation) according to Winkler (1888), and total alkalinity (mg L^{-1}) by the GRAN method (Carmouze 1994). We determined total nitrogen (ug L^{-1}) and total phosphorous (TP, ug L^{-1}) according to Golterman et al. (1978) and Mackereth et al. (1978), respectively.

We calculated a trophic state index (TSI) as proposed by the Sanitation Company of São Paulo State (Companhia de Tecnologia de Saneamento Ambiental - CETESB 2004) for each of the 40 sites. The TSI and its component indices were calculated as follows:

$$TSI = [TSI\ (TP\ ) + TSI\ (Chl)\ ] / 2;$$
$$TSI\ (TP) = 10x(6-(1.77 - 0.42x(\ln TP)/\ln 2));\ \text{and}$$
$$TSI\ (Chl) = 10x(6-((0.92 - 0.34x(\ln Chl))/\ln 2)).$$

We measured sediment organic matter content through calcination in a muffle furnace at 550 °C for 4 h (Esteves et al.

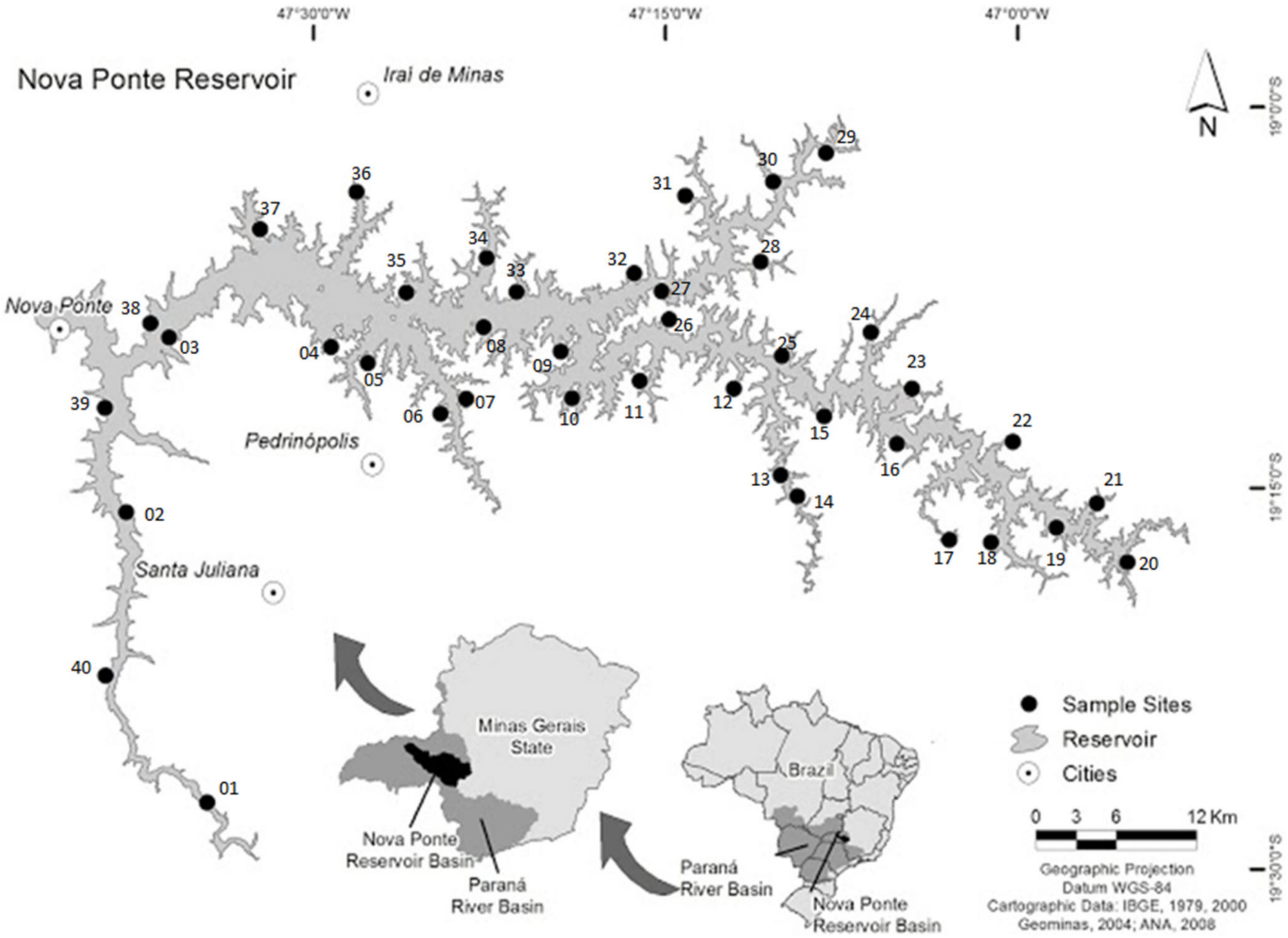

Figure 1. Location of 40 sampling sites on Nova Ponte Reservoir, in the Araguari river basin, Minas Gerais.

1995) and granulometric composition by sieving, following Suguio (1973) as modified by Callisto & Esteves (1996).

2.4. Human disturbance. To evaluate the level of human disturbance at the sites, we applied the IDI (Integrated Disturbance Index) of Ligeiro et al. (2013), which was calculated from a Buffer Disturbance Index (BDI) and a Local Disturbance Index (LDI). We calculated the BDI according to the intensity of the disturbance in the 500 m buffer area as follows:

BDI = (4 × % residential construction area) + 2 × (% agricultural area + % bare soil area) + (% pasture area).

We used the RDis_IX index of Kaufmann et al. (2014) to calculate the LDI. We incorporated human disturbances in both riparian and drawdown areas along with horizontal drawdown distance (Table1) in the calculation of RDis_IX (Kaufmann, unpublished data).

To incorporate the BDI and LDI into the IDI we first plotted the BDI and LDI scores for each site on a biplot, then we calculated the Euclidean distance of the position of the site relative to the graph origin. This was performed through application of the Pythagorean theorem: $IDI = [(LDI/2.25)^2 + (BDI/3)^2]^{1/2}$. The greater the site IDI value, the greater its deviation from the graph origin and the greater the level of disturbance (Ligeiro et al. 2013).

3. *Biological assemblage sampling*

3.1 Benthic macroinvertebrates. We collected macroinvertebrates in the littoral zone of each site with an Eckman-Birge grab (0.0225 cm^2). The samples were stored in plastic bags, fixed in 10% formalin, and then washed in a sieve (0.5 mm mesh) in the laboratory. The organisms were identified to family under a stereo-microscope using Pérez (1988), Merritt & Cummins (1996), Fernández & Domínguez (2001), Costa et al. (2006), Mugnai et al. (2010), and Trivinho-Strixino (2011), and the Chironomidae were identified to genera. Then they were fixed in 70% alcohol and deposited in the Benthic Ecology Laboratory reference collection (França & Callisto 2007), Institute of Biological Sciences, Federal University of Minas Gerais. We considered alien species as those that occurred outside their past or present natural geographic range, and whose dispersal is aided by humans (Falk-Petersen et al. 2006).

3.2 Fish. We sampled fish through use of gillnets with mesh sizes between 3 and 16 cm (distance between opposite knots), heights ranging between 1.6 and 1.8 m, and lengths of 20 m. At each sampling site, we placed a set of five pairs of nets in the late afternoon and removed them the following morning, with a total exposure time of approximately 15 h. In the field, the captured specimens were separated by mesh size and sampling site, labeled, fixed in 10% formalin, placed in plastic drums, and

Table 1. Metrics used to calculate the LDI (Local Disturbance Index), calculated based on Ligeiro, et al. (2013).

Metric	Description	Min	Med	Max
Pdraw	Ratio of horizontal drawdown distance divided by the field plot size (15m).	0.4	0.8	1.0
rviWoody	Summed coverage of woody vegetation in the canopy, understory and ground cover.	0.0	0.7	0.9
rvfcCanBig	Mean proportional areal cover of large diameter trees averaged over the 10 plots.	0.0	0.0	0.0
rvfcGrdBare	Mean proportional areal cover of bare ground (soil) averaged over the 10 plots.	0.0	1.0	1.0
hifpAnyCirca	Proportion of plots with at least one type of human activity.	0.0	0.3	0.7
hiiAg	Proportion of plots with agricultural activities.	0.0	0.1	0.3
hiiNonAg	Proportion of plots with non-agricultural activities.	0.0	0.3	0.9
hiiAll	Sum of the proportions of plots with agricultural and non-agricultural activities.	0.0	0.3	1.0
hiiAllCirca	Proportion between agricultural and non-agricultural activities.	0.2	0.9	1.0

transported to the Ichthyology Laboratory at Pontifícia Universidade Católica de Minas Gerais for sorting, biometry, and identification.

In the laboratory, we washed the fish in water and identified them to species through use of Britski et al. (1986) and Graça & Pavanelli (2007). The individuals that were difficult to identify as well as part of the collected material were deposited as vouchers in the Ichthyological Collection of the State University of São José do Rio Preto, São Paulo, Brazil. We considered as alien species those from other river basins or those that originally did not belong to this reach of the Upper Paraná River (Oliveira et al. 2003, Graça & Pavanelli, 2007).

4. *Data analyses*

4.1 Spatial autocorrelation assessment. To assess spatial autocorrelation between sampling sites, we applied Mantel tests (Mantel 1967) on Bray-Curtis similarity analyses of macroinvertebrate and fish abundance data in PAST software (Hammer et al. 2003). We calculated dissimilarity matrices from the geographic coordinates (Euclidean distance) of each site. The value of the test is the Pearson correlation coefficient (R) between the two matrices. The significance of the test was generated by comparing the R value with the R value estimated from 10,000 randomly generated permutations from the biological samples.

4.3. Biotic metrics. For benthos, we calculated the following metrics: total abundance, family richness, Chironomidae abundance and genera richness, number and percentage of EPT (Ephemeroptera, Plecoptera and Trichoptera) individuals and taxa, number and percentage of resistant individuals and taxa, number and percentage of alien individuals and taxa, and number and percentage of tolerant individuals and taxa.

The fish metrics employed were total number of species, total number of native species, number and percentage of alien species, number and percentage of migratory species, number and percentage of rheophilic species, abundance and percentage of native individuals, percentage of species that account for 90% of total abundance, abundance and percentage of rheophilic individuals, catch per unit effort of individuals (CPUEn), catch per unit effort of native species (CPUEnNat), catch per unit effort of alien species (CPUEnExot), and percentage catch per unit effort of alien individuals (% CPUEnAlien).

4.4 Influence of anthropogenic disturbance on biological assemblages. To assess the influence of human disturbances around the reservoir on benthic macroinvertebrate and fish assemblages, we made scatterplots and regressed biological metrics against the IDI, in Statistica 8.0 (StatSoft Inc. 2007). Prior to those analyses, metrics that comprised abundance and richness data were log (x +1) transformed. Biotic metrics expressed as percentages and IDI values were arcsine square root transformed (Legendre & Legendre 1998, Zar 1996).

4.5 Influence of water quality on biological assemblages. Initially, redundant biotic and abiotic variables were excluded ($r > 0.7$) through use of Spearman Rank Correlation. If only two variables were correlated, the one with higher average correlation coefficient was excluded from further analysis (Feld & Hering 2007, Hughes et al. 2009, Raposeiro et al. 2011). We then performed an RDA (Redundancy Analysis) on the selected environmental variables standardized by Statistica 8.0 (StatSoft Inc. 2007) and biological metrics transformed as described above. For this, we used R 2.15.1 (R Core Team 2008).

Results

1. *Biological assemblages*

1.1 Benthic macroinvertebrates. We collected 1,116 organisms and 39 taxa, dominated by Chironomidae (46%) and Oligochaeta (42%) (Figure 2a). Among the Chironomidae, we found 462 individuals and identified 21 genera (Figure 2b), dominated by *Tanytarsus* (van der Wulp 1984) (46%) and *Polypedilum* (Kieffer 1913) (15%). In the sites located in the buffer region of rivers and tributaries (24, 29, and 30) we observed the highest richness (6 and 7) of benthic taxa. The sampling sites with lowest richness (1 to 3) were located close to the dam (sites 2, 3, 37, 38, 39 and 40). We also collected non-native *Corbicula fluminea* (Müller 1974) (Corbiculidae, Bivalvia) and *Melanoides tuberculatus* (Müller 1974) (Thiaridae, Gastropoda) near the dam (sites 01, 02, 37, 38, 39, and 40), and *Macrobrachium amazonicum* (Heller 1862) (Decapoda) in some sites.

1.2 Fish. We captured 2,463 individuals representing 5 orders, 13 families, and 29 species. Three species were migratory: *Leporinus obtusidens* (Valenciennes 1836), *Salminus hilarii* (Valenciennes 1850), and *Prochilodus lineatus* (Valenciennes 1836), representing only 2.2% of the abundance; and five were non-native: *Oreochromis niloticus* (Linnaeus 1758), *Tilapia rendalli* (Boulenger 1897), *Pygocentrus nattereri* (Kner 1858), *Cichla piquiti* (Kullander & Ferreira 2006), and *Metynnis lippincottianus* (Cope 1870). The most abundant species were: *Iheringichthys labrosus* (Lütken 1874), *Pimelodus maculatus* (Lacepède 1803), *Astyanax fasciatus* (Cuvier 1829), *Schizodon nasutus* (Kner 1858), and *Galeocharax knerii* (Steindachner

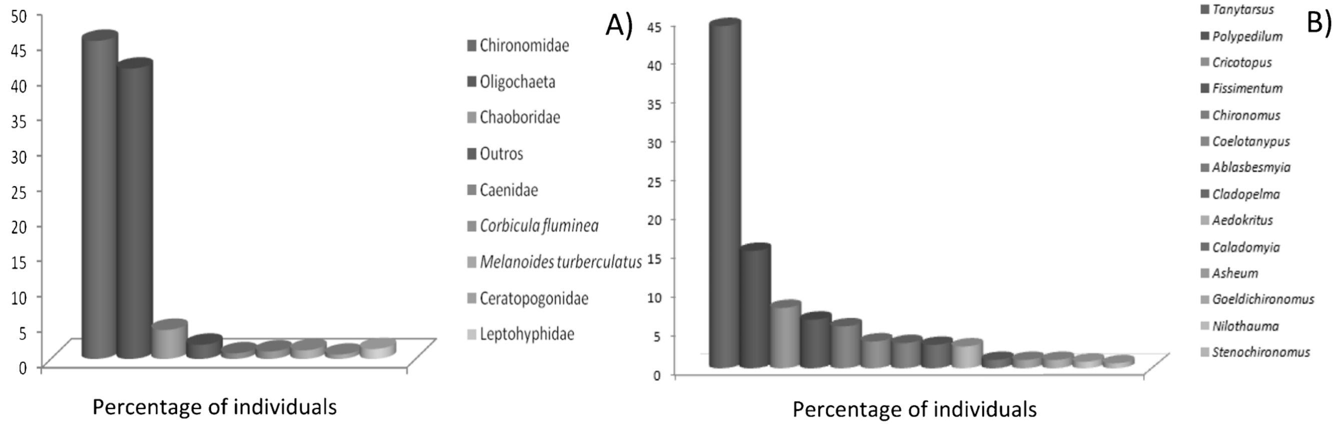

Figure 2. A) Percentages of benthic macroinvertebrate taxa collected via Eckman-Birge grab. B) Percentages of individuals of the most abundant Chironomidae genera (> 1%) collected via Eckman-Birge grab.

1879), together representing 72.8% of the captures. The non-native *P. nattereri* and *C. piquiti* were among the eight most frequently captured and were collected, respectively, in 36 and 34 of the 40 sampling sites. Two of the sites with the highest fish abundance were in the Santo Antônio tributary of the Quebra Anzol River. Similarly, two out of the four sites with greatest species richness were located in the river mouths of the Capivara and Santo Antônio tributaries.

Because there was insignificant correlation between the relative abundances of fish and macroinvertebrates with site geographical location (Macroinvertebrate R = -0.001, p = 0.57; Fish R = -0.22, p = 0.99), we infer that there was no spatial autocorrelation among sites for abundance.

2. *Water and sediment character*

The pH and dissolved oxygen values indicated neutral to slightly alkaline (7.26 to 7.96) and well-oxygenated (6.4 to 10.1 mg/L) waters. All 40 sampling sites were classified as ultraoligotrophic (TSI ≤ 47) (CETESB 2004); hence, there were no differences in trophic level among sites (Table 2). The sediments were mostly composed of fine sediments (sand, silt, and clay); in some sites we observed a predominance of larger particles (site numbers 10, 13, 22, 32, 37), such as pebbles and gravel (Table 2).

3. *Human disturbance*

Buffer land-use was dominated by natural grassland (34.1%), natural forest (33.6%), and agriculture (21.7%), followed by pasture (9.4%), bare soil (0.9%), and residential development (0.3%). The integrated disturbance index (IDI, Figure 3) shows a set of nine sites with low (< 0.2 IDI) scores (site numbers 4, 6, 10, 11, 14, 15, 21, 22, 37). These sites had buffers composed predominantly of natural vegetation. There were many moderately disturbed sites, and a set of four sites with high (> 0.8 IDI) scores (site numbers 2, 8, 38, 39), these sites had buffers dominated by pasture and agriculture. Only

Table 2. Abiotic values (average and standard deviation), granulometric composition (%), and organic matter content (dry weight %) and codes used in RDA (Redundancy Analyses) in Nova Ponte Reservoir.

Variables	Means and standard deviations	Max	Min
Cobbles % (64 – 250 mm)	16.42 ± 25.73	87.3	0
Gravel % (2 – 63 mm)	8.59 ± 15.38	59.2	0
Coarse sand % (0.50 – 1 mm)	3.42 ± 3.67	14.9	0
Medium sand % (0.250 – 0.49 mm)	12.82 ± 10.60	34.4	0.05
Fine sand % (0.1 – 0.249 mm)	13.02 ± 8.83	28.9	0.03
Silt/clay % (<0.062 mm)	11.83 ± 11.85	47.7	0.14
Organic matter (% D.W.)	9.21 ± 4.22	17.1	2.25
Site Depth (m)	4.21 ± 2.23	12	1.2
Secchi Depth (m) SEC	3.13 ± 1.45	7.7	1.2
Air temperature (°C)	29.22 ± 2.86	35	23
Water temperature (°C)	25.63 ± 0.42	26.4	24.7
pH	7.56 ± 0.19	7.9	7.2
Conductivity (µS cm^{-1})	22.8 ± 4.21	45	18
Total Dissolved Solids (TDS)(mg L^{-1})	0.01 ± 0.00	0.029	0.011
Dissolved Oxygen (DO) (mg L^{-1})	7.74 ± 0.71	10.1	6.3
Turbidity (Trb) (NTU)	2.53 ± 1.47	7.2	1.1
Chlorophyll a (Ch) (µg L^{-1})	0.88 ± 0.41	2.1	0.3
Total Nitrogen (TN) (mg L^{-1})	0.05 ± 0.01	0.08	0.04
Total Phosphorus (TP) (mg L^{-1})	0.01 ± 0.00	0.03	0

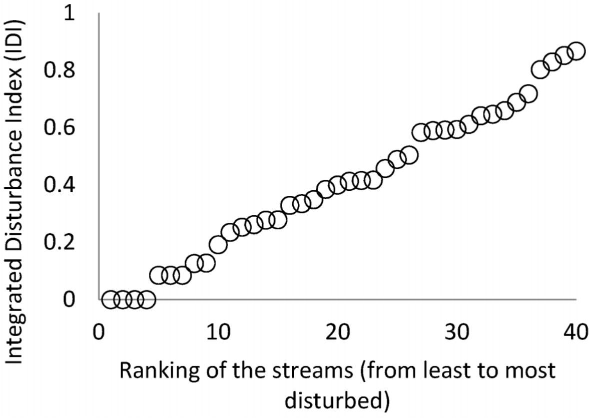

Figure 3. Integrated Disturbance Index (IDI) values for 40 Nova Ponte Reservoir sites. Sites with values close to 1 are most disturbed.

five alien macroinvertebrate and fish metrics were significantly related to disturbance as measured by the IDI (Table 3).

4. *Influence of water quality on biological assemblages*

Following redundancy analyses, we selected abiotic variables (Table 2) and 8 and 10 macroinvertebrate and fish metrics, respectively (Table 4) to enter into the RDA. The total variation explained by the first two RDA axes was 18% (Axis 1 = 13%, Axis 2= 5%). Axis 1 was positively related to Secchi depth and negatively related to total dissolved solids. Axis 2 was positively related to total nitrogen and negatively related to total phosphorus. Alien biotic metrics D, H, M, and P were associated with greater dissolved oxygen (DO) concentrations and Secchi depths (Figure 4). The RDA separated two clusters of sites along a turbidity, total dissolved solids, total phosphorus and chlorophyll-a gradient. One of these clusters included sites mainly located in the central portion of the reservoir. In this region the ground cover was dominated by agriculture (sites 5, 6, 7, 8, 9, 26, 31, 33, 34, 35). At these sites there were greater concentrations of phosphorus, total solids and chlorophyll, and greater turbidity. Benthic macroinvertebrate groups considered resistant were related to the presence of these parameters in high concentrations (C and G, Figure 4). The second cluster of sites is located in the upper portion of the reservoir, and had mostly natural vegetation in their buffers (13, 14, 15, 18, 19, 22, 24, 28, 29, 30).

Discussion

Benthic macroinvertebrate assemblages are efficient tools for assessing ecological conditions of aquatic ecosystems (Callisto et al. 2005). In Nova Ponte Reservoir, we observed that sites with lower family richness were concentrated near the dam. Sites with greater family richness and individual abundances were located far from the dam. Sites where we collected *Chironomus* (Meigen 1803) and *Goeldichironomus* (Fittkau 1965) had abundant aquatic macrophytes and agriculture drainage. These genera prefer sites with greater sediment organic matter content and aquatic macrophytes (Barbosa & Callisto 2001). *Tanytarsus* (van der Wulp 1984) was the most abundant genus, with a broad distribution in all regions of the reservoir. Because this genus has low blood hemoglobin concentration (Panis et al. 1996), it indicates environments with good water quality.

Ligeiro et al. (2013) indicated that the IDI is a good descriptor of disturbances at different spatial scales. With its implementation, we found that the Nova Ponte reservoir had mostly natural vegetation buffers and intermediate IDI values. However, some sample sites had high levels of agriculture, high values of IDI, and substantial numbers of non-native species. USEPA (2009) emphasized that lakes with poor cover and complexity of riparian and littoral habitat are approximately 3 times more likely to have poor biological integrity, likely because of habitat simplification and reduced riparian buffer protection from upland stressors. Human activities can alter environmental quality, reducing plant cover and physical habitat complexity in reservoir littoral zones (Molozzi et al. 2011, Kaufmann et al. 2014). According to Benedito-Cecílio et al. (1997), habitat modification directly influences such fish biological functions as diet, reproduction, and growth. Allan (2004) reported that watercourses draining croplands that had once been forests supported fewer macroinvertebrate and fish species than those draining forests. However, tools for the assessment of lentic systems have been poorly developed (Irz et al. 2008) and the influence of agriculture on the structure of reservoir aquatic assemblages has been poorly studied. Molozzi et al. (2011) assessed the influence of habitat structural complexity on benthic macroinvertebrate assemblages in three urban reservoirs in the Paraopeba River Basin, southeastern Brazil. They observed the highest richness of benthic organisms and the fewest non-native individuals in the reservoir with the greatest riparian complexity and the least littoral zone disturbance.

Of all the macroinvertebrate metrics examined, only three were significantly related to differences in disturbance among sites in the reservoir, and these were alien species metrics. One of the non-native mollusks recorded near the dam, *Melanoides tuberculatus* (Gastropoda: Thiaridae), is native to East Africa, Southeast Asia, China, and the Indo-Pacific Islands and is broadly distributed in Brazil (Silva & Barros 2011). Its introduction may be related to the trade of ornamental plants and fish (Fernandez et al. 2003) and to control *Biomphalaria glabrata* (Say 1818), the intermediate host of *Schistosoma*

Table 3. Metrics significantly related to anthropogenic disturbance: results of simple regression analysis between biological metrics and the IDI (Integrated Disturbance Index).

Metrics	P value	r	r^2
Abundance of alien benthic macroinvertebrate taxa	0.01	0.42	0.18
Percentage of alien benthic macroinvertebrate taxa	0.03	0.35	0.12
Richness of alien macroinvertebrate taxa	0.02	0.38	0.14
Percentage of alien fish species	0.03	0.35	0.12
Number of alien fish species	0.03	0.35	0.12

Table 4. Selected biotic metrics.

	Code	Max	Med	Min
Macroinvertebrates				
Number of individuals	A	158	27.9	1
Number of resistant individuals	B	140	24.6	1
Percentage of resistant individuals	C	98	86.1	19
Percentage of non-native individuals	D	80	8	0
Number of EPT individuals	E	12	1.1	0
Resistant organisms taxa richness	F	2	1.6	1
Percent resistant taxa richness	G	100	69.7	25
Percent non-native taxa richness	H	66	8.6	0
Fish				
Number of native species	I	12	7.6	4
Number of non-native species	J	4	2.3	0
Percent species representing 90% of abundance	L	85.7	61.5	37.5
Percent non-native species richness	M	37.5	24.3	11.1
Percent migratory species	N	33.3	5.5	0
Percent native species abundance	O	100	86.3	58.9
Percent non-native individuals	P	66.8	19	0
Catch per unit effort of non-native species	R	31.7	12.6	2.08
Abundance of rheophilic individuals	S	1.8	0.2	0

mansoni, as it is a possible competitor of the snail (Giovanelli et al. 2002). Another non-native mollusk collected, the bivalve *Corbicula fluminea,* also has a broad distribution in Brazil (Silva & Barros 2011). That species has a Chinese origin and was introduced in the Americas for food (Suriani et al. 2007). One of the problems resulting from the introduction of these species is the obstruction of pipes in reservoirs and hydroelectric structures (Silva & Barros 2011). In some sites, we observed *Macrobrachium amazonicum* (Palaemonidae, Decapoda). This species is broadly distributed in South America, in the basins of the Orinoco, Amazonas, and Paraguay Rivers. Its type locality is the central basin of the Amazon River, in the region of Manaus (Silva et al. 2007).

Similar to macroinvertebrates, only two alien fish metrics were significantly related to differences in disturbance among sites in the reservoir. In Nova Ponte Reservoir, out of five introduced fish species, *P. nattereri* and *C. piquiti* stood out, for being collected in most sampling sites and for being the most abundant. The invasion of non-native species is currently considered the second highest cause of biodiversity loss at a

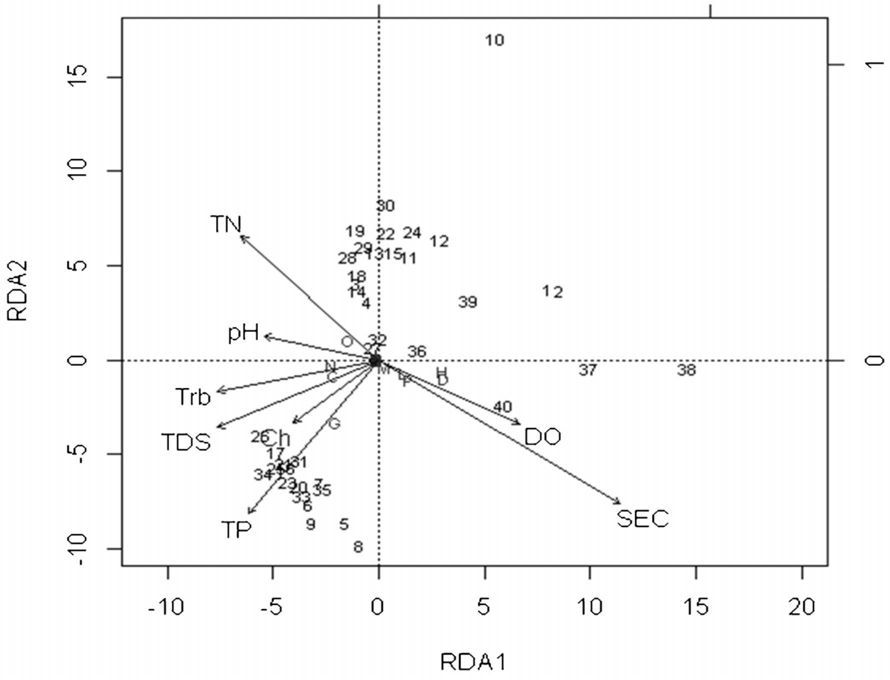

Figure 4. RDA ordination of 40 Nova Ponte Reservoir sites based on water quality. Numbers represent sampling sites, letter combinations represent water quality metrics (Table 3), single letters represent biological metrics (Table 4).

global scale (Coradin & Tortato 2006). These transformations are even more drastic in simplified biological environments, such as reservoirs and when the aliens are piscivores (Hughes & Herlihy 2012). We observed greater native fish species richness and abundance close to the tributaries, which probably resulted from the tendency of the ichthyofauna to colonize sites with physical characteristics similar to the original lotic environment (Agostinho et al. 2007).

Some limnological characteristics were related to the presence of agriculture in the vicinity of some sampling sites. This activity degrades aquatic ecosystems by increasing the entry of pollutants, degrading physical habitat, reducing or completely removing riparian cover, and increasing nutrient concentrations to damaging levels (Allan, 2004). Otherwise, water quality and sediment variables varied little in our study. Homogeneity in physicochemical variables has been reported for other reservoirs also (Beltrão et al. 2009). Araújo & Santos (2001) reported weak associations between abiotic parameters and the ichthyofauna. However, Beghelli et al. (2012) observed a relationship between macroinvertebrates and the trophic state index at different sampling sites in a reservoir in São Paulo state. That study indicated that the benthic macroinvertebrate assemblage responded to nutrient availability and dissolved oxygen concentration. Silva et al. (2006) related low correlations between fish abundance and limnological characteristics to a low susceptibility of fish to alterations in limnological characteristics. In contrast, several studies observed associations between abiotic variables and the distribution of the ichthyofauna in this type of environment (Oliveira et al. 2005, Prchalová et al. 2008). Some environmental variables are particularly associated with fish assemblages, such as depth (Prchalová et al. 2008), availability of littoral zone food and shelter (Vidotto & Carvalho 2007), presence of aquatic vegetation (Pelicice et al. 2005, Abes & Agostinho 2001), dissolved oxygen, temperature, pH, (Castro et al. 2003, Araújo et al. 2009), transparency (Petry et al. 2003) and conductivity (Rodríguez & Lewis 1997). Distribution and abundance patterns of fish species in reservoirs can also be affected by other physical habitat attributes, such as type and size of substrate, presence of macrophytes or submerged vegetation, and type and integrity of riparian vegetation (Kaufmann et al. 2014).

We did not reject our hypothesis that macroinvertebrate and fish assemblages in the reservoir respond to habitat disturbance and water quality. Disturbances at multiple scales may alter natural patterns and processes, leading to environmental changes and damaging biological communities (Ligeiro et al. 2013). Our results reinforce the importance of assessing reservoir ecological conditions at several scales. The study of land use, littoral zone physical habitat, water quality, and assemblage structure set the ground for proposing actions to rehabilitate and conserve aquatic ecosystems (USEPA 2009).

Anthropogenic disturbances are important for defining priority sites for rehabilitation and conservation of ecological characteristics and aquatic biota. Based on our results we suggest further studies in the reservoir to test other explanations for the results observed, as well as to validate the initial assessment, according to the method described by USEPA (2011). Monitoring environmental quality is very important for hydroelectric enterprises responsible for managing a natural resource that has been modified by humans, is sensitive to alterations in time and space, and subjected to multiple competing uses.

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editorial

São Paulo Dialogue: *Biodiversity, ecosystem services and human wellbeing – Matching capacity building needs with resources*

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1. The São Paulo Dialogue was an initiative of the IPBES Task Force on Capacity Building, planned by members of the task force and its Technical Support Unit and approved by the IPBES Bureau and Multidisciplinary Expert Panel (MEP) as an intersessional activity of IPBES. The dialogue was supported by the Governments of Norway and Brazil, and by State of São Paulo Research Foundation (FAPESP) through the BIOTA Program.
2. The objective of the dialogue was to provide advice on how IPBES might go about developing a "matchmaking facility" for bringing those who have capacity building needs (whether financial or technical) together with those who can help address those needs. Such advice will also be relevant in reporting to the third IPBES Plenary and in planning the IPBES Capacity Building Forum.
3. Participants, deliberately selected to cover a range of interests and sectors, were provided a discussion paper which set the essential context and provided some ideas for discussion. This was supplemented by inviting a number of participants to make brief presentations to "kick start" discussion.
4. Participants were encouraged to explore the matters in question from different angles and "think outside the box", helping to identify new approaches rather than repeating the same model unthinkingly. At the time several deliverables under the IPBES work programme were still in the early stages of implementation, and it was recognised that intergovernmental considerations on how these deliverables can best be achieved will benefit from deliberations such as the current dialogue.

Context

5. IPBES aims to strengthen the science policy interface for biodiversity and ecosystem services and thereby contribute to long term human wellbeing and sustainable development. An essential part of this will be sustainably building capacity at the science-policy interface.
6. One key challenge in building capacity is to find effective ways to sustainably address the current asymmetries in the ability to engage in science-policy interface processes such as assessment, development of policy support tools and knowledge generation.
7. In addressing capacity building it is important to reach out to different stakeholders across multiple sectors, in order to communicate to them how biodiversity and ecosystem services contribute to human wellbeing. However it is also important to establish a dialogue with those sectors whereby IPBES also can learn from their different experiences.
8. New institutional initiatives may be necessary, but improved networking and cooperation are essential to making the most effective use of what already exists. This may require investment, innovation, and exploration of how missions, objectives and business plans between potential partners best can be aligned.

Learning from existing initiatives

9. Matchmaking facilities of one form or another have been developed and implemented by a number of other organizations, and IPBES can learn from their experience. Activities undertaken by existing 'matchmaking' approaches include:

    a) Creating and building partnerships between donors and those who have particular needs which require financial support.
    b) Technical support and advice to help in development of proposals for funding, including helping to ensure it aligns with donor interests.
    c) Helping to convene national recipient roundtable meetings to ensure alignment within the country before any proposal is taken to donors.
    d) Helping to convene donor roundtables meetings to bring together those who have projects needing supporting, and existing and potential donors, including the necessary preparatory work.
    e) Stimulating expression of interest submissions, aligned with national planning and relevant to the interests of the process sponsoring the matchmaking.
    f) Advertise offers and opportunities for support online in areas such as volunteers, internships, training and partnerships.
    g) Developing a cadre of ambassadors through engagement such as internships, training, presentations to students to spread knowledge about the tools and approaches available.

10. One additional point is that inviting providers to focus on a specific theme can directly and indirectly over time help raise the profile of the needs associated with the theme. This point may be considered as the Task Force prepares for the Capacity Building Forum.

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11. Challenges and lessons learned from existing matchmaking approaches related to the one IPBES is planning, indicate that an IPBES initiative should:

    ○ benefit from alignment with existing processes used by potential donors, providers and recipients
    ○ be designed so as not to raise expectations beyond the capacity to meet demands
    ○ consider the need for sustainability of funding for management and delivery
    ○ focus on technical and process needs, as well as on financial needs
    ○ have a degree of active management, and not rely on an online clearing house alone
    ○ provide a means to bring people together both virtually and in reality
    ○ address the fact that some potential recipients may need help in expressing their needs
    ○ be demand-driven, addressing the priority needs of experts, institutions, countries and regions
    ○ embrace the need for careful planning based on identified needs and responses
    ○ recognize that much can be done to develop/deliver capacity building through in kind support
    ○ consider approaches that engage and involve the community
    ○ recognize that language barriers exist
    ○ begin small and expand over time through an iterative and modular process

12. Gaining clarity on priority capacity building needs is essential and urgent. There are so many capacity building needs in the environment and development arena, and IPBES efforts risk being a failure unless the matchmaking facility focuses on the specific contribution that IPBES can and should make.
13. It is also essential that IPBES focuses on capacity building activities that respond to real demands and the challenges in meeting such demands. This may necessitate increased attention to understanding why some countries and/or organizations have not had their needs met in the past.
14. This will also include recognising and addressing needs relevant to (and focused on) specific regions and sub-regions, or even nations. May also need to recognise who the key actors are with respect to each of the different needs (which may also vary from one location to another).
15. One obvious lesson is that communication about the facility is essential in order to ensure awareness of what the facility is, where to find it, and what it can do for users. One way of doing this is through the IPBES National Focal Points, but it was noted that as of yet there is not an IPBES focal point in place in each country, nor terms of reference for such focal points.
16. However, additional communication through networks is essential rather than just communicating through national focal points. Reaching out through personal and professional networks of like-minded interest groups and individuals, including both national and regional networks, would spread the message and lead to involvement of many more people.
17. Part of the communication approach should be in convincing people that they are helping themselves by engaging with the matchmaking facility. This should be supported by follow up in order to pick up on those that do not respond the first time round.
18. Given the breadth of the existing landscape, and the range of different types of organizations with which IPBES could be working, and which could be brought together through matchmaking and other approaches, it is important to consider which specific types of institutions or processes should be prioritized, particularly at the start. This might include in the first instance:

    ○ focusing on people and institutions that already have proven experience and know-how
    ○ encouraging south-south cooperation
    ○ promoting those public and private "centres of excellence" already working in this area
    ○ working with existing regional partnerships and networks

IPBES Capacity Building Task Force

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inventory

Non-volant mammals from Núcleo Santa Virgínia, Serra do Mar State Park, São Paulo, Brazil

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Abstract: This study presents data on the composition and species richness of non-flying mammals in the northern part of the Parque Estadual da Serra do Mar, called Núcleo Santa Virgínia (NSV - around 17000 hectares of Atlantic Forest), São Paulo state, southeastern Brazil. The species list was based on *ca.* 660 km of line-transects, 25512 hours of cameras traps, 7740 trap.nights for small mammals, and 394 track-station.days, as well as occasional records and registers from local people (period 2002 to 2009). Based on these complementary methods, a total of 58 species were recorded from the 85-104 possible. Eighteen taxa are listed in the Brazilian endangered species list, 29 in the state list. The high species richness of non-volant mammals and the presence of threatened species show the importance of NSV for the conservation of Atlantic Forest mammals.

Keywords: *Atlantic forest, inventory, Mammalia, sampling methods, species richness.*

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Resumo: Este estudo apresenta dados de composição e riqueza de espécies de mamíferos não voadores da porção norte do Parque Estadual da Serra do Mar, que corresponde à região do núcleo Santa Virgínia (NSV – cerca de 17.000 hectares de Floresta Atlântica), estado de São Paulo, sudeste do Brasil. A listagem de espécies foi elaborada durante o período de 2002 a 2009, por meio de *ca.* 660 km de transecções lineares, 25.512 horas de armadilha fotográfica, 394 armadilhas-de-pegada.dia, registros ocasionais e relatos de moradores da região (entrevistas) para mamíferos de médio e grande porte, e 7.740 armadilhas.noite para pequenos mamíferos. Foram registradas 58 espécies de 85-104 de possível ocorrência dada suas potenciais distribuições. Dezoito espécies fazem parte da lista nacional da fauna ameaçada de extinção e 29 da lista estadual. A elevada riqueza de mamíferos não voadores com a presença de várias espécies ameaçadas, indica a importância do NSV para conservação da mastofauna regional.

Palavras-chave: *Floresta Atlântica, inventário, Mammalia, métodos de amostragem, riqueza de espécies.*

Introduction

The Atlantic Forest, one of the most threatened biomes on the planet, contains 298 species of mammals, 90 of which are endemic (Paglia et al. 2012) and 14% threatened under extinction (Chiarello et al. 2008). With approximately 60% of the Brazilian population living in these areas (Pinto et al. 2006), the Atlantic Forest remains under pressure due to urbanization, increasing road network, construction of pipelines, uncontrolled growth of ecotourism (SMA 1999, MMA 2002), hunting and extraction of plant resources (Galetti & Chivers 1995, Dean 1996, Galetti & Fernandez 1998, Cullen et al. 2000). As a consequence, currently less than 11% (16,377,472 ha) of its original vegetation remains, and of these, only 13.8% are legally protected (Ribeiro et al. 2009).

Although threatened and with an urgent need for scientific surveys, biodiversity in few localities of this biome have been investigated, and most often, few groups were targeted for study. In the case of mammals, this scenario is further complicated. Rare are the times in which the group is inventoried as a whole (e.g. Voss & Emmons, 1996), studies with partial sampling being more common. These "partial" studies lacks some methods and/or last just a short time. Mammal surveys tend to adopt the following division, based on animals' habits and different sampling protocols: small terrestrial mammals (e.g. Barros-Battesti et al. 2000, Pardini & Umetsu 2006, Pinto et al. 2009), Bats (e.g. Bianconi et al. 2004, Faria et al. 2006, Luz et al. 2011) and medium and large bodied mammals (e.g. Negrão & Valladares-Pádua 2006, Abreu & Köhler 2009). Exceptions being studies, such as Geise et al. (2004), Cunha & Rajão (2007) and Passamani et al. (2005) that included all non-flying mammals, or even Paglia et al. (2005) and Modesto et al. (2008) that additionally included bats.

The largest set of Atlantic Forest remnants is located in the Serra do Mar, mainly in the state of São Paulo and represents approximately 7% of what remains of the biome (Ribeiro et al. 2009). The Serra do Mar State Park ("Parque Estadual da Serra do Mar" - PESM) protects an area of 315,000 ha in this region, situated in a highly populated area of São Paulo (ca. 14 million) (Instituto Florestal 2006). Due to its size, the park is managed through eight regional administrative centers that are in different situations with regard to regularization, environmental pressures, conservation status and fiscalization (Instituto Florestal 2006).

Located in the northern portion of PESM the Núcleo Santa Virginia (NSV) is recognized for its high biological diversity, being an active site for important faunal and floristic studies in the state of São Paulo (e.g., Galetti et al. 2009, Rocha-Mendes 2010, Martins 2011, Silva & Tozzi 2013). Among terrestrial vertebrates, some groups that have been locally assessed include birds (Goerck 1999), serpents (Hartmann et al. 2009) and fish (Gomiero & Braga 2006). For mammals, the species list available comes from the Management Plan of the park (Instituto Florestal 2006) and Wang (2002), who described the diets of three spotted cats and listed their preys. With the aim of expanding the knowledge of mammals in this important conservation area, the PESM, and in particular the NSV, this paper presents the results obtained through a combination of field sampling methods applied during the period of 2002-2009 to survey non-flying mammals.

Material and methods

Study area

Núcleo Santa Virginia (NSV - 23°17' to 23°24'S and 45°03' to 40°11'W) is an administrative division of the Serra do Mar State Park. NSV covers approximately 17,000 ha, and is located within the municipalities of Cunha, Natividade da Serra, São Luis do Paraitinga and Ubatuba in the State of São Paulo (Figure 1). NSV is situated on a narrow strip of the Atlantic plateau between the coast and the Paraiba valley, forming the Atlantic Plateau Unit ("Unidade Planalto Atlântico") - of the Upper Paraíba Basin ("Bacia Superior do Paraíba"). The local climate is "coastal humid characteristic of tropical coasts exposed to the Atlantic" with an annual average rainfall of 2,200 mm and seasonal rainfall differences, with the austral autumn and winter periods considered driest. The average temperature ranges from 18 °C to 22 °C (Instituto Florestal 2006).

Vegetation cover consists of 60 % dense rainforests and pristine/little changed montane forests, with the remainder a mixture of disturbed areas and plantations of *Pinus* spp. and *Eucalyptus saligna* (Tabarelli et al. 1994, Instituto Florestal 2006), the relief is very steep with embedded valleys and straight strands, and the average altitude is 860 meters to 1500 meters (Instituto Florestal 2006). Hunting pressure within NSV ranges from almost nonexistent to moderate (Marques 2004) and it is considered a priority area for PESM biodiversity conservation, due to the floral and faunal importance of the region, with species restricted to the plateau and highly diverse primary vegetation (Instituto Florestal 2006). Most of the mammal sampling effort was concentrated around two research bases: Itamambuca (headquarters - 45°5'16"W/23°19'29"S) - located in the northern portion, bordering Núcleo Cunha and Vargem Grande (headquarters - 45°14'39"W/23°26'16"S) - located in the central portion, bordering Núcleo Picinguaba (Figure 1).

Data collection

Mammal species were recorded through a combination of standardized methods, namely: diurnal and nocturnal line transect census, camera trapping, track-stations, live-traps (Sherman traps of three different sizes [23 x 7.5 x 8.5 cm, 30 x 7.5 x 9.5 cm , and 37.5 x 10 x 12 cm], and Tomahawk traps [45 x 16 x 16 cm]), pitfalls, as well as occasional records and information from third parties.

Sampling of small non-flying mammals - here marsupials and cricetidae and echimyids rodents - was performed with equal effort in both research bases in bimonthly sessions of five capture nights, from September 2008 to September 2009. One hundred and eighty live traps were distributed equally in six sample plots of 0.6 ha (60 x 100 m), three at each base. Each plot consisted of 24 sample locations (20 m equidistant), which randomly received a Sherman trap, and six also received a Tomahawk, totaling 30 traps per plot, always located on the ground. Additionally, twelve lines of pitfall traps were installed, six in each base. Each line consisted of four 60 L plastic buckets separated by 10 m and joined by a plastic screen (approximately 50 cm tall), the lines were paired, equally spaced 30 meters. At the same base, both live trap plots and pitfall line pairs were separated by at least 100 m from the closest plot or line pair.

The live traps, as well as pitfalls were baited with a mix of mashed banana, peanut butter, bacon and ground cornmeal. The marsupials and rodents caught were identified and marked with numbered tags (Ear tags, National Band and Tag Co., Newport, Kentucky, USA) and then released (following guidelines of the American Society of Mammalogists - ASM, Sikes et al. 2011). Due to the difficulty of identifying species using only external characters, some specimens were retained for morphological, cytogenetic and molecular analysis (with specialists' help), and comparison with reference collections (IBAMA license No. 14428-2). These specimens were submitted as references to the Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu Nacional (MN) and Museu da Universidade Federal do Espírito Santo (UFES). Specimens that had not been deposited yet in these scientific collections are denoted by the initials of the collector: Carolina Lima Neves (CLN) (more information Di-Nizo et al. 2014).

The sampling success of terrestrial small mammals was assessed using species accumulation curves and rarefaction curve (Jackknife 1), both related to the sampling effort in number of traps per night - EstimateS Version 8.2.0 (Copyright R. K. Colwell: http://viceroy.eeb.uconn.edu/estimates) program (Colwell 2009).

The records of other terrestrial mammals took place during two sampling periods, from 2002 to 2005 and then from 2007 to 2009. The methods used were line transects, camera traps and track-stations, along pre-existing trails within NSV (trails: Rio Grande, Rio do Veado, Pau de Bala, Santa Virgínia-Cunha),

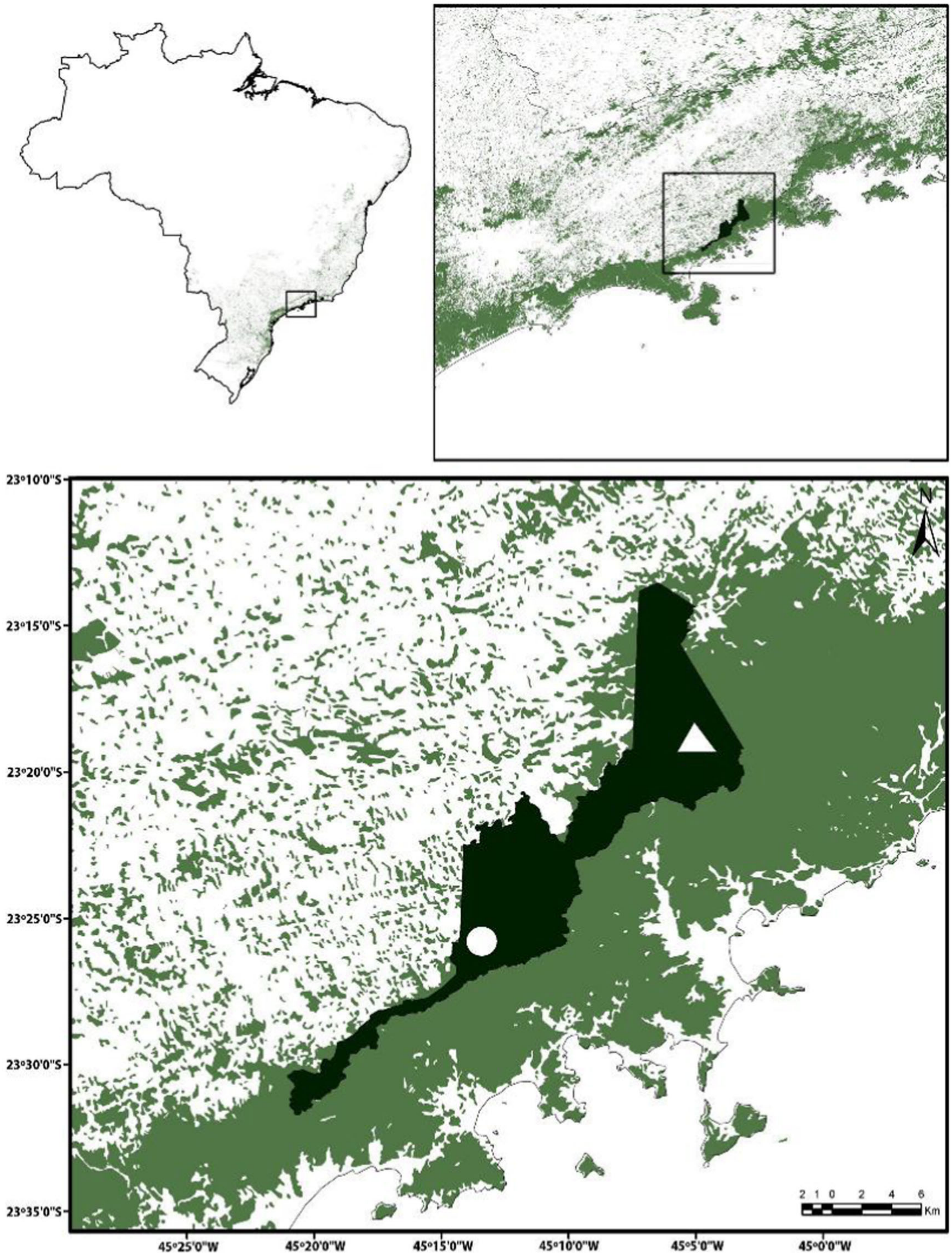

Figure 1. Location of Núcleo Santa Virgínia, Serra do Mar State Park – east São Paulo State, in the context of Brazil, showing remnants of Atlantic Forest (source: SOS Mata Atlântica 2010). In detail the study sites: Vargem Grande base = circle, Itamambuca base = triangle.

predominantly close to the research bases of Itamambuca and Vargem Grande, in native vegetation area. Transects were walked (average speed of 1 km/h) throughout the day and timings varied with climatic conditions. The camera traps were placed along the trails and in the forest, where they remained active for seven to 30 consecutive days. Track-stations were used for only three months (August-November 2004) and consisted of sand plots (50 x 50 cm x 3 cm deep), spaced every 100 m along four trails, totaling 59 stations. Each of the track-station trails was evaluated for six to eight times during the sample period.

The sampling effort employed at the end of the study using systematic methods can be seen in Table 1, in addition, other records were collected on an occasional basis over the course of field activities as well as through informal conversations with NSV staff and locals. To compile the species list for the area, basic information from the Parks management plan was also

Table 1. Sampling effort used to survey non-volant mammals in Núcleo SantaVirginia, Serra do Mar State Park - São Paulo.

Method	Effort
Line transect	659.15 km
Camera traps	25,512 h
Track-stations	394 station.days
Live trap	6,300 trap.nights
Pitfall	1,440 bucket.nights

considered (Instituto Florestal 2006). The conservation status of the species in state and national levels followed the information available at: Fauna Ameaçada de Extinção no Estado de São Paulo: Vertebrados (2009), MMA & Fundação Biodiversitas (2008) and Machado et al. (2005).

Results

A total of 58 species of non-flying mammals were recorded at NSV, of which 50 were captured or observed using standardized techniques (present study), six from reports regarding current or historical presence in the area (*Chironectes minimus*, *Callicebus nigrifrons*, *Brachyteles arachnoides*, *Panthera onca*, *Chrysocyon brachyurus* and *Speothos venaticus*), and two during the implementation of the Management Plan (*Monodelphis americana* and *Akodon cursor*) (Table 2). With 20 species Rodentia was the best represented order, followed by Carnivora (n=9) and Didelphimorphia (n=9) (Table 2). *Canis lupus familiaris* was the only exotic species recorded in the NSV, however was not included in the final listing.

Among the methods used, interviews and the occasional records provided the greatest number of species, with 29 (50% of the total) and 26 (45%) species, respectively. Approximately 41% of the species were uniquely identified by a single sampling method and approximately 29% were recorded using two different methods. Track-stations and line transects did not produce unique records of any mammal, while the data collected using live-traps, pitfalls and interviews resulted in three, seven and six unique records, respectively (Table 2).

Mean cumulative species curve, made on the basis of 20 taxa of small mammals captured, considering the effort of both the live and pitfall traps, showed a tendency towards stabilization, whereas the cumulative curve of species caught showed that only two additional taxa were included in the sample after the first half of the sampling effort (3,870 trap.nights) (Figure 2). This richness of small mammals corresponds to 87% of that predicted using the Jackknife 1 estimator (23 species).

Regarding the conservation status, 14 of the 58 species (i.e., 24% of the total) are under threat at the state level. Being classified as "Critically Endangered" (CE): *Panthera onca*, "Endangered" (EN): *Leopardus wiedii*, *Brachyteles arachnoides*, and *Tayassu pecari* and "Vulnerable" (VU): another 10 species (Table 2). Eleven other species are classified as "Near Threatened" (NT) (i.e. there is an indication that they are close to being classified into one of these categories in the near future), while five qualify as "Data Deficient" (DD). According to the national list of threatened species, eight species are classified as VU and one is listed as EN (*Brachyteles arachnoides*), while four are classified as NT and four as DD (Table 2).

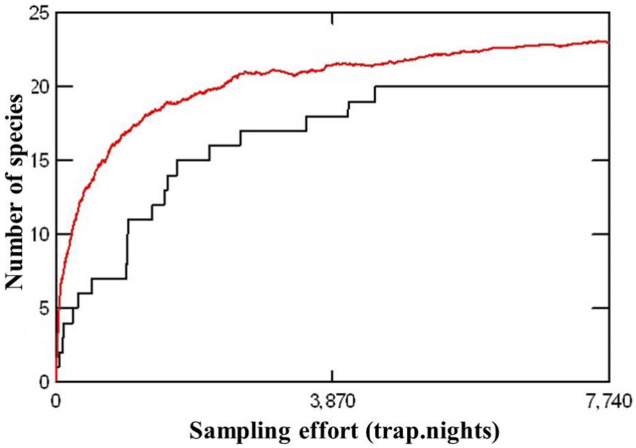

Figure 2. Mean species accumulation curve (red line) and cumulative curve of species captured (in black) of small non-volant mammals in relation to sampling effort.

Discussion

Considering the species of non-flying mammals occurring in Brazil (Paglia et al. 2012), São Paulo (Vivo et al. 2011) and, potentially occurring in the study region (cf. NaturaServe 2014), NSV has 12% of the recorded species for the country, 45% of those occurring in the state, and between 55-68% of species expected for the region (Table 3).

In comparing the results of this study with other studies carried out in the Atlantic Forest of southeastern Brazil, NSV has one of the highest species richness of non-flying mammals (Table 2 and 3). In the Parque Estadual do Desengano (RJ - 22,400 ha) a total of 41 taxa were recorded, 17 of them based solely on the reports of others (Modesto et al. 2008). Cunha & Rajão (2007) recorded 26 species in the Terra Indígena Sapukai (RJ - 2,100 ha), including three exotics (*Canis lupus familiaris*, *Felis catus* and *Mus musculus*), and Passamani et al. (2005) recorded 48 species around the Estação Ecológica Santa Lucia (ES - 440 ha). For the state of São Paulo, De Vivo and Gregorin (2001) reported 58 species for Parque Estadual de Intervales (SP - 48,000 ha) and, more recently, Brocardo et al. (2012) reported 53 species for the Parque Estadual Carlos Botelho (SP - 37,644 ha) - Paranapiacaba forest continuum. Particularly for the PESM, Pinheiro & Geise (2008) recorded 13 species of small mammals (five marsupials and eight rodents) in núcleo Pinciguaba, located in the lowland forests of the protected area, compared to 24 species (9 marsupials and 15 rodents) considered in the present study.

Six new species records have been added to the list of non-flying mammals (n = 69) available in the PESM Management Plan - which considers the entire length of the unit (Instituto Florestal 2006). They are, the marsupial *Monodelphis* sp. and rodents *Akodon montensis* and *Kannabateomys amblyonyx*; the armadillo *Cabassous tatouay* and the canids *Chrysocyon brachyurus* and *Speothos venaticus*. Although the last two records came from third-party reports, for the maned wolf the source of information is reliable (J.P. Villani, area manager, reports the capture of an individual within the limits of NSV), and for the bush dog, there is corroborating data available

Table 2. Mammal species recorded in Núcleo Santa Virginia, Serra do Mar State Park, São Paulo. Taxonomic classification based on Wilson & Reeder (2005).

ORDER / FAMILY / Species	**Technical vernacular**	**Record type**	**Conservation status**	
			São Paulo	**Brazil**
DIDELPHIMORPHIA				
DIDELPHIDAE				
Chironectes minimus (Zimmermann, 1780)	cuíca-d'água	In	NT	
Didelphis aurita (Wied-Neuwied, 1826)	gambá-orelha-preta	Lt, Pf, Ct, Ro	LC	
Marmosa paraguayana (Tate, 1931)	cuíca	Lt	LC	
Marmosops incanus (Lund, 1840)	cuíca	Lt, Pf	NT	
Monodelphis sp.	catita	Pf		
Monodelphis americana (Müller, 1776)	catita	B	NT	DD
Monodelphis iheringi (Thomas, 1888)	catita	Pf	VU	DD
Monodelphis scalops (Thomas, 1888)	catita	Lt, Pf	NT	DD
Philander frenatus (Olfers, 1818)	cuíca-quatro-olhos	Lt, Pf	LC	
CINGULATA				
DASYPODIDAE				
Dasypus novemcinctus Linnaeus, 1758	tatu-galinha	In, Ct, Ro, B	LC	
Euphractus sexcinctus (Linnaeus, 1758)	tatu peba	In, Ro	LC	
Cabassous tatouay (Desmarest, 1804)	tatu-do-rabo-mole	Ro	DD	DD
PILOSA				
BRADYPODIDAE				
Bradypus variegatus Schinz, 1825	bicho-preguiça	Ro, B	LC	
MYRMECOPHAGIDAE				
Tamandua tetradactyla (Linnaeus, 1758)	tamanduá-mirim	Ct, Ro	LC	
PRIMATES				
CEBIDAE				
Callithrix aurita (É. Geoffroy, 1812)	sagüi	In, Tl, Ro	VU	VU
Sapajus nigritus (Goldfuss, 1809)	macaco-prego	In, Tl, Ro	NT	NT
PITHECIDAE				
Callicebus nigrifrons (Spix, 1823)	sauá	In	NT	NT
ATELIDAE				
Alouatta clamitans Cabrera, 1940	bugio	In, Tl, Ro	NT	NT
Brachyteles arachnoides (É. Geoffroy, 1806)	mono	In	EN	EN
RODENTIA				
SCIURIDAE				
Guerlinguetus ingrami (Thomas, 1901)	serelepe	In, Tl, Ro, B	LC	
CRICETIDAE				
Akodon cursor (Winge, 1887)	rato	B	LC	
Akodon montensis (Thomas, 1913)	rato	Lt, Pf	LC	
Blarinomys breviceps (Winge, 1887)	rato	Pf	DD	
Brucepattersonius soricinus Hershkovitz, 1998	rato	Lt, Pf	NT	
Calomys tener (Winge, 1887)	rato	Pf	LC	
Drymoreomys albimaculatus Percequillo, Weksler & Costa, 2011	rato	Pf		
Euryoryzomys russatus (Wagner, 1848)	rato	Lt, Pf	VU	
Juliomys pictipes (Osgood, 1933)	rato	Pf	LC	
Nectomys squamipes (Brants, 1827)	rato	Lt, B	LC	
Oligoryzomys nigripes (Olfers, 1818)	rato	Lt, Pf	LC	
Rhipidomys itoan Costa, Geise, Pereira and Costa, 2011	rato	Pf		
Sooretamys angouya (Fischer, 1814)	rato	Lt	LC	
Thaptomys nigrita (Lichtenstein, 1829)	rato	Lt, Pf, B	VU	
ERETHIZONTIDAE				
Coendou spinosus Cuvier, 1823	ouriço	In, Ro	LC	
CAVIIDAE				

Continued on next page

Table 2. Continued.

ORDER / FAMILY / Species	**Technical vernacular**	**Record type**	**Conservation status**	
			São Paulo	**Brazil**
Hydrochoerus hydrochaeris (Linnaeus, 1766)	capivara	In, Tl, Ro	LC	
DASYPROCTIDAE				
Dasyprocta iacki Feijó & Langguth, 2013	cutia	In, Tl, Ct, Ro		
CUNICULIDAE				
Cuniculus paca (Linnaeus, 1766)	paca	In, Ct, Ro	NT	
ECHIMYIDAE				
Kannabateomys amblyonyx (Wagner, 1845)	rato-da-taquara	Ro	DD	
Trinomys iheringi (Thomas, 1911)	rato	Lt, Pf	LC	
LAGOMORPHA				
LEPORIDAE				
Sylvilagus brasiliensis (Linnaeus, 1758)	tapeti	In, Ro, B	LC	
CARNIVORA				
FELIDAE				
Leopardus guttulus (Hensel, 1872)	gato-do-mato	Ct, B	VU	VU
Leopardus pardalis (Linnaeus, 1758)	jaguaririca	In, Tl, Ct, Ro, B	VU	VU
Leopardus wiedii (Schinz, 1821)	gato-maracajá	Ct, B	EN	VU
Panthera onca (Linnaeus, 1758)	onça-pintada	In	CR	VU
Puma concolor (Linnaeus, 1771)	suçuarana	In, Ct, Ro	VU	VU
Puma yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	gato-mourisco	Ct	LC	
CANIDAE				
Cerdocyon thous (Linnaeus, 1766)	cachorro-do-mato	In, Ct, Ro	LC	
Chrysocyon brachyurus (Illiger, 1815)	lobo-guará	In	VU	VU
Speothos venaticus (Lund, 1842)	cachorro-vinagre	In	DD	VU
MUSTELIDAE				
Lontra longicaudis (Olfers, 1818)	lontra	In, Ro	NT	NT
Eira barbara (Linnaeus, 1758)	irara	In, Tl, Ct, Ro	LC	
Galictis cuja (Molina, 1782)	furão	In, Ro, B	DD	
PROCYONIDAE				
Nasua nasua (Linnaeus, 1766)	quati	In, Tl, B	LC	
Procyon cancrivorous (G.[Baron] Cuvier, 1798)	mão-pelada	In, Ct, Ro	LC	
PERISSODACTYLA				
TAPIRIDAE				
Tapirus terrestris (Linnaeus, 1758)	anta	In, Ct, Ts, Ro	VU	
ARTIODACTYLA				
TAYASSUIDAE				
Pecari tajacu (Linnaeus, 1758)	cateto	In, Ct, Tl, Ro	NT	
Tayassu pecari (Link, 1795)	queixada	In, Ct, Tl, Ro	EN	
CERVIDAE				
Mazama americana (Erxleben, 1777)	veado	In, Ro	VU	

Type of record = VLT – Visual during line transects, Ct – camera traps, Ts – track-station, Lt – live trap (*Sherman or Tomahawk*), Pf – pitfall, Ro – occasional record, In – Interviews, B – bibliographic data (Wang 2002, Instituto Florestal 2006). *Conservation Status* (species classification category IUCN 2001)/Level of Threat following Decreto N° 53.494, (2 October 2008), Fauna Ameaçada de Extinção no Estado de São Paulo: Vertebrados (2009), MMA & Fundação Biodiversitas (2008) and Machado et al. (2005): NT (Near threatened); LC (Least concern); DD (Data deficient); VU (Vulnerable); EN (endangered); CR (Critically endangered).

(Emmons & Feer 1997, Eisenberg & Redford 1999, Cheida et al. 2011) including the study region (*lato sensu*) within its range. Exclusive records of small mammals from Wang (2002) were not used, because it is not a specific work with the group, which has so many identification intrinsic problems.

For other taxa that were only recorded through interviews, evidences of their current or historical presence in the area are strong and persuasive. *Callicebus nigrifrons*, for example, occurs in dense mountain rain forest in PESM (Cunha/Indaiá), a vegetation formation also present in the NSV (Instituto Florestal 2006). *Brachyteles arachnoides* was recorded in the vicinity, specifically in Cunha (Marques 2004), which is part of the same continuous forest. And, *Panthera onca* was recently confirmed by genetic analysis of scats carried out by the Departamento de Genética e Evolução – Universidade Federal de São Carlos (P.M. Galetti Jr. pers. com). Finally, *Chironectes minimus*, the only small species to be recorded only through the reports of others, in addition to being easily

Table 3. Representation of mammals occurring in Núcleo Santa Virginia in relation to Brazil (Paglia et al. 2012), São Paulo State (Vivo et al. 2011) and NatureServe (2014) projections.

Order	Brazil	São Paulo	Projection of NatureServe	Núcleo Santa Virginia
Didelphimorphia	55	24	19-22	9(a)
Cingulata	11	5	5-6	3
Pilosa	8	3	3	2
Primates	118	10	5-8	5(b)
Lagomorpha	1	1	1	1
Carnivora	26	17	12-15	14(c)
Perissodactyla	1	1	1	1
Artiodactyla	10	8	6	3
Rodentia	234	58	33-42	20
TOTAL	464	127	85-104	58

(a) One species with unconfirmed record; (b) Two species with unconfirmed records; (c) Three species with unconfirmed records.

identified by their conspicuous traits, is also a specialist animal for a particular type of habitat (streams, usually isolated) (Bianconi & Rossi 2011), which is frequent in the area.

Both species of small mammals (*Monodelphis americana* and *Akodon cursor*) recorded exclusively during the elaboration of the Management Plan (Instituto Florestal 2006) deserve caution. Besides having cryptic characteristics, these taxa were not identified with cytogenetic or molecular analyzes during the technical work (A.P. Carmignotto pers. com.). All specimens of the genus *Akodon* and *Monodelphis* (with three stripes) collected during this study were genetically identified as *A. montensis* and *Monodelphis iheringi* respectively (R.D. Cardoso pers. com.). Thus, more detailed examination of the specimens collected on the Management Plan would be prudent to elucidate whether these species occur in sympatry in NSV.

As noted in the Management Plan, a single deer species represented the order Artiodactyla: *Mazama americana*. This result may be related to the low population density of co-generas - especially *M. gouazoubira*, which is considered to be the most abundant and widely distributed Brazilian deer species (Duarte 1996) - or even the absence of individuals in the region. For the other orders of non-flying mammals, the richness observed in NSV was very close to the expected (Instituto Florestal 2006, NatureServe 2014).

The use of several complementary sampling methods was essential to provide a complete as possible list of mammals occurring in the NSV. For small mammals, the observed richness was satisfactory, accounting for 87% of the estimated species (Jackknife 1), of which 90% were registered in the first half of the sampling effort (Figure 2). However, based on the collectors curve and the state and regional lists (Vivo et al. 2011, NatureServe 2014), new taxa should be incorporated, especially through the effort increment and sampling in other environments, such as different successional stages and altitudes.

Based on the elevated mammal richness, including many endangered species (Table 2) and with the presence of species from various trophic levels (e.g., herbivores, frugivores, carnivores, prey and predators), the uniqueness and significance of NSV for the maintenance and conservation of regional biodiversity becomes explicit. Also noteworthy is its relevance as a location for diverse ecological studies as well as studies that continue to inventory the local mammals, with an expansion of sampling methods and inclusion of the order Chiroptera.

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Bird-termite interactions in Brazil: A review with perspectives for future studies

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Abstract: We present a review on the principal interactions between birds and termites in Brazil. We found 218 bird species feeding on termites or using termitaria for nesting or perching. Termites were mentioned as food source for 179 bird species. Alates were the most consumed caste. Termitaria were mentioned as nest site for 45 bird species. Some bird species also perch on the top of termite mounds to search for their prey or to conduct territorial and/or courtship displays. Considering all interactions between both animal groups, little is known about the identification of termite genera or species. Therefore, we suggest more detailed studies to be conducted on the natural history and ecology of interactions between birds and termites in Brazil.

Keywords: *birds, Brazil, feeding, nesting, termites.*

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Resumo: Apresentamos aqui uma revisão sobre as principais interações entre aves e cupins no Brasil. Foram registradas 218 espécies de aves alimentando-se de cupins ou usando cupinzeiros para nidificar ou se empoleirar. Os cupins foram citados como recurso alimentar para 179 espécies de aves, sendo as formas aladas as mais consumidas. Os cupinzeiros foram citados como sítio de nidificação para 45 espécies de aves. Algumas espécies de aves também se empoleiram no alto de termiteiros para localizar suas presas ou para realizar exibições territoriais e/ou de corte. Considerando-se todas as interações entre ambos os grupos de animais, pouco ainda se conhece sobre a identificação dos gêneros e espécies de térmitas envolvidos. Assim, sugerimos a realização de estudos mais detalhados sobre história natural e ecologia das interações entre aves e cupins no Brasil.

Palavras-chave: *aves, Brasil, alimentação, nidificação, cupins.*

Introduction

Termites (Insecta: Isoptera) have been reported as an important food resource for birds around the world (Eisenmann 1961, De Bont 1964, Thiollay 1970, Dial & Vaughan 1987, Paiva 1998, Kok et al. 2000, Kopij 2000, Mallet-Rodrigues 2001, Gussoni & Campos 2003, Olson & Alvarenga 2006, Faria 2007, Sazima 2008). Termitaria (termite nests) also represent nest sites for several bird species (Hardy 1963, Sazima 1989, Dubs 1992, Naka 1997, Sick 1997, Brightsmith 2000).

Brazil holds one of the richest world avifaunas, with c. 1,800 bird species (Sick 1997, CBRO 2014). Nevertheless, little is known about various aspects of natural history of these species. Examples are the interactions between birds and termites. The 19th century German naturalist, Prince Maximilian of Wied-Neuwied explored the Campos Geraës, between the states of Minas Gerais and Bahia, and appears to have been the first to report such observations (Wied-Neuwied 1821).

Later, the German ornithologist Helmut Sick, who visited and stayed in Brazil since 1939 and is one of the leading exponents of Brazilian ornithology of the 20th century, also studied termites when he was a prisoner on Ilha Grande, during the World War II (Gonzaga 1991, Sick 1997). He also remarked the importance of termites either as food as providing shelter for birds and other animals, especially in his study of the Cerrado fauna (Sick 1965) and in his classic book on Brazilian ornithology (Sick 1997).

The naturalist Balthasar Dubs was also devoted to the study of birds in the vegetations of the central-western regions of Brazil. His book on the birds of the Pantanal and adjacent areas (Dubs 1992) presents a discussion on the role of termite mounds in forming the landscape of patches of cerradão or forest in the Pantanal region (the mounds are called "murundus" – for a review of the theories on their role in the landscape formation, see Oliveira-Filho 1992a, b), including photographs of this habitat type.

Recently, some authors reported termites as a food resource for birds in Brazil (Paiva 1998, Mallet-Rodrigues 2001, Gussoni & Campos 2003, Olson & Alvarenga 2006, Faria 2007, Sazima 2008). Nevertheless, studies and information on the interaction between birds and termites in this country are very scarce and fragmentary. The aim of this paper is to present a review on the importance of termites for Brazilian birds and to suggest perspectives for future research.

Materials and methods

The present review attempted to cover all published information on interactions between birds and termites in Brazil, which includes articles, book chapters, books and photographs available online (www.wikiaves.com.br) until January 2014 (see Table 1). On the Wiki Aves database we searched for photos using the keywords for "foraging", "feeding" and "nest" or "nesting". The principal interactions we found were those related to birds using termites as food resources and termitaria as nest sites or perches. We also included unpublished observations made by several colleagues, as well as some of our personal field observations. Wherever possible, for each record, we considered the lowest taxonomic level of identification of the termites, the castes involved (alates, soldiers and workers - in the case of food resource) and the type of termite nest, according to the building site: epigean or mound; arboreal (supported on a tree or similar); rupicolous (upon a rock). Taxonomy of bird species follows the Comitê Brasileiro de Registros Ornitológicos (CBRO 2014).

Results and Discussion

1. *General inventory of bird-termite interactions in Brazil*

We found a total of 218 bird species that use the termites in a direct way (food resource) or indirectly (such as the use of termitaria as nesting or perching sites) (Table 1). This number represents approximately only c. 12% of Brazilian the avifauna (Sick 1997, CBRO 2014). Below, we present and discuss each of these types of interactions.

2. *Termites as food resource for Brazilian birds*

Termites have been reported as food resource for 179 species of birds in Brazil, of 51 families (Table 1). The families with the largest number of bird species feeding on termites are: Thraupidae (29 species), Tyrannidae (25), Picidae (11) and Thamnophilidae (10) (Figure 1).

Little is known about the taxonomic groups of termites consumed by birds. Among the 277 records, in 189 (68.2%) termites were identified at order level; in 50 (18.1%), at the family level; in 33 (11.9%), at the genus level and only in 5 (1.8%), at specific level (Figure 2).

Considering the different castes consumed by birds, among the 290 records, 189 (65.2%) report alates, 17 (5.9%) are related to soldiers and 15 (5.2%) mention workers. In 69 records (23.7%), castes were not mentioned (Figure 3).

Thus, alates seem to represent the main caste consumed by birds. But the problem is that swarms are unpredictable events in space and time, so that winged termites represent a resource that should be exploited in an opportunistic manner. Predation of alates by birds has been studied in more details in Africa (e.g., De Bont 1964, Thiollay 1970, Dial & Vaughan 1987, Kok et al. 2000, Kopij 2000). Unfortunately, little has been studied about this interaction in Brazil. For example, opportunistic information was reported by Cunha (1961), who observed a domestic hen, swallows and tyrant-flycatchers feeding on winged termites. In September 1989, Paiva (1998) observed 12 species of birds preying alates in an urban park in Piracicaba/SP.

Gussoni & Campos (2003) reported 26 species of birds feeding on alates in Arujá/SP, in January 2002.

In the montane forests of the Serra da Mantiqueira, in April 2001, Olson & Alvarenga (2006) observed 23 species of birds feeding on winged termites. In this event, they recorded many specimens of the Buff-throated Warbling-Finch (*Poospiza lateralis*), a species endemic to the high mountains of south-eastern Brazil (Assis et al. 2007). Further, three Black-capped Piprites (*Piprites pileata*), a threatened species (BirdLife International 2000, Machado et al. 2005), were also feeding on alates. The authors observed that several species that commonly forage on the ground or among bushes were catching those termites in the air during this event.

In the same mountain range, in December 2002, C. R. M. Abreu and M. Maldonado-Coelho (*pers. comm.*) observed alates swarming after rain, in a transitional area of montane forest and high-altitude grassland (*campo de altitude*), in Matutu Valley (elevation: 1,990 m), Aiuruoca/MG. Six bird species were consuming these insects: the Highland Elaenia (*Elaenia obscura*), the Blue-billed Black-Tyrant (*Knipolegus cyanirostris*), the Blue-and-white Swallow (*Pygochelidon cyanoleuca*), the Diademed Tanager (*Stephanophorus diadematus*), the Rufous-collared Sparrow (*Zonotrichia capensis*) and the Bay-chested Warbling-Finch (*Poospiza thoracica*). *Pygochelidon cyanoleuca* captured termites in flight, while *K. cyanirostris*, *Z. capensis* and *P. thoracica* catched insects among leaves (in the forest edge) and in the bushes (in the grassland). *Elaenia obscura* and *S. diadematus* captured termites both in flight, as well as among the foliage.

Also in the Serra da Mantiqueira, a termite swarm was observed after a light rain in the late afternoon of 27 March 2007, in a transition area between a montane forest and the *campo de altitude* at Pedra de São Domingos (elevation: c. 1,970 m), in Gonçalves/MG (MFV *pers. obs.*). Only one specimen of *Z. capensis* and two individuals of *P. lateralis* were observed feeding on the winged termites among the foliage.

In November 2001, MFV and S. D'Angelo-Neto observed a swarm in Lavras/MG. Alates were flying in the edge of a secondary forest and adjacent open areas (pastures), being captured by the domestic Helmeted Guineafowl (*Numida meleagris*, n = 2), and the following native species: Green-barred Woodpecker (*Colaptes melanochloros*, n = 1), Rufous Hornero (*Furnarius rufus*, n = 2), Masked Water-Tyrant (*Fluvicola nengeta*, n = 2), Social Flycatcher (*Myiozetetes similis*, n = 1), Boat-billed Flycatcher (*Megarynchus pitangua*, n = 1), Streaked Flycatcher (*Myiodynastes maculatus*, n = 1), Variegated Flycatcher (*Empidonomus varius*, n = 1), Crested Becard (*Pachyramphus validus*, n = 1), Hooded Tanager (*Nemosia pileata*, n = 2), Pileated Finch (*Lanio pileatus*, n = 1), Sayaca Tanager (*Tangara sayaca*, n = 3), Swallow Tanager (*Tersina viridis*, n = 2), Rufous-collared Sparrow (n = 1), Saffron Finch (*Sicalis flaveola*, n = 2), Crested Oropendola (*Psarocolius decumanus*, n = 1) and Shiny Cowbird (*Molothrus bonariensis*, n = 1). Except *F. nengeta*, *Z. capensis* and *L. pileatus*, which caught the alates when they landed on the ground, all other species caught insects in the air. The Helmeted

Table 1. Bird species and their interactions with termites in Brazil.

	Interaction Type			Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Tinamidae								
Crypturellus soui	X			Termitidae	soldier	-	-	Schubart et al. (1965)
Crypturellus parvirostris	X			Isoptera	worker	-	-	Moojen et al. (1941)
				Isoptera	not mentioned	-	-	Hempel (1949)
				Termitidae	not mentioned	-	-	Schubart et al. (1965)
Rhynchotus rufescens	X			*Syntermes silvestrii*	not mentioned	-	-	Hempel (1949)
				Syntermes parallelus	not mentioned	-	-	Hempel (1949)
				Isoptera	not mentioned	-	-	Hempel (1949)
				Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				Syntermes sp.	not mentioned	-	-	Penha (1995)
				Isoptera	not mentioned	-	-	Sick (1997)
Nothura minor	X			Isoptera	not mentioned	-	-	Hempel (1949)
Nothura maculosa	X			Isoptera	not mentioned	-	-	Hempel (1949)
				Isoptera	alate	-	-	Belton (1994)
Taoniscus nanus	X			*Procornitermes araujoi*	not mentioned	-	-	Teixeira & Negret (1984)
				Isoptera	not mentioned	-	-	Sick (1997)
Cracidae								
Crax blumenbachii	X			Isoptera	not mentioned	-	-	Sick (1997)
Odontophoridae								
Odontophorus gujanensis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Numididae								
Numida meleagris	X			Isoptera	alate	-	-	pers. obs.
Phasianidae								
Gallus gallus	X			Isoptera	alate	-	-	Cunha (1961)
Accipitridae								
Elanoides forficatus	X		X	Isoptera	alate	-	-	Sick (1997)
Ictinia plumbea	X			Isoptera	not mentioned	-	-	Hempel (1949)
				Termitidae	alate, soldier	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Sick (1997)
Rupornis magnirostris	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Leucopternis sp.	X			Termitidae	alate	-	-	Schubart et al. (1965)
Psophiidae								
Psophia crepitans	X			Termitidae	worker	-	-	Schubart et al. (1965)
Psophia viridis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Rallidae								
Neocrex erythrops	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Charadriidae								
Vanellus chilensis	X			Termitidae	worker	-	-	Schubart et al. (1965)
Pluvialis dominica	X			Termitidae	soldier	-	-	Schubart et al. (1965)

Continued on next page

Table 1. Continued.

	Interaction Type			Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Scolopacidae								
Actitis macularius	X			Isoptera	alate	-	-	Sick (1997)
Tringa melanoleuca	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Tringa flavipes	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Laridae								
Chroicocephalus maculipennis	X			Isoptera	alate	-	-	Belton (1994)
Sternidae								
Phaetusa simplex	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	alate	-	-	Sick (1997)
Sterna hirundinacea	X			Isoptera	alate	-	-	Sick (1997)
Cuculidae								
Guira guira	X			Isoptera	alate	-	-	Belton (1994)
Strigidae								
Megascops choliba		X		-	-	*Constrictotermes cyphergaster*	arboreal	Negret & Teixeira (1983)
				-	-	Isoptera	arboreal	Sick (1997)
Glaucidium brasilianum	X	X		*Nasutitermes* sp.	soldier	-	-	Schubart et al. (1965)
				-	-	Isoptera	epigean	Sick (1997)
Athene cunicularia	X	X	X	Isoptera	alate	-	-	Martins & Egler (1990)
				-	-	Isoptera	epigean	Burmeister apud Euler (1900)
				-	-	Isoptera	epigean	Wied-Neuwied (1821)
				-	-	Isoptera	epigean	Cunha (1961)
				-	-	Isoptera	epigean	Negret & Teixeira (1983)
				-	-	Isoptera	epigean	Sick (1997)
				-	-	Isoptera	epigean	pers. obs.
Nyctibiidae								
Nyctibius aethereus	X			Isoptera	not mentioned	-	-	Moojen et al. (1941)
Nyctibius griseus	X			Isoptera	alate	-	-	Sick (1997)
Caprimulgidae								
Hydropsalis albicollis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Hydropsalis parvula	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Hydropsalis candicans			X	-	-	-	-	Rodrigues et al. (1999)
Hydropsalis longirostris	X			Isoptera	alate	-	-	Sick (1997)
				Isoptera	alate	-	-	Vasconcelos et al. (1999)
Hydropsalis torquata	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Hydropsalis forcipata	X			Isoptera	not mentioned	-	-	Moojen et al. (1941)
Chordeiles rupestris	X			Isoptera	alate	-	-	Sick (1997)

Continued on next page

Table 1. Continued.

	Interaction Type			Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Chordeiles acutipennis	X			Termitidae	alate	-	-	Schubart et al. (1965)
Apodidae								
Streptoprocne zonaris	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Tachornis squamata	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
				Isoptera	not mentioned	-	-	Sick (1997)
Panyptila cayennensis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
				Isoptera	not mentioned	-	-	Sick (1997)
Cypseloides sp.	X			Isoptera	alate	-	-	Sick (1997)
Trochilidae								
Eupetomena macroura	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Sazima (2008)
Trogonidae								
Trogon viridis		X		-	-	Isoptera	arboreal	von Ihering (1914)
				-	-	Isoptera	arboreal	Dubs (1992)
				-	-	Isoptera	arboreal	Sick (1997)
				-	-	Isoptera	arboreal	Ribas (2010)
Trogon surrucura	X	X		-	-	Isoptera	arboreal	Euler (1900)
				-	-	Isoptera	arboreal	Dubs (1992)
				-	-	Isoptera	arboreal	Sick (1997)
				-	-	Isoptera	arboreal	Silva (2004)
				-	-	Isoptera	arboreal	Alexandrino (2009)
				-	-	Isoptera	arboreal	Menq (2009)
				-	-	Isoptera	arboreal	Santos (2009)
				-	-	Isoptera	arboreal	Boso (2010)
				-	-	Isoptera	arboreal	Bucci (2010)
				-	-	Isoptera	arboreal	Konze (2010)
				-	-	Isoptera	arboreal	Licco (2010)
				-	-	Isoptera	arboreal	Oliveira (2010b)
				-	-	Isoptera	arboreal	Pereira (2010a)
				-	-	Isoptera	arboreal	Pereira (2010b)
				-	-	Isoptera	arboreal	Sanson (2010)
				-	-	Isoptera	arboreal	Si (2010)
				-	-	Isoptera	arboreal	Zimer (2010)
				-	-	Isoptera	arboreal	Amaral (2011)
				-	-	Isoptera	arboreal	Biazotto (2011)
				-	-	Isoptera	arboreal	Hansch (2011)
				-	-	Isoptera	arboreal	Luccia (2011)
				-	-	Isoptera	arboreal	Motta (2011)
				-	-	Isoptera	arboreal	Riedtmann (2011)

Continued on next page

Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
				-	-	Isoptera	arboreal	Salazar (2012)
				-	-	*Nasutitermes* sp.	arboreal	pers. obs.
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
Trogon violaceus	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Trogon curucui		X		-	-	Isoptera	arboreal	Soares (2010)
				-	-	Isoptera	arboreal	Silveira (2010)
				-	-	Isoptera	arboreal	Adeodato (2012)
Trogon rufus		X		-	-	Isoptera	arboreal	Sick (1997)
Trogon collaris		X		-	-	Isoptera	arboreal	Sick (1997)
Alcedinidae								
Chloroceryle americana		X		-	-	Isoptera	epigean	Sick (1997)
Galbulidae								
Jacamaralcyon tridactyla	X			Isoptera	not mentioned	-	-	Melo-Júnior (2001)
Galbula ruficauda		X		-	-	Isoptera	epigean	Sick (1997)
Bucconidae								
Notharchus macrorhynchos		X		-	-	Isoptera	arboreal	Sick (1997)
Notharchus tectus		X		-	-	Isoptera	arboreal	Sick (1997)
				-	-	Isoptera	arboreal	Castro (2012)
				-	-	Isoptera	arboreal	Mazzoni et al. (2013)
Bucco tamatia		X		-	-	Isoptera	arboreal	Czaban (2003)
Monasa nigrifrons	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Chelidoptera tenebrosa	X			Isoptera	not mentioned	-	-	Sick (1997)
Ramphastidae								
Ramphastos toco		X		-	-	Isoptera	epigean	Sick (1997)
				-	-	*Cornitermes* sp.	epigean	Buzzetti & Silva (2005)
				-	-	Isoptera	not mentioned	Rodrigues & Costa (2006)
Ramphastos vitellinus	X		X	Isoptera	alate	-	-	Sick (1997)
Pteroglossus castanotis		X		-	-	Isoptera	arboreal	Sick (1997)
				-	-	*Cornitermes* sp.	epigean	Silva e Silva (pers. comm.)
Picidae								
Veniliornis passerinus	X			*Heterotermes* sp.	soldier	-	-	Schubart et al. (1965)
				Termitidae	not mentioned	-	-	Schubart et al. (1965)
Veniliornis mixtus	X			Isoptera	not mentioned	-	-	Vasconcelos et al. (2006)
Piculus chrysochloros		X		-	-	Isoptera	arboreal	Dubs (1992)
Colaptes melanochloros	X			Isoptera	alate	-	-	Sazima (2008)
				Isoptera	alate	-	-	pers. obs.

Continued on next page

Table 1. Continued.

	Interaction Type			Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Colaptes campestris	X	X	X	Isoptera	not mentioned	-	-	Wied -Neuwied (1821)
				-	-	Isoptera	not mentioned	von Ihering (1900)
				-	-	Isoptera	arboreal	Negret & Teixeira (1983)
				-	-	Isoptera	epigean	Negret & Teixeira (1983)
				-	-	*Cornitermes cumulans*	epigean	Negret & Teixeira (1983)
				-	-	*Cornitermes cumulans*	epigean	Redford (1984)
				-	-	Isoptera	not mentioned	Dubs (1992)
				-	-	*Cornitermes cumulans*	epigean	Sick (1997)
				-	-	*Constrictotermes cyphergaster*	arboreal	Sick (1997)
				-	-	Isoptera	epigean	Castro (2000)
				-	-	Isoptera	arboreal	Amaral (2003)
				-	-	Isoptera	not mentioned	Silva e Silva (2004)
				-	-	Isoptera	not mentioned	Rodrigues & Costa (2006)
				-	-	Isoptera	epigean	Santos (2007)
				-	-	Isoptera	epigean	Avelino (2009)
				-	-	Isoptera	epigean	Bete (2009)
				-	-	Isoptera	epigean	Bucci (2009)
				-	-	Isoptera	epigean	Rodrigues (2009)
				-	-	Isoptera	epigean	Cezar (2010)
				-	-	Isoptera	epigean	Zachetti (2010)
				-	-	Isoptera	epigean	Bessa (2011)
				-	-	Isoptera	epigean	Filho (2011)
				-	-	Isoptera	epigean	Vieira (2011)
				Termitidae	alate, worker	-	-	Schubart et al. (1965)
				Isoptera	not mentioned	-	-	Sick (1997)
Celeus elegans	X			*Nasutitermes* sp.	alate, worker, soldier	-	-	Schubart et al. (1965)
Celeus lugubris	X	X		*Nasutitermes* sp.	worker, soldier	-	-	Schubart et al. (1965)
				Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				-	-	Isoptera	arboreal	Dubs (1992)
Celeus flavescens	X			Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				Nasutitermes sp.	worker, soldier	-	-	Schubart et al. (1965)
				Isoptera	not mentioned	-	-	Sick (1997)
Celeus torquatus	X			*Nasutitermes* sp.	worker, soldier	-	-	Schubart et al. (1965)

Continued on next page

Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Dryocopus lineatus	X			Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				Nasutitermes sp.	soldier	-	-	Schubart et al. (1965)
Campephilus rubricollis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Campephilus robustus	X			Isoptera	not mentioned	-	-	Moojen et al. (1941)
Picumnus sp.		X		-	-	Isoptera	epigean	Sick (1997)
Cariamidae								
Cariama cristata			X	-	-	-	-	Redford (1984)
Falconidae								
Daptrius ater	X			Isoptera	alate	-	-	Sick (1997)
Ibycter americanus	X			Isoptera	alate	-	-	Sick (1997)
Caracara plancus	X		X	*Cornitermes cumulans*	not mentioned	-	-	Redford (1984)
Milvago chimachima	X			Isoptera	alate	-	-	Sick (1997)
Falco sparverius	X	X		-	-	*Constrictotermes cyphergaster*	arboreal	Negret & Teixeira (1983)
				-	-	*Cornitermes cumulans*	epigean	Redford (1984)
				-	-	Isoptera	epigean	Sick (1997)
				Termitidae	alate	-	-	Schubart et al. (1965)
Falco femoralis	X			Isoptera	alate	-	-	Sick (1997)
Falco peregrinus	X			*Syntermes dirus*	alate	-	-	Sick (1997)
Psittacidae								
Primolius maracana		X		-	-	Isoptera	epigean	Cunha (2010b)
Aratinga auricapillus		X		-	-	*Cornitermes* sp.	epigean	pers. obs.
Eupsittula aurea	X	X		Isoptera	alate	-	-	Sazima (1989)
				Isoptera	alate	-	-	Sick (1997)
				Isoptera	not mentioned	-	-	Faria (2007)
				-	-	*Constrictotermes cyphergaster*	arboreal	Negret & Teixeira (1983)
				-	-	*Cornitermes cumulans*	epigean	Redford (1984)
				-	-	Isoptera	arboreal	Sazima (1989)
				-	-	Isoptera	arboreal	Dubs (1992)
				-	-	*Constrictotermes cyphergaster*	arboreal	Sick (1997)
				-	-	Isoptera	not mentioned	Bianchi et al. (2000)
				-	-	Isoptera	not mentioned	Silva e Silva (2004)
				-	-	Isoptera	rupicolous	Rodrigues & Costa (2006)
				-	-	Isoptera	arboreal	Stamato (2009)
				-	-	Isoptera	epigean	Camargo (2010)

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
				-	-	Isoptera	arboreal	Dalessandro (2010)
				-	-	Isoptera	arboreal	Araujo (2011)
				-	-	Isoptera	arboreal	Costa (2011)
				-	-	Isoptera	arboreal	Oliveira (2011)
				-	-	Isoptera	arboreal	Olyntho (2011)
				-	-	Isoptera	epigean	Sales (2011)
				-	-	Isoptera	arboreal	Ribeiro (2012)
				-	-	*Cornitermes* sp.	epigean	Silva e Silva (pers. comm.)
				-	-	*Cornitermes* sp.	epigean	pers. obs.
				-	-	*Constrictotermes cyphergaster*	arboreal	pers. obs.
Eupsittula pertinax		X		-	-	Isoptera	arboreal	Carvalho (2010)
Eupsittula cactorum		X		-	-	*Nasutitermes* sp.	arboreal	Naka (1997)
				-	-	Isoptera	arboreal	Netto (2010a)
				-	-	Isoptera	epigean	Netto (2010b)
				-	-	Isoptera	arboreal	Netto (2010c)
				-	-	Isoptera	arboreal	Netto (2010d)
				-	-	Isoptera	arboreal	Teixeira (2010)
Pyrrhura frontalis		X		-	-	Isoptera	arboreal	Couto (2010)
Forpus xanthopterygius		X		-	-	Isoptera	not mentioned	Sick (1997)
Brotogeris tirica		X		-	-	Isoptera	arboreal	Costa (2008)
Brotogeris chiriri		X		-	-	*Nasutitermes* sp.	arboreal	Negret & Teixeira (1983)
				-	-	Isoptera	arboreal	Dubs (1992)
				-	-	*Nasutitermes* sp.	not mentioned	Sick (1997)
				-	-	Isoptera	arboreal	Raso (2008)
				-	-	Isoptera	arboreal	Santos (2008)
				-	-	Isoptera	arboreal	Cunha (2010a)
				-	-	Isoptera	arboreal	Flores (2010)
				-	-	Isoptera	arboreal	Lima (2012)
Touit melanonotus		X		-	-	Isoptera	arboreal	Costa (2009)
Touit surdus		X		-	-	Isoptera	arboreal	Sonntag (2011)
Alipiopsitta xanthops		X		-	-	*Cornitermes* sp.	epigean	Silva e Silva (2004)
				-	-	*Cornitermes* sp.	epigean	Silva e Silva (pers. comm.)
Amazona aestiva		X		-	-	Isoptera	not mentioned	Bianchi et al. (2000)
				-	-	*Cornitermes* sp.	epigean	Buzzetti & Silva (2005)
Thamnophilidae								
Myrmeciza atrothorax	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Formicivora grisea	X			Isoptera	alate	-	-	Sick (1997)
Formicivora melanogaster	X			*Eutermes* sp.	alate	-	-	Teixeira (1987)

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Herpsilochmus sellowi	X			*Eutermes* sp.	alate	-	-	Teixeira (1987)
Sakesphorus cristatus	X			*Eutermes* sp.	alate	-	-	Teixeira (1987)
Thamnophilus pelzelni	X			Isoptera	not mentioned	-	-	Lopes et al. (2005)
Thamnophilus ambiguus	X			Isoptera	not mentioned	-	-	Lopes et al. (2005)
Taraba major	X			Termitidae	worker	-	-	Schubart et al. (1965)
				Nasutitermes sp.	not mentioned	-	-	Schubart et al. (1965)
Rhopornis ardesiacus	X			*Eutermes* sp.	alate	-	-	Teixeira (1987)
Willisornis poecilinotus	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Melanopareiidae								
Melanopareia torquata	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Rhinocryptidae								
Scytalopus novacapitalis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Formicariidae								
Formicarius analis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Scleruridae								
Sclerurus rufigularis	X			Termitidae	alate	-	-	Schubart et al. (1965)
Geositta poeciloptera		X	X	-	-	Isoptera	epigean	Silva e Silva (2005)
Dendrocolaptidae								
Sittasomus griseicapillus	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
Xiphorhynchus obsoletus		X		-	-	Isoptera	arboreal	Dubs (1992)
Lepidocolaptes angustirostris		X		-	-	Isoptera	epigean	Marantz et al. (2003)
Xenopidae								
Xenops rutilans	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Furnariidae								
Furnarius leucopus	X			Termitidae	soldier	-	-	Schubart et al. (1965)
Furnarius rufus	X			Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Sazima (2008)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Philydor erythrocercum	X			Isoptera	not mentioned	-	-	Schubart et al. (1965)
Philydor atricapillus	X			Isoptera	not mentioned	-	-	Mallet-Rodrigues (2001)
Philydor rufum	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Syndactyla dimidiata		X		-	-	Isoptera	arboreal	Pacheco (1995a)
				-	-	Isoptera	arboreal	Pacheco (1995b)
Synallaxis spixi	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
Synallaxis scutata	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Furnarius sp.	X			Isoptera	alate	-	-	Sick (1997)

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Onychorhynchidae								
Onychorhynchus sp.	X			Isoptera	alate	-	-	Sick (1997)
Tityridae								
Pachyramphus validus	X			Isoptera	alate	-	-	pers. obs.
Cotingidae								
Gymnoderus foetidus	X			Isoptera	alate	Isoptera	arboreal	Sick (1997)
Cotinga maculata		X		-	-	-	-	Sick (1997)
Pipritidae								
Piprites pileata	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Rhynchocyclidae								
Mionectes rufiventris	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Phylloscartes ventralis	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Tolmomyias flaviventris	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Tyrannidae								
Camptostoma obsoletum	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Elaenia flavogaster	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Ruptitermes sp.	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Elaenia parvirostris	X			Isoptera	alate	-	-	Belton (1994)
Elaenia chiriquensis	X			Isoptera	alate	-	-	pers. obs.
Elaenia obscura	X			Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)
Elaenia sp.	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Phaeomyias murina	X			*Ruptitermes* sp.	alate	-	-	pers. obs.
Legatus leucophaius	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Ruptitermes sp.	alate	-	-	pers. obs.
Myiarchus swainsoni	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Myiarchus tyrannulus	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Pitangus sulphuratus	X			Isoptera	alate	-	-	Sazima (2008)
Machetornis rixosa	X			Isoptera	alate	-	-	Paiva (1998)
				Ruptitermes sp.	alate	-	-	pers. obs.
Myiodynastes maculatus	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	pers. obs.
Megarynchus pitangua	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Myiozetetes similis	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	pers. obs.

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Tyrannus melancholicus	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Sazima (2008)
				Ruptitermes sp.	alate	-	-	pers. obs.
Tyrannus savana	X			Isoptera	alate	-	-	Cunha (1961)
				Termitidae	alate	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Sick (1997)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
Empidonomus varius	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	pers. obs.
Colonia colonus	X			*Ruptitermes* sp.	alate	-	-	pers. obs.
Myiophobus fasciatus	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
Fluvicola nengeta	X			Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Lathrotriccus euleri	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Knipolegus cyanirostris	X			Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)
Knipolegus lophotes	X			Isoptera	alate	-	-	pers. obs.
Xolmis velatus		X		-	-	Isoptera	epigean	Sick (1997)
				-	-	*Cornitermes* sp.	epigean	Buzzetti & Silva (2005)
Xolmis irupero		X		-	-	Isoptera	not mentioned	von Ihering (1914)
Xolmis sp.		X		-	-	*Cornitermes cumulans*	epigean	Redford (1984)
Muscipipra vetula	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Vireonidae								
Cyclarhis gujanensis	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Vireo olivaceus	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
Hylophilus poicilotis	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Corvidae								
Cyanocorax cyanomelas	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Cyanocorax cyanopogon	X			Isoptera	alate	-	-	Sick (1997)
Hirundinidae								
Pygochelidon cyanoleuca	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
				Isoptera	alate	-	-	Sazima (2008)

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Progne tapera	X	X		Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
				Isoptera	alate	Isoptera	arboreal	Sick (1997)
				-	-	-	-	Sick (1997)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Sazima (2008)
Progne chalybea		X		-	-	Isoptera	arboreal	Sick (1997)
				-	-	Isoptera	arboreal	Oliveira (2010a)
Tachycineta leucorrhoa		X		-	-	Isoptera	epigean	Bessa (2008)
				-	-	Isoptera	epigean	Guedes (2009)
				-	-	Isoptera	epigean	Couto (2011)
Troglodytidae								
Troglodytes musculus	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Sazima (2008)
Cyphorhinus arada	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Turdidae								
Turdus leucomelas	X			Isoptera	not mentioned	-	-	Lopes et al. (2005)
				Isoptera	alate	-	-	Sazima (2008)
				Ruptitermes sp.	alate	-	-	pers. obs.
Turdus amaurochalinus	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	not mentioned	-	-	Lopes et al. (2005)
Turdus subalaris	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Mimidae								
Mimus saturninus	X			Isoptera	not mentioned	-	-	Moojen et al. (1941)
				Termitidae	worker, soldier	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Schubart et al. (1965)
				Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Sazima (2008)
Passerellidae								
Zonotrichia capensis	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	alate	-	-	Paiva (1998)
				Neocapritermes sp.	alate	-	-	Vasconcelos (1999)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
				Isoptera	alate	-	-	Sazima (2008)
				Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)

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Table 1. Continued.

Interaction Type				Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
				Isoptera	alate	-	-	pers. obs.
				Isoptera	alate	-	-	pers. obs.
Arremon taciturnus	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Parulidae								
Setophaga pitiayumi	X			Isoptera	alate	-	-	Belton (1994)
Basileuterus culicivorus	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Myiothlypis flaveola	X			Isoptera	not mentioned	-	-	Lopes et al. (2005)
Icteridae								
Psarocolius decumanus	X			Isoptera	alate	-	-	pers. obs.
Cacicus chrysopterus	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Icterus cayanensis	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Gnorimopsar chopi		X		-	-	Isoptera	epigean	Sick (1997)
Molothrus bonariensis	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	alate	-	-	pers. obs.
Quiscalus lugubris	X			Isoptera	alate	-	-	Sick (1997)
Psarocolius sp.	X			Isoptera	alate	-	-	Sick (1997)
Cacicus sp.	X			Isoptera	alate	-	-	Sick (1997)
Thraupidae								
Coereba flaveola	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Sazima (2008)
				Ruptitermes sp.	alate	-	-	pers. obs.
Saltator similis	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
Orchesticus abeillei	X			Isoptera	alate	-	-	Sick (1997)
Nemosia pileata	X			Isoptera	alate	-	-	pers. obs.
Thlypopsis sordida	X			Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
Pyrrhocoma ruficeps	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Tachyphonus coronatus	X			Isoptera	not mentioned	-	-	Lopes et al. (2005)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
Ramphocelus carbo	X			Isoptera	alate	-	-	Sazima (2008)
Lanio pileatus	X			Isoptera	alate	-	-	pers. obs.
Lanio melanops	X			Isoptera	alate	-	-	Sick (1997)
Tangara sayaca	X			Isoptera	alate	-	-	Belton (1994)
				Isoptera	alate	-	-	Sick (1997)
				Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Sazima (2008)
				Isoptera	alate	-	-	pers. obs.

Continued on next page

Table 1. Continued.

	Interaction Type			Feeding on termites		Nesting on termitaria		Source
Family / Species	**Feeding**	**Nesting**	**Perching**	**Taxon**	**Caste**	**Taxon**	**Termitaria type**	
Tangara palmarum	X			*Ruptitermes* sp.	alate	-	-	pers. obs.
Tangara ornata	X			*Ruptitermes* sp.	alate	-	-	pers. obs.
Tangara cayana	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	Olson & Alvarenga (2006)
				Isoptera	alate	-	-	Sazima (2008)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Stephanophorus diadematus	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
				Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)
Neothraupis fasciata	X			Isoptera	not mentioned	-	-	Alves (1991)
Schistochlamys ruficapillus	X			Isoptera	alate	-	-	pers. obs.
Pipraeidea melanonota	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
Pipraeidea bonariensis	X			Isoptera	alate	-	-	Belton (1994)
Tersina viridis	X			Isoptera	not mentioned	-	-	Sick (1997)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Dacnis cayana	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
				Isoptera	alate	-	-	pers. obs.
				Ruptitermes sp.	alate	-	-	pers. obs.
Cyanerpes cyaneus	X			Isoptera	alate	-	-	Sick (1997)
Conirostrum speciosum	X			Isoptera	alate	-	-	Gussoni & Campos (2003)
Poospiza thoracica	X			Isoptera	alate	-	-	C. R. M. Abreu & M. M. Coelho (pers. comm.)
Poospiza lateralis	X			Isoptera	alate	-	-	Olson & Alvarenga (2006)
				Isoptera	alate	-	-	pers. obs.
Sicalis flaveola	X			Isoptera	alate	-	-	pers. obs.
Embernagra longicauda	X			Isoptera	not mentioned	-	-	pers. obs.
Volatinia jacarina	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Sporophila nigricollis	X			*Ruptitermes* sp.	alate	-	-	pers. obs.
Cardinalidae								
Piranga flava	X			Termitidae	not mentioned	-	-	Schubart et al. (1965)
Passeridae								
Passer domesticus	X			Isoptera	alate	-	-	Sick (1997)
				Isoptera	alate	-	-	Paiva (1998)
				Isoptera	alate	-	-	Sazima (2008)

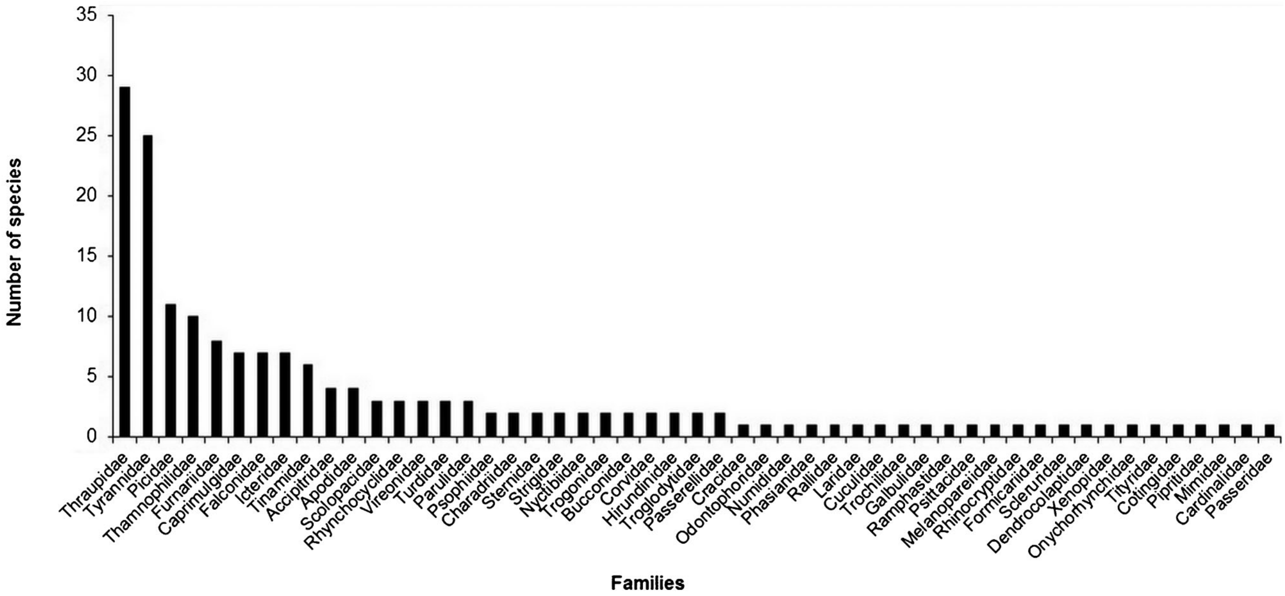

Figure 1. Number of bird species, per family, recorded feeding on termites in Brazil.

Guineafowl, despite being a terrestrial species, jumped and caught the termites in flight. Although it is a domestic and exotic species, it also feeds on termites in wildlife, as recorded by Thiollay (1970) in Africa.

In the course of another swarm, observed in December 2005 at a grassland savannah (*campo cerrado*), in the Serra do Mascate, Congonhas/MG, MFV (*pers. obs.*) recorded the following species of birds feeding on winged termites: Lesser Elaenia (*Elaenia chiriquensis*, n = 1), Crested Black-Tyrant (*Knipolegus lophotes*, n = 1), Blue-and-white Swallow (n = 5), Cinnamon Tanager (*Schistochlamys ruficapillus*, n = 2), Sayaca Tanager (n = 2), Burnished-buff Tanager (*Tangara cayana*, n = 3) and Blue Dacnis (*Dacnis cayana*, n = 2).

On 22 January 2008, at c. 17:30 h, MFV and L. N. Souza observed a swarm of *Ruptitermes* sp. at a light rain in Fazenda Bocaina (20° 00’ 01’’S, 43° 28’ 17’’W; elevation: c. 750 m), Santa Bárbara/MG. The alates were emerging from a hole in the soil of an orchard, protected by workers. Birds of the following species were observed catching these winged termites: Rufous Hornero (n = 2), Yellow-bellied Elaenia (*Elaenia flavogaster*, n = 1), Masked Water-Tyrant (n = 1), Long-tailed Tyrant (*Colonia colonus*, n = 1), Cattle Tyrant (*Machetornis rixosa*, n = 1), Piratic Flycatcher (*Legatus leucophaius*, n = 1), Boat-billed Flycatcher (n = 1), Tropical Kingbird (*Tyrannus melancholicus*, n = 1), Blue-and-white Swallow (n = 1), Pale-breasted Thrush (*Turdus leucomelas*, n = 1), Bananaquit (*Coereba flaveola*, n = 1), Palm Tanager (*Tangara palmarum*, n = 2), Golden-chevroned Tanager (*Tangara ornata*, n = 2), Burnished-buff Tanager (n = 2) and Swallow Tanager (n = 2). Interestingly, several birds that usually do not perform aerial foraging tactics, such as: *E. flavogaster*, *T. leucomelas*, *T. ornata*, *T. palmarum*, *T. cayana* and *T. viridis*, caught insects in flight, landing later to consume them. In the case of *T. viridis*, the same specimen (a male) captured up to five alates in a single attempt. *Megarynchus pitangua* and *C. flaveola* captured winged termites that landed in trees and shrubs. One specimen of *T. cayana* combined both foraging techniques (in flight and perched in the shrubs). Birds that usually forage on the ground caught alates that were still on the ground, such as: *F. rufus*, *F. nengeta* and *M. rixosa*.

Around 17:00 h, on 28 January 2008, another swarm of *Ruptitermes* sp. was observed by MFV and L. N. Souza in a

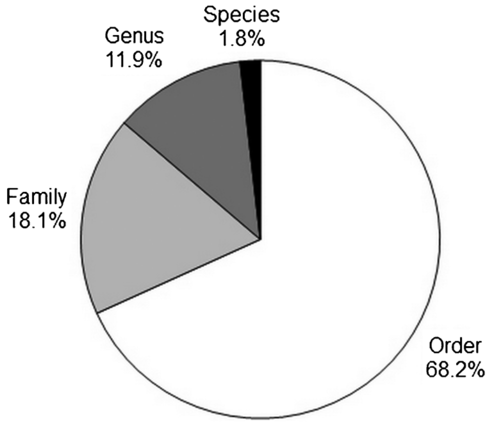

Figure 2. Percentages of identification, in different taxonomic levels, of the termites recorded as food resource for birds in Brazil.

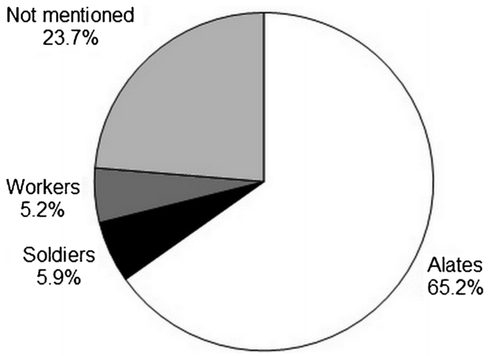

Figure 3. Percentage of termite castes recorded as food resource by birds in Brazil.

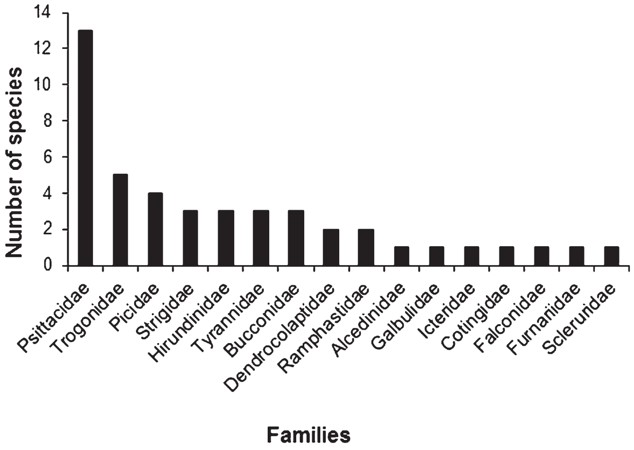

Figure 4. Number of bird species, per family, using termitaria as nesting sites in Brazil.

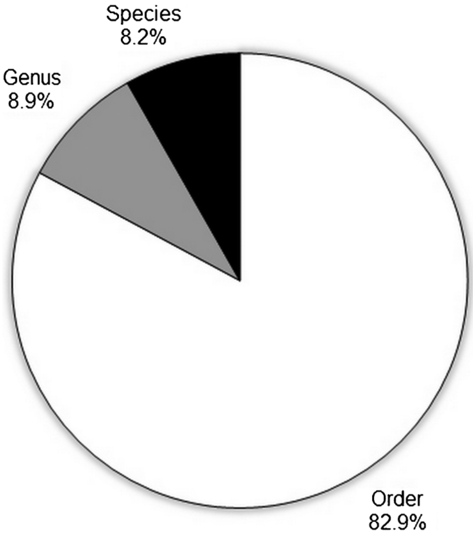

Figure 5. Percentages of identification, in different taxonomic levels, of the termites that build termitaria used as nest site by birds in Brazil.

secondary forest edge at Córrego do Sítio (20° 00' 36" S, 43° 30' 45" W), also in Santa Bárbara/MG. The following species of birds captured insects in flight: Yellow-bellied Elaenia (n = 1), Mouse-colored Tyrannulet (*Phaeomyias murina*, n = 1), Blue Dacnis (n = 2; a couple) and Yellow-bellied Seedeater (*Sporophila nigricollis*, n = 2; a couple).

In a recent paper, Sazima (2008) also reported 16 bird species feeding on alates in Campinas/SP, in July 2007. He also noted the changing of regular foraging behavior of several species as pointed out by Olson & Alvarenga (2006).

The flight activity is unknown for most termites. Although not a rule, in southeastern Brazil swarmings generally occur from the end of the dry season to the beginning of the rainy season (between September and March), but in some parts of the Amazon region the effects of seasonality are less pronounced (Silvestri 1903, Costa-Lima 1938, Martius et al. 1996, Medeiros et al. 1999). It is noteworthy that most termite swarms seems to coincide with the breeding season of birds, i.e. the beginning of the rainy season. As alates are rich in proteins and lipids (Nutting 1969), their predation during the breeding season of birds seems to be important to supplement their energy and protein demands. The Rufous-collared Sparrow was recorded feeding on alates of *Neocapritermes* sp. at the time that this species reproduces in the central state of Minas Gerais (Vasconcelos 1999). Melo-Júnior (2001) observed the Three-toed Jacamar (*Jacamaralcyon tridactyla*), a rare bird species endemic to the Atlantic Forest, also feeding on termites during its breeding season.

In the case of ground-foraging birds, such as the Red-winged Tinamou (*Rhynchotus rufescens*) and the Dwarf Tinamou (*Taoniscus nanus*), there are reports that these species dig termite mounds with their beaks to feed on those insects (Teixeira & Negret 1984, Sick 1997). Sick (1997) mentioned that this work is facilitated when mounds were previously damaged by other predators (such as anteaters) and repaired by termites with still fresh material. Other species of tinamous (Tinamidae) probably also exhibit this behavior, but have not yet been observed. When birds dig termite mounds, they can feed on other castes (workers and soldiers) and immatures (as nymphs, which are rich in fat and protein). Probably, the termites also enrich the diet of other groups of flying birds that burrow into mounds for nesting sites, such as parrots (Psittacidae), woodpeckers (Picidae) and trogons (Trogonidae) (see Euler 1900, Schubart et al. 1965, Sazima 1989, Dubs 1992, Naka 1997, Sick 1997).

3. *Termitaria as nest sites for Brazilian birds*

Termitaria were recorded as nesting sites for 45 species of Brazilian birds of 16 families (Table 1). The most representative families are: Psittacidae (13 species), Trogonidae (5), Picidae (4), Strigidae, Hirundinidae, Bucconidae and Tyrannidae (3) (Figure 4). These families are represented by several species that nest in holes in trees or natural walls. In general, birds of the families Alcedinidae (kingfishers) and Galbulidae (jacamars) nest in holes dug into ravines, being noteworthy Sick's (1997) observations on one species of each family nesting in termite mounds.

Again, little is known about the termite species that build termitaria used by birds as nest sites. Among the 146 records, in 121 (82.9%) termites were identified at the order level; in 13 (8.9%), at the generic level and only in 12 (8.2%), at species level (Figure 5).

Concerning the types of termitaria used by birds, from 146 records, 84 (57.5%) are arboreal, 50 (34.3%) are epigean and only one (0.7%) is rupicolous. In 11 records (7.5%) termitaria types were not mentioned (Figure 6). In the only record of rupicolous mound, Rodrigues & Costa (2006) described the Peach-fronted Parakeet (*Eupsittula aurea*) nesting on a termitaria built on rocky walls of a canyon in the Serra do Cipó/MG.

Nesting inside termitaria can offer advantages to birds, as protection against predators and propitious micro-climate (Sick 1997). However, it is not always possible to know whether a bird that nests inside the termitaria dig its own nest or use a cavity excavated by another bird. Woodpeckers (Picidae), parrots (Psittacidae), trogons (Trogonidae) and puffbirds (Bucconidae) were reported excavating termitaria for nesting (Sazima 1989, Dubs 1992, Sick 1997). On the afternoon of 6 August 1999, for about 15 minutes, MFV observed a male of the Surucua Trogon (*Trogon surrucura surrucura*) digging an arboreal termitarium of *Nasutitermes* sp. at Morro do Diabo State Park, Teodoro Sampaio/SP. This termitarium was about

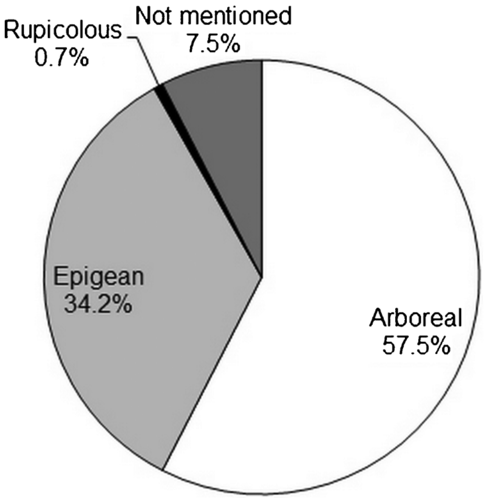

Figure 6. Percentages of termitaria types used by birds as nest sites in Brazil.

3 m above the ground in a tree at the edge of secondary forest. The bird perched on the termitarium like a woodpecker, grabbed by its feet. It also used its tail as a support, worning its rectrices (Figure 7). The female remained perched in a nearby tree and watched the work carried out by the male, without participating in the excavation.

Among parrots, R. Silva e Silva (*pers. comm.*) observed the following bird species nesting in mounds of *Cornitermes* sp.: Peach-fronted Parakeet (in Tapira/MG) and Yellow-faced Parrot (*Alipiopsitta xanthops*; at Emas National Park, Mineiros/GO). In the *cerrado* region of Minas Gerais state, the Peach-fronted Parakeet is also commonly observed nesting in arboreal termite nests of *Constrictotermes cyphergaster*, in Sete Lagoas, Paraopeba and Inhaúmas (Figure 8). This parakeet was recorded nesting in these termitaria between the months of April and July (MFV *pers. obs.*).

It is noteworthy that termites restore the termitaria walls that were excavated by birds, but generally respects the birds' incubatory chamber (Sick 1997) and it remains unchanged even after the nest is abandoned by the birds. Naka (1997) reported that termites also restored the exterior walls damaged in arboreal termitaria which were used for nesting by the Cactus Parakeet (*Eupsittula cactorum*). In this context, it is noteworthy that parrots have a preference for active termitaria, *i.e.*, those occupied by termites, since abandoned termitaria are very dry and break easily (Hardy 1963).

Figure 7. A male of the Surucua Trogon (*Trogon surrucura surrucura*) digging an arboreal termitarium of *Nasutitermes* sp. at Morro do Diabo State Park/SP, showing the worning of its rectrices that support him in the termitaria. Photo by Marcelo Ferreira de Vasconcelos.

Figure 8. In the *cerrado* region of Minas Gerais state, the Peach-fronted Parakeet (*Eupsittula aurea*) is commonly observed nesting in arboreal nests of *Constrictotermes cyphergaster*. This nest was found in July 2007 in the *cerrado* of Inhaúma/MG. In its interior it was found a single white and rounded egg. Photo by Marcelo Ferreira de Vasconcelos.

Sick (1997) mentioned the following bird species that use excavations in termitaria previously made by other birds: the American Kestrel (*Falco sparverius*), the Tropical Screech-Owl (*Megascops choliba*), the Ferruginous Pygmy-Owl (*Glaucidium brasilianum*), the Toco Toucan (*Ramphastos toco*), the White-rumped Monjita (*Xolmis velatus*), the Brown-chested Martin (*Progne tapera*) and the Chopi Blackbird (*Gnorimopsar chopi*). In Catalão/GO, R. Silva e Silva (*in litt.*) photographed one specimen of the Chestnut-eared Aracari (*Pteroglossus castanotis*) leaving its nest, located in a mound of *Cornitermes* sp., which was probably dug by another bird. This species can nest in both epigean and in arboreal termitaria (Sick 1997). Bird species reported by Sick (1997) as diggers of holes in termitaria which are later used by other species were parakeets (Psittacidae) and woodpeckers (Picidae), especially the Peach-fronted Parakeet and the Campo Flicker (*Colaptes campestris*). The Burrowing Owl (*Athene cunicularia*) is also mentioned as an excavator of termite mounds, but also exploits pre-existing holes, so that a couple simply extend it, using their feet and beaks (see Euler 1900, Cunha 1961, Negret & Teixeira 1983, Sick 1997).

It is also noteworthy that termitaria appear to be a critical resource for maintaining populations of many species of birds that nest in cavities. This is because large trees, which forms potential hollows for nesting-cavity birds, are extremely scarce in secondary forests, as well as in the *cerrado* of central Brazil (Negret & Teixeira 1983, MFV pers. obs.).

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Despite birds use termitaria as nest sites, there is a recent report of termites (*Microcerotermes* cf. *exiguus*) using an abandoned nest of the Pale-legged Hornero (*Furnarius leucopus*) in the Caatinga of northeastern Brazil (Silva et al. 2013).

4. *Termitaria as perching sites for Brazilian birds*

Termite mounds can also be used as perching sites for birds. In some cases, these mounds are marked by manure of birds that use them (Fontes 1998a: 218). Thus termitaria provide for birds of prey, such as the Southern Caracara (*Caracara plancus*) and the Burrowing Owl, strategic points to search for preys in the open landscapes of Brazil, represented the various grassland and savannah natural physiognomies of the *cerrado* region and man-made pastures (Cunha 1961, Redford 1984, Develey & Endrigo 2004, Silva e Silva 2004; MFV pers. obs.). Some species also use termitaria as a spot to feed on alates in flight, like the Swallow-tailed Kite (*Elanoides forficatus*) and the Channel-billed Toucan (*Ramphastos vitellinus*) (Sick 1997). Importantly, in the *cerrado* of central Brazil, the termite mounds are important perching sites for two species of endangered birds that are endemic to this region (following Silva 1995, Silva & Bates 2002, Machado et al. 2005): the White-winged Nightjar (*Hydropsalis candicans*) and the Campo Miner (*Geositta poeciloptera*) (Rodrigues et al. 1999, Remsen Jr. 2003, Silva e Silva 2004). The Campo Miner perchs on mound in the *cerrado* to sing and to perform a wing display which is related to territoriality and attraction of sexual partners (Remsen Jr. 2003). Similar behavior has been recorded for the Red-legged Seriema (*Cariama cristata*), which perchs on top of mounds of *Cornitermes cumulans* to vocalize its territorial song (Redford 1984).

5. *Conclusions and perspectives for future researches*

Based on the present review, we conclude that the small number of bird species recorded using termites, for the purposes above described, reflects the lack of observations and the limited published data on natural history. In several bird families recorded in those interactions, other species have the same feeding and breeding habits of the recorded species. Thus, the consumption of termites and the use of termitaria should be more widespread than that reported in the literature. For example, in the families Hirundinidae (swallows) and Apodidae (swifts), with several species represented exclusively by aerial insectivorous, a higher number of species that feed on alates is expected. The same applies to other aerial insectivores, like the nightjars (Caprimulgidae) and tyrant-flycatchers (Tyrannidae). Similarly, it is also expected that many more bird species use termitaria as nest sites or perches in comparison to the current knowledge.

Furthermore, there are other interactions between birds and termites, not addressed in this review, which should be better studied. For example, Sick (1997) mentions that barbets (Capitonidae) hammer termite mounds with their beaks in search for arthropods and that the Lineated Woodpecker (*Dryocopus lineatus*), puffbirds (Bucconidae) and trogons (Trogonidae), use arboreal termitaria as roosting sites.

The majority of termite species used by Brazilian birds was not identified even at the family or generic levels. This shows a lack of basic natural history information in Brazil. Studies on molecular biology and modeling algorithms are now highly valued, while those on the basic interactions between organisms in nature are declining. Worse, thousands of hectares of native vegetation are destroyed each year in Brazil and we passively watch the biodiversity loss without knowing basic interactions between species. In future studies on termites as food resource or on termitaria as nesting or perching sites for birds, we suggest the collection and identification of these insects. Alates may be easily collected. Sometimes the exit holes can be found in the ground or in the mounds or nests (see Vasconcelos 1999), and this will be an opportunity to also obtain specimens of the soldier caste and the workers, which greatly facilitates the taxonomic identification.

All termite castes (soldiers, workers, nymphs, alates) should be collected preferably with delicate forceps or with small brushes impregnated with alcohol. Termites must be kept in 70-80% alcohol (Fontes 1995) for later identification with the aid of keys and illustrations (see Mathews 1977, Fontes 1992, 1995, 1998b, Constantino 1999, Milano & Fontes 2002) or should preferably be sent to taxonomists. It is important to stress that collection should be conducted with permission provided by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), the Brazilian environment agency that deals with scientific collection activities.

Since different species of birds change their foraging behavior when feeding on alates (Eisenmann 1961, Belton 1994, Olson & Alvarenga 2006; MFV pers. obs.), foraging tactics of each species must be described in detail (see Fitzpatrick 1980, Remsen Jr & Robinson 1990). Photographs of birds feeding on termites or using termitaria as nesting or perching sites are also recommended in new publications.

Termitaria used by birds as nest sites should be photographed with details of the surface, and eventually one similar mound or nest may be collected or dissected and documented, since the architectural pattern is useful for the recognition of the termite species (see Mathews 1977, Fontes 1995). It is also important to record at the time of the bird nesting, if the mound was active (occupied by termites) or abandoned. Detailed measurements of the nest entrance, the access tunnel and the incubation chamber should be made carefully. It is also desirable to conduct schematic drawings showing the position of the incubation chamber, as well as the direction of the access tunnel inside the termitarium (see Naka 1997). Moreover, it is necessary to study the material that constitutes the incubation chamber (if present) and describe details about the nest according to the recent review on this subject (Simon & Pacheco 2005). In case of arboreal termitaria, it is always suggested to note its height from the ground, the tree species support and the direction of the nest entrance (north, south, east or west).

Finally, we conclude that there is still a gap in understanding various aspects concerning the natural history and the ecology of interaction between birds and termites. These are some of the challenges that must be faced by naturalists and field biologists in the future.

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short communication

First record of the camboatá *Megalechis picta* (Müller & Troschel, 1849) (Siluriformes: Callichthyidae) for the Pantanal, Brazil

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TENCATT, L., SEVERO-NETO, F., FROEHLICH, O. **First record of the camboatá *Megalechis picta* (Müller & Troschel, 1849) (Siluriformes: Callichthyidae) for the Pantanal, Brazil.** Biota Neotropica. 15(1): e20140096. http://dx.doi.org/1676-06032015009614

Abstract: Herein we report the first record of *Megalechis picta* in the Brazilian Pantanal based in a single specimen captured in a tributary to the rio Miranda, municipality of Corumbá, rio Paraguay basin, State of Mato Grosso do Sul, Brazil. Additional discussion about its co-occurrence with *M. thoracata* is also provided.

Keywords: *Callichtyinae, Introduced species, Neotropical region, rio Paraguay, rio Orinoco.*

TENCATT, L., SEVERO-NETO, F., FROEHLICH, O. **Primeiro registro do camboatá *Megalechis picta* (Müller & Troschel, 1849) (Siluriformes: Callichthyidae) para o Pantanal, Brasil.** Biota Neotropica. 15(1): e20140096. http://dx.doi.org/1676-06032015009614

Resumo: Aqui reportamos o primeiro registro de *Megalechis picta* no Pantanal brasileiro baseado em um único espécime capturado em um tributário do rio Miranda, município de Corumbá, bacia do rio Paraguai, Estado de Mato Grosso do Sul, Brasil. Uma discussão adicional sobre a sua coocorrência com *M. thoracata* também é fornecida.

Palavras-chave: *Callichtyinae, Espécies introduzidas, região Neotropical, rio Paraguai, rio Orinoco.*

Introduction

The Callichthyidae are characterized by the presence of two longitudinal series of dermal plates on flanks, and currently comprises about 200 valid species allocated in two subfamilies, Callicthyinae and Corydoradinae (Reis, 2003; Eschmeyer, 2014). Callichthyinae is composed by five valid genus, *Callichthys* Scopolli, 1777, *Dianema* Cope, 1871, *Hoplosternum* Gill, 1858, *Lepthoplosternum* Reis, 1997 and *Megalechis* Reis, 1997 (Reis 1998, 2003) and can be promptly distinguished from the remaining Callichthyidae by the presence of anal-fin spine (*vs.* absence). *Megalechis* is distinguished from the other Callichthyinae by the unique combination of features: infraorbital bones exposed (*vs.* covered by thick layer of skin), caudal fin truncate or convex (*vs.* forked or concave) and presence of two unbranched rays in dorsal fin (*vs.* one). The genus currently comprises two valid species, *M. picta*, from the Amazon, Orinoco and Essequibo river basins, and additionally from coastal rivers of northern Brazil, and *M. thoracata*, from the Amazon and Orinoco rivers basins, and further coastal drainages of Guianas and north-eastern Brazil (Reis et al. 2005).

After the analysis of all the *Megalechis* material hosted in the Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul (ZUFMS-PIS), a single specimen of *M. picta* (Figure 1a) from the southern Pantanal region, State of Mato Grosso do Sul, was identified, consisting in the first record of this species for the Pantanal region, which is stated herein. A map showing the new record, with the addition of the other two available non-native records of *M. picta* is also provided (Figure 2).

Material and methods

The *Megalechis picta* specimen (Figure 1a) was collected by Otávio Froehlich, in October 1990, in the Baía do Quadrado, tributary to the rio Miranda, geographical coordinates 19° 24’ 14” S and 57° 02’ 40” W, municipality of Corumbá, State of Mato Grosso do Sul. The confection of the map was made through the software Quantum GIS, version 1.8.0. The specimen was captured using a trawl net, firstly fixed in 10% formalin, transferred to 70% hydrated ethanol, and posteriorly deposited in the Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul, under voucher ZUFMS-PIS 30. The identification of the species was performed according to Reis et al. (2005). In figure legends, SL means standard length and CP means “comprimento padrão”.

Figure 1. Lateral view of the (a) *Megalechis picta* specimen, ZUFMS-PIS 30, 100.0 mm SL, collected in the Baía do Quadrado, and (b) *Megalechis thoracata*, ZUFMS-PIS 54, 66.8 mm SL, from a lagoon tributary to the rio Miranda.

Results and discussion

Recently, Tencatt et al. (2013) reported the first occurrence record of *Megalechis picta* in the upper rio Paraná basin, region of the Corumbá IV Reservoir, and commented on the taxonomic rearrangements that resulted in the revalidation of *Megalechis picta* and the synonymy of *M. personata* under *M. thoracata* (for more details see Reis et al. 2005). The occurrence of *Megalechis thoracata* (Figure 1b) is already reported for the Pantanal region (see Britski et al. 2007: 153). *Megalechis picta* is native in the Amazon, Orinoco and Essequibo river basins and can be clearly distinguished from *M. thoracata* mainly by the color pattern of caudal fin (proximal and distal margins of caudal-fin blackened, with a conspicuous transversal black bar in its middle portion, the regions between the blackened bands are clearly whitish yellow *vs.* proximal margin of caudal-fin whitish, the remaining portion is dusky or black spotted).

In addition to the syntopic occurrence of *Megalechis thoracata* and *M. picta* in the rio Paraguay basin, other records also stated the presence of *M. thoracata* (Castro et al. 2004; Langeani et al. 2007; Perez-Júnior and Garavello 2007; Apone et al. 2008; Oliveira et al. 2009) and of *M. picta* (Tencatt et al. 2013) co-occurring in the upper rio Paraná basin. Despite this new record, the species was never captured again in the rio

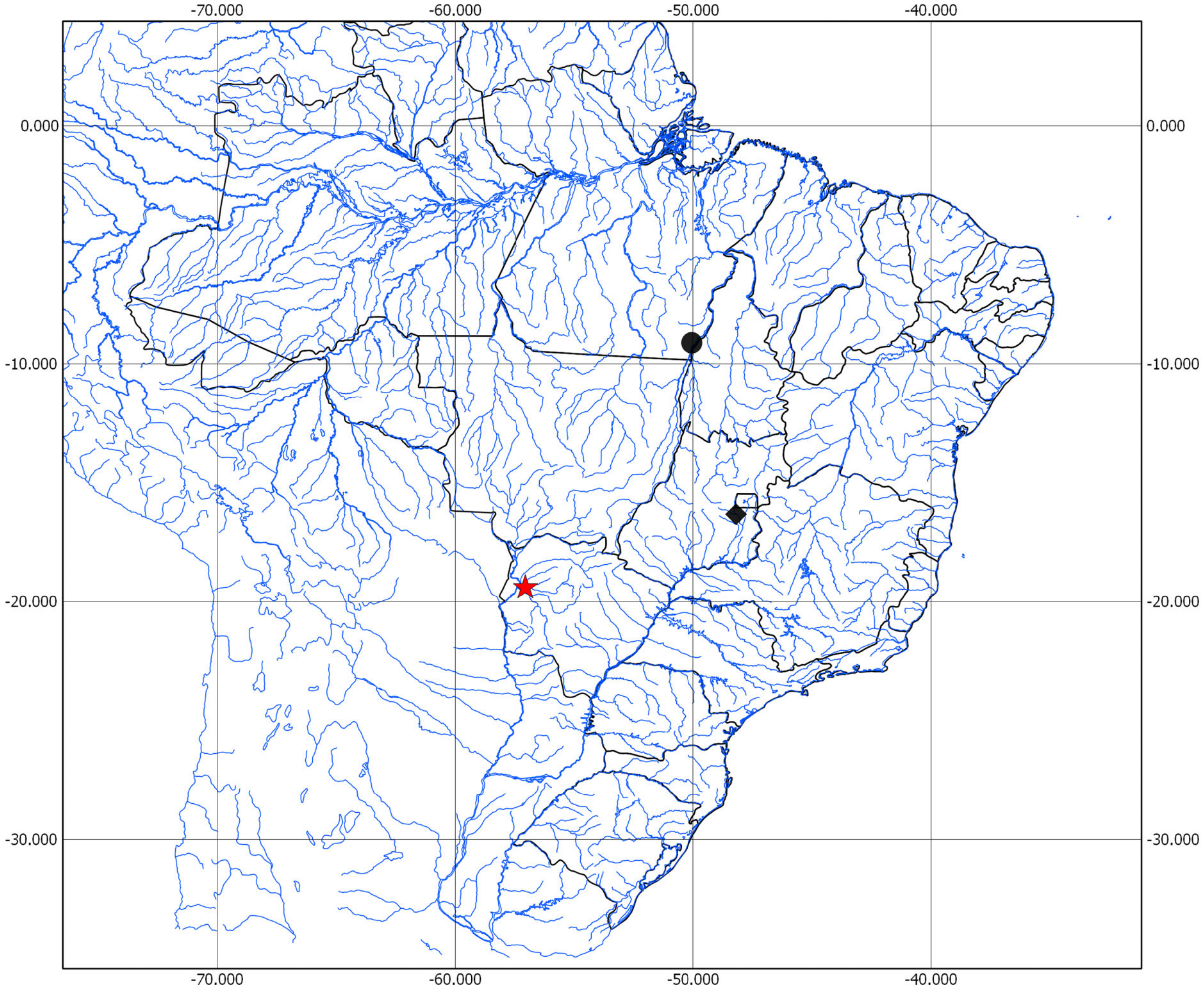

Figure 2. Map showing the new record for *Megalechis picta* in the southern Pantanal region (red star), and the available records for the rio Araguaia basin (black circle) and upper rio Paraná basin (black diamond).

Paraguay basin. The Núcleo de Pesquisas em Ictiologia, Limnologia e Aquicultura (Nupélia) staff have colleted in the region of Manso Reservoir, State of Mato Grosso, for four years and no specimen of *M. picta* was captured. Additionally, other surveys efforts conducted by ZUFMS-PIS staff in the same region of the captured specimen and in the Bodoquena Plateau region also have not resulted in its capture. As mentioned by Tencatt et al. (2013) the introduction of *M. picta* in the upper rio Paraná basin is probably due to its use as a live bait, which can be a plausible explanation to its occurrence in the rio Paraguay basin. The possibility that both species were introduced together in these basins is also plausible due to their difficult distinction by non-experts, thus, can be easily mistaken and sold as a single species by sellers of live baits and in aquarium shops.

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inventory

Floristic characterization of an Atlantic Rainforest remnant in Southern Sergipe: Crasto forest

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LANDIM, M.F., PROENÇA, C.E.B., SALES, A.B., MATOS, I.S. **Floristic characterization of an Atlantic Rainforest remnant in Southern Sergipe: Crasto forest.** Biota Neotropica. 15(1): e20130036. http://dx.doi.org/10.1590/1676-06032014003613

Abstract: The state of Sergipe has suffered extreme reduction of its Atlantic Forest area in the last decades. The objective of this study is to present an inventory of the Mata do Crasto flora, the largest Atlantic Forest Remnant in Sergipe (approximately 1,000 ha), located in the Municipality of Santa Luzia do Itanhy. An intensive survey was undertaken with monthly plant collections in the study area, for four years (1995 to 1999). Additionally, collections deposited in herbaria were consulted to complete the species list. A total of 324 species were found, belonging to 84 families and 193 genera. This study adds an additional 29 genera and 96 species to the Sergipe flora as new occurrences. The four most speciose families were the Fabaceae (33 species), Rubiaceae (24 species), Myrtaceae (23 species) and Melastomataceae (15 species), that accounted for ca. 30% of the total species. The taxonomic distinction of the area is very similar to three other lowland forests in Northeastern Brazil, although its species composition is quite distinct.
Keywords: *Flora, Coastal Vegetation, Taxonomic diversity, São Francisco River.*

LANDIM, M.F., PROENÇA, C.E.B., SALES, A.B., MATOS, I.S. **Caracterização florística de um remanescente de Mata Atlântica no sul de Sergipe: Mata do Crasto.** Biota Neotropica. 15(1): e20130036. http://dx.doi.org/10.1590/1676-06032014003613

Resumo: O estado de Sergipe sofreu extrema redução da área de Mata Atlântica nas últimas décadas. Este trabalho tem como objetivo inventariar a composição florística da Mata do Crasto, maior remanescente de Mata Atlântica de Sergipe (aproximadamente 1.000 ha), situada no Município de Santa Luzia do Itanhy. Um inventário intensivo foi realizado com coletas florísticas na área de estudo por quatro anos (1995 a 1999). Adicionalmente, exsicatas depositadas em herbários foram consultadas para complementar a lista de espécies. Um total de 324 espécies foram identificadas, pertencentes a 84 famílias e 193 gêneros. Este estudo adicionou 96 espécies à flora de Sergipe como novas ocorrências. As famílias com maior número de espécies são Fabaceae (33 espécies), Rubiaceae (24 espécies), Myrtaceae (23 espécies) e Melastomataceae (15 espécies), que juntas somam cerca de 30% do total de espécies. A distinção taxonômica do remanescente é surpreendentemente similar ao de outras florestas de terras baixas no Nordeste do Brasil embora suas espécies sejam bastante distintas.
Palavras-chave: *Flora, Vegetação costeira, Diversidade taxonômica, Rio São Francisco.*

Introduction

The Brazilian Atlantic Rainforest is one of the 25 ’hotspots’ of the world, i.e., areas that have a high concentration of endemic species and that are liable to significant loss of habitat, containing at least 2% of known plants and vertebrates (Myers et al. 2000). Recent surveys of Atlantic Forest recognize 13,708 species and 1,782 genera in 208 families of angiosperms, of which 126 genera (7%) and 6,663 species (49%) are endemic to the forests (Stehmann et al. 2009).

Analyses of the distribution of Atlantic Forest plant species have identified two or more centers of endemism, depending upon the objectives and organisms being considered (Murray-Smith et al. 2008; Fiaschi & Pirani 2009). However, a north-south divide is agreed by most researchers, the northern part of which extends from Rio Grande do Norte to northern Espírito Santo, approximately coinciding with the Rio Doce Valley (Fiaschi & Pirani 2009).

In the northern region of the Atlantic Forest two centers of endemism are recognized: Northern Espírito Santo/Bahia and

Pernambuco (Thomas et al. 1998). However, despite the importance and high floristic diversity of the Atlantic Forest (Stehmann et al. 2009), a high percentage of the remaining forest area are still poorly studied and the geographic distribution of many taxa incomplete (Fiaschi & Pirani 2009). Studies of the extant areas are of fundamental importance to establishing hotspots within the Atlantic Forest (Giulietti et al. 2005; Murray-Smith et al. 2008), permitting better understanding of species distributions and understanding the possible effects of the São Francisco River as a geographic barrier.

It has been estimated that only 11.73% of the original Atlantic Forest remains (Ribeiro et al. 2009). The current situation may be a vicious circle; the better studied areas showing a high diversity and therefore concentrating Atlantic Forest conservation investment. In view of the accelerated rhythm of deforestation the Atlantic Forest has experienced to date (Dean 1996), specifically the northern sector (Freyre 2004), it is necessary to ensure that poorly studied areas are inventoried urgently, since many are threatened, in spite of the Brazilian legal protection instruments (Law N° 11.428/2006). Throughout the Atlantic Forest northern sector, the forest fragments are vulnerable, due to their high timber value, and extreme reduction and fragmentation (Ranta et al. 1998; Tabarelli et al. 2006).

In Sergipe, the Atlantic Forest covered the whole coastal zone, occupying a strip approximately 40 km wide. At the beginning of the 20th century, it was estimated that 41% of the state was covered by forests (Campos, 1912); recent estimates show that Atlantic Forest covers only 9% of its original area in the state (Fundação SOS Mata Atlântica/INPE 2005). In this region, forest vulnerability is increased by the gently rolling landscape and by the low social-economic level of the population which exploits forest fragments for fuelwood, building and hunting.

Sergipe was one of the last Brazilian States to have its flora investigated scientifically. In the 19th century it was visited only by George Gardner, who collected 210 samples from around the mouth of the São Francisco River, in 1838. Although some of these samples state "Bahia" as their location, he goes on to cite the Villa de Propriá (Stephen Harris, OXF, pers. comm.), and Propriá is now part of Sergipe. Herbarium specimens made available by CRIA (2013) reveal only sporadic collections in the 20th century. One collection by J.G. Kuhlmann (RB) from 1923 and some collections by D. Andrade-Lima from the 1950s and 1960s were found. Significant sampling of the Sergipe flora did not start until the 1970s, with the foundation of the ASE herbarium at the Universidade Federal de Sergipe.

The Atlantic Forest fragments of Sergipe have attracted little attention. However, investigations of these fragments have shown they are important for conservation (Landim & Siqueira 2001) because of their floristic diversity, and for harboring rare and threatened animals, such as *Callicebus coimbrai*, a recently described primate, found almost exclusively in Atlantic Forest remnants of Sergipe (Brasil/MMA 2003, Jerusalinsky et al. 2006, Veiga et al. 2008).

The southern part of Sergipe has several Atlantic Forest remnants important for conservation, and the *Litoral e complexo das matas do sul de Sergipe* region was considered one of the areas of the highest importance and urgency amongst those selected for immediate action (BRASIL/MMA 2007). The present study aimed to characterize floristically the largest Atlantic Forest fragment in southern Sergipe. Additionally, the flora of this fragment was compared to other fragments in the northern sector of the Brazilian Atlantic Forest, to find similarities between them.

Materials and methods

Study area

This study was undertaken in the *Mata do Crasto* (11°22' S, 37°25' W), an ombrophilous lowland forest remnant of ca. 1,000 ha, with altitudes from 5 to 90m, located in the Santa Luzia do Itanhy Municipality, Sergipe. The region is situated in the Piauí River basin; its climate is classified as coastal wet with strongly seasonal precipitation, with rainfall concentrated in the middle of the year. Climatic data was obtained from the Meteorological Center of the *Secretaria de Estado do Meio Ambiente e dos Recursos Hídricos* (SEMARH/SRH). The closest PCD (*Plataforma de Coleta de Dados*) weather station to the study area, in the city of Estância (ca. 10.5 km from Santa Luzia do Itanhy) registered total rainfall of 794.2 mm and an average temperature of 25.1° C in 2012. Long-term rainfall data from the region, registered an average rainfall of 2,096.2 mm between 1964 and 1985; during this period annual rainfall varied between 1,452.3 and 3,438.5 mm.

Data sampling and analysis

Monthly collections were made in the study area mainly between 1995 and 1999. The material was collected and dried using standard herbarium techniques (Mori et al. 1989) and deposited in the Universidade Federal de Sergipe (ASE) herbarium. Duplicates were distributed to other herbaria, particularly in northeastern Brazil, but also to Universidade de Brasília (UB), Instituto de Botânica de São Paulo (SP), Jardim Botânico do Rio de Janeiro (RB) and Arizona State University (ASU) herbaria.

Family and species circumscription, as well as spelling and authorities adopted for scientific names, followed, except when explicitly informed, the Lista de Espécies da Flora do Brasil (2014). The listed *vouchers* are those with the widest distribution in herbaria, selected from the examined material. Information on plant habits was obtained from herbarium material and, when these were missing, from the literature. A species was considered as "previously recorded from Sergipe" when it was either cited in Lista de Espécies da Flora do Brasil (2014) or in Volume 1 of Flora de Sergipe (Prata et al. 2013).

Taxonomic richness (Warwick & Clarke 1995; Clarke & Warwick 1998) of the *Mata do Crasto* fragment was compared with that of similar floristic inventories (i.e., those that included all angiosperms, independent of habit) and in similar phytophysiognomies (ombrophilous forests or semi-deciduous lowland forests) in other states of the northern sector of the Atlantic Forest. This index, calculated from presence and absence data, records the average distance between two species chosen at random (Clarke & Warwick 1998). The selected inventories had their species lists checked at the data base of the Centro de Referência em Informação Ambiental (http://www.cria.org.br/), in order to identify the existence of more recent determinations, and being afterwards standardized taxonomically, using Lista de Espécies da Flora do Brasil (2014) synonymy or The Plant List (2013).

Vouchers unidentified to species level in original lists were checked against on-line herbaria in Centro de Referência em Informação Ambiental (http://www.cria.org.br/) for possible

Table 1. List of the 321 species and morphospecies of Angiosperms found in the Atlantic Forest remnant of *Mata do Crasto*, Santa Luzia do Itanhy, Sergipe, organized in alphabetical order by family with vouchers. * = species absent from the Lista de Espécies da Flora do Brasil (2014).

Family / Species	**Vouchers Collector Number (Herbaria)**	**Habit**
ACANTHACEAE		
Aphelandra nitida Nees & Mart.	Santos 478 (ASE)	Shrub
Justicia symphyantha (Nees ex Mart.) Lindau	Santos 457 (ASE)	Herb
Lepidagathis alopecuroidea (Vahl) R.Br. ex Griseb.	Sant'Ana 457 (NY)	Shrub
ACHARIACEAE		
Carpotroche brasiliensis (Raddi) Endl.	Jardim 469 (ASE, NY)	Shrub
ANACARDIACEAE		
Astronium sp.	Landim 954 (ASE)	Tree
Schinus terebinthifolius Raddi	Landim 466 (ASE, SPF)	Tree
Tapirira guianensis Aubl.	Landim 279 (ASE, SPF)	Tree
ANNONACEAE		
Annona glabra L.	Landim 442 (ASE)	Tree
Annona pickelii (Diels) H.Rainer	Landim 940 (ASE, UFRN)	Tree
Annona salzmannii A. DC.	Landim 751 (ASE)	Tree
Annona sp.	Landim 950	Tree
Xylopia brasiliensis Spreng.	Landim 943 (ASE)	Tree
Xylopia frutescens Aubl.	Amaral 1 (ASE, JPB)	Tree
Xylopia laevigata (Mart.) R.E.Fr.	Landim 635 (ASE, HUEFS, UFRN)	Tree
APOCYNACEAE		
Himatanthus bracteatus (A. DC.) Woodson	Landim 875 (ASE)	Tree
Mandevilla scabra (Hoffmanns. ex Roem. & Schult.) K. Schum.	Amorim 1493 (NY)	Climber
Oxypetalum banksii Schult.	Landim 997 (ASE)	Climber
Apocynaceae N.I.	Landim 1277 (ASE)	Tree
ARACEAE		
Anthurium bellum Schott	Prata 2310 (ASE, JPB)	Herb
ARALIACEAE		
Schefflera morototoni (Aubl.) Maguire *et al.*	Landim 564 (ASE, UFRN)	Tree
Araliaceae N.I.	Landim 911 (ASE)	Tree
ARECACEAE		
Bactris sp.	Landim 1216 (ASE)	Shrub
Allagoptera caudescens (Mart.) Kuntze	Gomes 51 (ASE)	Tree
ARISTOLOCHIACEAE		
Aristolochia birostris Duch.	Amorim 1498 (ASE, NY)	Climber
Aristolochia labiata Willd.	Landim 919 (ASE)	Climber
ASTERACEAE		
Albertinia brasiliensis Spreng.	Landim 921 (ASE, SPF)	Climber
Centratherum punctatum Cass.	Amorim 1469 (ASE, NY)	Herb
Gochnatia oligocephala (Gardner) Cabrera	Landim 357 (ASE)	Shrub
Melanthera sp.	Landim 647 (ASE)	Shrub
BALANOPHORACEAE		
Langsdorffia hypogaea Mart.	Gomes 7 (ASE)	Herb
BIGNONIACEAE		
Adenocalymma comosum (Cham.) DC.	Landim 379 (ASE)	Climber
Bignonia corymbosa (Vent.) L. Lohmann	Landim 650 (ASE)	Climber
Fridericia chica (Bonpl.) L.G.Lohmann	Landim 335 (ASE)	Climber
Handroanthus chrysotrichus (Mart. ex DC.) Mattos	Moura 901 (ASE, HUEFS)	Tree
Jacaranda aff. *obovata* Cham	Sant'Ana 434 (ASE)	Tree
Lundia cordata (Vell.) A. DC.	Landim 231 (ASE)	Climber
BORAGINACEAE		
Cordia taguahyensis Vell.	Carvalho 4342 (ASE, NY)	Shrub
Tournefortia sp.	Landim 348 (ASE)	Shrub
BROMELIACEAE		
Aechmea mertensii (G.Mey.) Schult. & Schult.f.	Landim 434 (ASE)	Epifite
Aechmea multiflora L.B. Sm	Amorim 1480 (ASE, NY)	Herb
BURMANNIACEAE		

Continued on next page

Table 1. Continued.

Family / Species	Vouchers Collector Number (Herbaria)	Habit
Apteria aphylla (Nutt.) Barnhart ex Small	Landim 625 (ASE)	Herb
Burmannia capitata (Walter ex J. F. Gmel.) Mart.	Sant'Ana 423 (ASE)	Herb
Gymnosiphon divaricatus (Benth.) Benth. & Hook.f.	Gomes 13 (ASE)	Herb
BURSERACEAE		
Protium heptaphyllum (Aubl.) Marchand subsp.*heptaphyllum*	Jardim 474 (ASE, MBM, NY)	Tree
Protium sagotianum Marchand	Jardim 482 (ASE, MBM)	Tree
Protium warmingianum Marchand	Souza 221 (ASE, SPF)	Tree
CALOPHYLLACEAE		
Calophyllum brasiliense Cambess.	Landim 375 (ASE)	Tree
Kielmeyerea neglecta Saddi	Landim 870 (ASE)	Tree
CELASTRACEAE		
Maytenus cf. *disticophylla* Mart. Ex Reissek	Landim 616 (ASE, HUEFS, UFRN)	Tree
Maytenus cf. *obtusifolia* Mart.	Sant'Ana 430 (ASE, CEPEC, MBM)	Tree
Maytenus opaca Reissek	Prata 2588 (ASE, JPB)	Tree
CHRYSOBALANACEAE		
Hirtella ciliata Mart. & Zucc.	Landim 753, 804, 867 (ASE)	Tree
Hirtella racemosa var.*hexandra* (Willd. ex Roem. & Schult.) Prance	Sant'Ana 448 (ASE, NY)	Tree
Hirtella sp	Landim 238 (ASE)	Tree
Licania octandra (Hoffmanns. ex Roem. & Schult.) Kuntze subsp. *Octandra*	Amorim 1483 (ASE, MAC, NY)	Tree
Parinari littoralis Prance	Landim 555 (ASE)	Tree
CLUSIACEAE		
Clusia nemorosa G.Mey	Landim 987 (ASE)	Tree
Clusia paralicola G.Mariz	Landim 929 (ASE)	Tree
Garcinia madruno (Kunth) Hammel	Landim917 (ASE)	Tree
COMBRETACEAE		
Buchenavia tetraphylla (Aubl.) R.A.Howard	Landim 708 (ASE)	Tree
CONNARACEAE		
Rourea cf. *pseudogardneriana* Forero *et al.*	Landim 309 (ASE, HUEFS)	Climber
CONVOLVULACEAE		
Jacquemontia blanchetii Moric.	Landim 994 (ASE)	Climber
Merremia macrocalyx (Ruiz & Pav.) O'Donell	Landim 1366 (ASE)	Climber
CUCURBITACEAE		
Gurania cf. *bignoniacea* (Poepp. & Endl.) C. Jeffrey	Landim 324 (ASE)	Climber
CYPERACEAE		
Abildgaardia ovata (Burm. f.) Kral	Carvalho 4316 (NY, UFP)	Herb
Eleocharis geniculata (L.) Roem. &Schult.	Landim 744 (ASE, HUEFS)	Herb
Rhynchospora comata (Link) Roem. &Schult.	Gomes 66 (ASE)	Herb
Scleria bracteata Cav.	Vicente 791 (ASE, HUEFS)	Climber
Scleria hirtella Sw.	Amorim 1470 (ASE)	Herb
DILLENIACEAE		
Curatella americana L.	Landim 798 (ASE)	Tree
Davilla kunthii A.St.-Hil.	Landim 909 (ASE)	Climber
Tetracera boomii Aymard	Landim 612 (ASE, HUEFS)	Climber
Tetracera cf. *breyniana* Schltdl.	Landim 440 (ASE)	Climber
EBENACEAE		
Diospyros gaultheriifolia Mart. ex Miq.	Carvalho 4328 (ASE, CEPEC)	Tree
ELAEOCARPACEAE		
Sloanea garckeana K.Schum.	Sant'Ana 470 (ASE, CEPEC, NY, UESC)	Tree
ERIOCAULACEAE		
Paepalanthus bifidus (Schrad.) Kunth	Landim 1000 (ASE, HUEFS)	Herb
ERYTHROXYLACEAE		
Erythroxylum affine A.St.-Hil.	Jardim 484 (NY)	Shrub
Erythroxylum mucronatum Benth.	Landim 300 (ASE)	Shrub
Erythroxylum mikanii Peyr.	Amorim 1462 (ASE, NY)	Shrub
Erythroxylum nobile O.E. Schulz	Amorim 1485 (ASE, NY)	SubShrub

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Table 1. Continued.

Family / Species	Vouchers Collector Number (Herbaria)	Habit
Erythroxylum squamatum Sw.	Landim 1205 (ASE, IPA)	Tree
EUPHORBIACEAE		
Croton lundianus (Didr.) Müll.Arg.	Landim 1209 (ASE, IPA)	Herb
Croton sellowii Baill.	Gomes 69 (ASE)	Shrub
Dalechampia cf. *brasiliensis* Lam.	Landim 750 (ASE, HUEFS)	Climber
Dalechampia sp.	Landim 659 (ASE, HUEFS)	Climber
FABACEAE		
Abarema cochliacarpos (Gomes) Barneby & J.W. Grimes	Landim 752 (ASE, HUEFS)	Tree
Aeschynomene marginata Benth.	Landim 543 (ASE, HUEFS)	SubShrub
Andira fraxinifolia Benth.	Sant'Ana 468 (ASE)	Tree
Bowdichia virgilioides Kunth.	Landim 730 (ASE, HUEFS)	Tree
Calopogonium mucunoides Desv.	Gomes 11 (ASE)	Climber
Centrosema bifidum Benth.	Landim 756 (ASE, HUEFS)	Climber
Centrosema virginianum (L.) Benth.	Landim 559 (ASE, HUEFS)	Climber
Chamaecrista nictitans var. *disadena* (Steud.) H.S. Irwin & Barneby	Landim 656 (ASE, HUEFS)	Herb
Clitoria laurifolia Poir.	Landim 761 (ASE)	Shrub
Crotalaria retusa L.	Landim 552 (ASE, HUEFS)	SubShrub
Crotalaria stipularia Desv.	Landim 553 (ASE)	SubShrub
Dioclea lasiophylla Mart. ex Benth.	Sant'Ana 383 (ASE, NY)	Climber
Dioclea violacea Mart. ex Benth.	Landim 464 (ASE)	Climber
Dioclea virgata (Rich.) Amshoff.	Landim 529 (ASE, HUEFS)	Climber
Inga bollandii Sprague & Sandwith	Amorim 3454 (HUEFS)	Tree
Inga capitata Desv.	Landim 729 (ASE, HUEFS)	Tree
Inga cayennensis Sagot ex Benth.	Gomes 14 (ASE)	Tree
Inga ciliata Presl. var.*ciliata*	Landim 327(ASE, HUEFS)	Shrub
Inga subnuda Salzm. Ex Benth. subsp. *subnuda*	Landim 754 (ASE, HUEFS)	Tree
Inga tenuis (Vell.) Mart.	Landim 915 (ASE, HUEFS)	Tree
Leptolobium bijugum (Spreng.) Vogel	Landim 376 (ASE, HUEFS)	Tree
Machaerium hirtum (Vell.) Stellfeld	Landim 795 (ASE, HUEFS)	Tree
Mimosa sensitiva L.	Landim 862 (HUEFS)	Herb
Mimosa somnians Humb. & Bonpl. exWilld.	Landim 554 (ASE, HUEFS)	SubShrub
Phanera outimouta (Aubl.) L.P.Queiroz	Sant'Ana 464 (ASE, NY)	Climber
Senna macranthera (DC. ex Collad.) H.S. Irwin & Barneby	Landim 801 (ASE, HUEFS)	Climber
Senna phlebadenia H.S. Irwin & Barneby	Landim 868 (ASE, HUEFS)	Tree
Senna spectabilis (DC.) H.S. Irwin & Barneby	Landim 1204 (ASE, IPA)	Shrub
Senna splendida (Vogel) H.S. Irwin & Barneby	Landim 550 (HUEFS)	Shrub
Stryphnodendron pulcherrimum (Willd.) Hochr.	Landim 802 (ASE, HUEFS)	Tree
Stylosanthes cf. *scabra* Vog.	Landim 536 (ASE)	Herb
Swartzia apetala Raddi var. *apetala*	Landim 290 (ASE, HUEFS)	Tree
Tachigali densiflora (Benth.) L.F. Gomes da Silva & H.C. Lima	Landim 660 (ASE, HUEFS, UB)	Tree
GENTIANACEAE		
Chelonanthus purpurascens (Aubl.) Struwe *et al.*	Landim 701 (ASE)	Herb
Coutoubea spicata Aubl.	Sant'Ana 385 (ASE, NY)	Herb
Schultesia guianensis (Aubl.) Malme	Landim 618 (ASE, HUEFS, UB, UFRN)	Herb
Voyria caerulea Aubl.	Jardim 475 (ASE, NY)	Herb
Voyria obconica Progel	Landim 1214 (ASE)	Herb
HERNANDIACEAE		
Sparattanthelium botocudorum. Mart	Fonseca ASE62 (ASE, JBRJ)	Tree
HUMIRIACEAE		
Sacoglottis guianensis Benth. var.*guianensis*	Carvalho 4346 (NY, MO,CEPLAC)	Tree
HYPERICACEAE		
Vismia guianensis (Aubl.) Choisy	Landim 435 (ASE)	Shrub
HYPOXIDACEAE		
Hypoxis decumbens L.	Landim 453 (ASE, HUEFS)	Herb
IRIDACEAE		
Cipura paludosa Aubl.	Landim 451 (ASE)	Herb

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Table 1. Continued.

Family / Species	Vouchers Collector Number (Herbaria)	Habit
Trimezia martinicensis (Jacq.) Herb.	Landim 654 (ASE, HUEFS)	Herb
LAMIACEAE		
Aegiphila verticillata Vell.	Landim 368 (ASE)	Shrub
Hyptis atrorubens Poit.	Landim 621 (ASE, HUEFS, UFRN)	Herb
LAURACEAE		
Cassytha filiformis L.	Landim 534 (ASE)	Parasite
Ocotea duckei Vattimo-Gil	Landim 1276 (ASE)	Tree
Ocotea glomerata (Nees) Mez	Jardim 479 (ASE, NY)	Herb
LECYTHIDACEAE		
Eschweilera ovata (Cambess.) Miers	Landim 240 (ASE)	Tree
Lecythis lurida (Miers) S.A. Mori	Amorim 1471 (ASE, NY)	Tree
Lecythis pisonis Cambess.	Landim 790 (ASE)	Tree
Lecythis sp.	Landim 947 (ASE)	Tree
LORANTHACEAE		
Psittacanthus robustus (Mart.) Mart.	Amorim 1487 (ASE, NY)	Parasite
Struthanthus flexicaulis Mart.	Landim 378 (ASE)	Parasite
Struthanthus syringifolius (Mart.) Mart.	Amorim 1472 (ASE, NY)	Parasite
LYTHRACEAE		
Cuphea racemosa (L. f.) Spreng.	Landim 619 (HUEFS)	Herb
MALPIGHIACEAE		
Byrsonima sericea DC.	Landim 206 (ASE)	Tree
Heteropterys nordestina Amorim	Landim 874 (ASE)	Climber
Heteropterys sericea (Cav.) A. Juss.	Carvalho 4335 (ASE, SP, NY)	Climber
Heteropterys sp.	Landim 810 (ASE)	Tree
Peixotoa hispidula A. Juss.	Landim 999 (ASE)	Climber
Stigmaphyllon blanchetii C.E. Anderson	Amorim 1495 (ASE, NY)	Climber
Tetrapterys phlomoides Nied.	Jardim 470 (ASE, NY)	Shrub
Tetrapterys sp.	Landim 788 (ASE)	Climber
MALVACEAE		
Briquetia spicata (Kunth) Fryxell	Landim 993 (ASE)	Shrub
Luehea ochrophylla Mart.	Landim 295 (ASE, JPB, RB)	Tree
Sida cordifolia L.	Amaral 3 (ASE)	Herb
Sida linifolia Cav.	Landim 996 (ASE)	Climber
Waltheria americana L.	Landim 530 (ASE, MAC)	Herb
Waltheria viscosissima A.St.-Hil.	Sant'Ana 469 (ASE, NY)	Herb
MARANTACEAE		
Monotagma plurispicatum (Körn.) K. Schum	Sant'Ana 447 (ASE, NY)	Herb
Stromanthe porteana Griseb.	Landim 558 (ASE, UFRN)	Herb
MELASTOMATACEAE		
Clidemia capitellata (Bonpl.) D.Don	Sant'Ana 417 (ASE, NY)	SubShrub
Clidemia hirta (L.) D.Don	Landim 323 (ASE, HUEFS)	SubShrub
Clidemia rubra (Aubl.) Mart.	Viana ASE275 (ASE)	Shrub
Comolia ovalifolia (DC.) Triana	Sant'Ana 380 (ASE, JBRJ, MO, NY, UPCB)	SubShrub
Leandra sp.	Landim 538 (ASE)	Herb
Miconia albicans (Sw.) Triana	Landim 1474 (ASE)	Shrub
Miconia amoena Triana	Carneiro 457 (ASE)	Shrub
Miconia ciliata (Rich.) DC.	Landim 1289 (ASE)	Shrub
Miconia elegans Cogn.	Viana 378 (ASE)	Shrub
Miconia holosericea (L.) DC.	Landim 317 (ASE, HUEFS)	Shrub
Miconia minutiflora (Bonpl.) DC.	Landim 527 (ASE)	Tree
Miconia pileata DC.	Sant'Ana 415	Shrub
Miconia prasina (Sw.) DC.	Prata 2274 (ASE)	Shrub
Nepsera aquatica (Aubl.) Naudin	Gomes 33 (ASE)	Herb
Pterolepis trichotoma (Rottb.) Cogn.	Landim 641 (ASE, HST, NY)	Herb
Tibouchina asperifolia Cogn.*	Landim 759 (ASE)	Shrub

Continued on next page

Table 1. Continued.

Family / Species	**Vouchers** **Collector Number (Herbaria)**	**Habit**
MELIACEAE		
Trichilia lepidota Mart. subsp. f*erruginea* T.D. Penn.*	Amorim 1484 (ASE, NY)	Tree
Trichilia lepidota Mart. subsp. l*epidota* T. D. Penn.	Landim 710 (ASE, JPB, MBM)	Tree
MENISPERMACEAE		
Cissampelos glaberrima A.St.-Hil.	Landim 653, 655 (ASE)	Climber
MORACEAE		
Ficus guianensis Desv.	Amorim 1491 (ASE, NY)	Tree
Ficus insipida Willd.	Landim 952 (ASE)	Tree
MYRTACEAE		
Calyptranthes brasiliensis Spreng.	Landim 800 (ASE, HUEFS)	Tree
Campomanesia aromatica (Aubl.) Griseb.	Landim 354 (ASE, MBM)	Tree
Campomanesia dichotoma (O. Berg) Mattos	Landim 920 (ASE)	Tree
Campomanesia guaviroba (DC.) Kiaersk.	Landim 346 (ASE, JPB)	Tree
Campomanesia ilhoensis Mattos	Landim 1202 (ASE, JPB)	Shrub
Eugenia brejoensis Mazine	Gomes 118 (ASE)	Tree
Eugenia candolleana DC.	Landim 1139 (ASE, UB)	Tree
Eugenia excelsa O. Berg.	Landim 404 (ASE, UB)	Tree
Eugenia hirta O. Berg	Sant'Ana 459 (ASE, NY, RB, SP)	Tree
Eugenia punicifolia (Kunth) DC.	Carvalho 4339 (ASE, MBM, RB, SP)	Shrub
Marlierea excoriata Mart.	Gomes 73 (ASE)	Tree
Myrcia amazonica DC.	Sant'Ana 438 (ASE, RB)	Shrub
Myrcia decorticans DC.	Landim 637 (ASE, HUEFS, JPB, UB)	Tree
Myrcia polyantha DC.	Landim (ASE, UB)	Shrub
Myrcia hirtiflora DC.	Landim799 (ASE, UB)	Tree
Myrcia racemosa (O. Berg) Kiaersk	Amorim 1466 (ASE, NY, RB, SP, UB)	Tree
Myrcia rosangelae NicLugh. & Lucas	Landim 237 (ASE, UB)	Tree
Myrcia splendens (Sw.) DC.	Landim 341, 362 (ASE, UB)	Tree
Myrcia sylvatica (Mey.) DC.	Landim 303 (ASE, UB)	Shrub
Myrcia verrucosa Sobral	Landim 623 (ASE, HUEFS, UB)	Tree
Myrciaria ferruginea O. Berg	Sant'Ana 421 (ASE, NY)	Shrub
Psidium guineense Sw.	Landim 643 (ASE, HUEFS, UB)	Shrub
Psidium oligospermum Link ex DC.	Pirani 2664 (K, NY, RB, SP, SPF)	Shrub
NYCTAGINACEAE		
Guapira noxia (Netto) Lundell	Gomes 62 (ASE)	Tree
Guapira opposita (Vell.) Reitz	Gomes 130 (ASE)	Shrub
Guapira pernambucensis (Casar.) Lundell	Landim 310 (ASE, JPB)	Shrub
Guapira sp.	Landim 299 (ASE, HUEFS, RB)	Tree
Pisonia cordifolia Mart. ex J.A.Schmidt*	Landim 306 (ASE, IPA)	Shrub
OCHNACEAE		
Ouratea crassa Tiegh.	Landim 871 (ASE)	Tree
Sauvagesia erecta L.	Landim 620 (ASE, HUEFS, JPB, UFRN)	Herb
OLACACEAE		
Heisteria perianthomega (Vell.) Sleumer	Amorim 1474 (ASE, MO, NYBG)	Tree
ONAGRACEAE		
Ludwigia cf. *octovalvis* (Jacq.) P.H.Raven	Landim 216 (ASE)	Climber
Ludwigia sp.	Landim 743 (ASE)	Shrub
ORCHIDACEAE		
Alatiglossum barbatum (Lindl.) Baptista	Carvalho 4334 (ASE, NY)	Epifite
Habenaria pratensis (Salzm. ex Lindl.) Rchb.f.	Landim 707 (ASE)	Herb
Liparis nervosa (Thumb.) Lindl.	Landim 439 (ASE)	Herb
OXALIDACEAE		
Oxalis puberula Nees & Mart.	Landim 455 (ASE, JPB)	SubShrub
PASSIFLORACEAE		
Passiflora contracta Vitta	Landim 872 (ASE, HUEFS)	Climber
Passiflora misera Kunth.	Landim 991 (ASE, HUEFS)	Climber
Passiflora silvestris Vell.	Landim 205 (ASE, HUEFS)	Climber

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Table 1. Continued.

Family / Species	Vouchers Collector Number (Herbaria)	Habit
PENTAPHYLACACEAE		
Ternstroemia brasiliensis Cambess.	Landim 760 (ASE)	Tree
PERACEAE		
Chaetocarpus echinocarpus (Baill.) Ducke	Landim 233 (ASE, HUEFS, UFRN)	Tree
Chaetocarpus myrsinites Baill.	Landim 454 (ASE, HUEFS)	Tree
Pera glabrata (Schott) Poepp. ex Baill.	Landim 869 (ASE, HUEFS)	Tree
PHYLLANTHACEAE		
Amanoa guianensis Aubl.	Landim 624 (ASE, HUEFS)	Tree
Phyllanthus corcovadensis Müll. Arg.	Sant'Ana 428 (ASE, NY)	Shrub
Phyllanthus tenellus Roxb.	Landim 208 (ASE, UFRN)	Shrub
PICRAMNIACEAE		
Picramnia andrade-limae Pirani	Landim 528 (ASE, JPB, MBM, SPF)	Tree
Picramnia glazioviana Engl. subsp. *glazioviana* Pirani	Jardim 451 (NY, SPF)	Tree
PIPERACEAE		
Piper divaricatum G. Mey	Sant'Ana 406 (ASE, NY, RB)	Shrub
Piper sp.	Gomes 569 (ASE)	Shrub
POACEAE		
Aristida longifolia Trin.	Viana 1291 (ASE)	Herb
Gymnosiphon divaricatus (Benth.) Benth. & Hook.f.	Landim 1278 (ASE)	Herb
Ichnanthus calvescens Nees	Costa 589 (ASE)	Herb
Ichnanthus leiocarpus (Spreng.) Kunth	Landim 706 (ASE, HUEFS, JPB)	Herb
Ichnanthus nemoralis (Schrad. ex Schult.) Hitchc. & Chase	Carvalho 4323 (ASE, NY)	Herb
Parodiolyra micrantha (Kunth) Davidse & Zuloaga	Landim 630 (ASE, HUEFS)	Herb
POLYGALACEAE		
Polygala galioides Poir.	Sant'Ana 374 (NY)	Herb
Polygala paniculata L.	Landim 992 (ASE, HUEFS)	Herb
POLYGONACEAE		
Coccoloba declinata (Vell.) Mart.	Carvalho 4336 (ASE, NY)	Tree
Coccoloba laevis Casar.	Landim 702 (ASE, HUEFS)	Shrub
Coccoloba mollis Casar.	Prata 2613 (ASE)	Tree
Coccoloba parimensis Benth.	Souza 231 (ASE)	Climber
Coccoloba rosea Meisn.	Landim 1368 (ASE, HUEFS, UB)	Tree
RHAMNACEAE		
Gouania blanchetiana Miq.	Landim 547 (ASE)	Climber
Gouania sp.	Landim 908 (ASE, MBM)	Shrub
RUBIACEAE		
Alseis floribunda Schott	Carvalho 4343 (ASE, SP, NY)	Tree
Alseis pickelii Pilg. & Schmale	Landim 1367 (ASE, JPB)	Tree
Borreria capitata (Ruiz &Pav.) DC.	Amorim 3463 (NY)	Herb
Borreria humifusa Mart.	Landim 705 (ASE, JPB)	Herb
Borreria scabiosoides Cham. & Schltdl.	Landim 539 (JPB)	SubShrub
Borreria verticillata (L.) G.Mey.	Landim 446 (ASE, JPB)	SubShrub
Chomelia anisomeris Müll.Arg.	Landim 811 (ASE)	Shrub
Chomelia obtusa Cham. &Schltdl.	Landim 369 (ASE, JPB)	Tree
Cordiera myrciifolia (K.Schum.) C.H.Perss. & Delprete	Gomes 31 (ASE)	Shrub
Coutarea hexandra (Jacq.) K. Schum.	Landim 957 (ASE, JPB, MBM)	Tree
Emmeorhiza umbellata (Spreng.) K.Schum.	Landim 995 (ASE)	Climber
Guettarda platyphylla Müll.Arg.	Carvalho 4326 (ASE, NY)	Tree
Guettarda viburnoides Cham. & Schltdl.	Landim 469 (ASE, JPB, MBM)	Tree
Malanea macrophylla Bartl. ex Griseb.	Amorim 1473 (ASE, NY)	Tree
Margaritopsis chaenotricha (DC.) C.M.Taylor	Landim 629 (ASE, HUEFS)	Shrub
Psychotria bracteocardia (DC.) Müll.Arg.	Landim 526 (ASE, JPB)	Shrub
Psychotria capitata Ruiz &Pav.	Landim 304 (ASE, JPB, RB)	Shrub
Psychotria carthagenensis Jacq.	Amorim 1504 (ASE, NY, SP)	Shrub
Psychotria hoffmannseggiana (Willd. ex Schult.) Müll.Arg.	Landim 928 (ASE, JPB)	Shrub
Psychotria platypoda DC.	Carvalho 4329 (ASE, NY)	Shrub

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Table 1. Continued.

Family / Species	**Vouchers Collector Number (Herbaria)**	**Habit**
Psychotria subtriflora Müll.Arg.	Gomes 48 (ASE)	Shrub
Psychotria sp.	Landim 740 (ASE, JPB)	Shrub
Sabicea grisea Cham. &Schltdl.	Landim 657 (ASE)	Climber
Salzmannia nitida DC.	Landim 614 (ASE, HUEFS, UB)	Shrub
RUTACEAE		
Ertela trifolia (L.) Kuntze	Landim 649 (ASE, JPB, SPF)	Herb
SALICACEAE		
Casearia decandra Jacq.	Landim 407 (ASE, HUEFS)	Tree
Casearia javitensis Kunth	Landim 792 (ASE)	Tree
Casearia sylvestris Sw.	Landim 935 (ASE)	Tree
SANTALACEAE		
Phoradendron chrysocladon A. Gray	Landim 463 (ASE)	Parasite
Phoradendron strongyloclados Eichler	Landim 444 (ASE)	Parasite
Phoradendron quadrangulare (Kunth) Griseb.	Landim 998 (ASE)	Parasite
SAPINDACEAE		
Allophylus edulis (A.St.-Hil. et al.) Hieron. ex Niederl.	Landim 429 (ASE, UB)	Tree
Cupania impressinervia Acev.-Rodr.	Landim 636 (ASE, HUEFS, UFRN)	Tree
Cupania racemosa (Vell.) Radlk.	Jardim et al. 461 (ASE, NY)	Tree
Cupania sp.	Landim 948 (ASE)	Tree
Paullinia racemosa Wawra	Landim 1275 (ASE, HUEFS)	Climber
Paullinia trigonia Vell.	Landim 374 (ASE)	Climber
Serjania paradoxa Radlk.	Landim 371 (ASE, HUEFS)	Climber
Serjania salzmanniana Schltdl.	Landim 352 (ASE, IPA, JPB)	Climber
SAPOTACEAE		
Chrysophyllum rufum Mart.	Gomes 177 (ASE)	Tree
Ecclinusa ramiflora Mart.	Landim 276 (ASE)	Tree
Manilkara maxima T.D.Penn.	Gomes 24, 76 (ASE)	Tree
Manilkara salzmannii (A.DC.) H.J.Lam	Landim 398 (ASE)	Tree
Micropholis compta Pierre in Urb.	Sant'Ana 454 (ASE, NY)	Tree
Micropholis gardneriana (A.DC.) Pierre	Landim 932 (ASE, EAC, HUEFS, JPB)	Tree
Pouteria grandiflora (A.DC.) Baehni	Jardim 472 (ASE, CEPEC, MO, RB)	Tree
Pouteria macahensis T.D.Penn.	Gomes 121 (ASE)	Tree
Pouteria macrophylla (Lam.) Eyma	Prata 2615 (ASE)	Tree
Pouteria venosa (Mart.) Baehni	Landim 349 (ASE, HUEFS)	Tree
Pradosia lactescens (Vell.) Radlk.	Landim 1281(ASE)	Tree
SCHOEPFIACEAE		
Schoepfia brasiliensis A. DC.	Landim 462 (ASE, UFRN)	Tree
SIMAROUBACEAE		
Simarouba versicolor A.St.-Hil.	Fonseca ASE184 (ASE)	Tree
SMILACACEAE		
Smilax rufescens Griseb.	Landim 562 (ASE)	Shrub
Smilax sp.	Landim 340 (ASE)	Climber
SOLANACEAE		
Cestrum salzmannii Dunal	Sant'Ana 449 (ASE)	Shrub
Cestrum sp.	Landim 1138 (ASE, JPB)	Shrub
Schwenckia americana Rooyen ex L.	Landim 642 (ASE, HUEFS, IPA)	Herb
Solanum capsicoides All.	Landim 565 (ASE)	Herb
Solanum paludosum Moric.	Landim 796 (ASE, JPB)	Shrub
Solanum polytrichum Moric.	Landim 292 (ASE, UB)	Shrub
Solanum stenandrum Sendtn.	Landim 566 (ASE)	Shrub
Solanum stipulaceum Willd. ex Roem. & Schult.	Sant'Ana 461 (ASE, NYBR_BR)	Shrub
TRIGONIACEAE		
Trigonia nivea Cambess. var. *nivea*	Sant'Ana 424 (ASE, NY)	Climber
Trigonia sp.	Landim 931 (ASE)	Climber
URTICACEAE		
Cecropia pachystachya Trécul	Amorim 1475 (ASE, NY)	Tree

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Table 1. Continued.

Family / Species	Vouchers Collector Number (Herbaria)	Habit
VERBENACEAE		
Lantana camara L.	Landim 548 (ASE)	Shrub
Lantana canescens Kunth	Landim 546 (ASE)	SubShrub
Lantana fucata Lindl.	Landim 646 (ASE)	Shrub
Lantana lucida Schauer	Landim 615 (ASE)	SubShrub
Stachytarpheta cayennensis (Rich.) Vahl	Landim 370 (ASE, HUEFS)	Herb
Stachytarpheta maximiliani Schauer	Amorim 3461 (HUEFS)	Herb
Stachytarpheta sp. 1	Amaral 2 (ASE)	Herb
Stachytarpheta sp. 2	Landim 567 (ASE)	Herb
Tamonea juncea Schauer	Landim 535 (ASE, HUEFS)	Herb
VIOLACEAE		
Hybanthus calceolaria (L.) Oken	Jardim 467 (ASE, CEPEC)	Herb
Rinorea guianensis Aubl.	Gomes 81 (ASE)	Shrub
VITACEAE		
Cissus erosa Rich.	Landim 648 (ASE, HUEFS, MAC)	Climber
VOCHYSIACEAE		
Vochysia lucida C.Presl	Landim 320 (ASE, UEFS)	Tree
XYRIDACEAE		
Xyris jupicai Rich.	Amorim 1486 (ASE, NY)	Herb

new determinations. The Taxonomic Distinction Index (Δ^+) was calculated using PAST, version 2.14 (Hammer et al. 2001). Four taxonomic levels (order, family, genus and species) were adopted and the same step length (=1) was used to attribute weight to distances between the different levels (Clarke & Warwick 1999).

Results and discussion

Floristic composition

The Mata do Crasto floristic list recorded 324 species of which 21 (6.5%) were identified only to genus and two (0.6%) only to family (Tabel 1). The floristic list recorded 84 families and 193 genera. Over a third of the species were new occurrences for Sergipe: 129 (30%) new species occurrences, 29 new generic occurrences and four new family occurrences (Humiriaceae, Onagraceae, Smilacaceae and Vochysiaceae) according to data available in the Lista de Espécies da Flora do Brasil (2014).

Although species accepted in the Lista de Espécies da Flora do Brasil (2014) were adopted as the taxonomic standard, three species not recognized by this list (not even as synonyms) were accepted: *Trichilia lepidota* Mart. subsp. *ferruginea* T.D. Penn. (Amorim 1484) was maintained since it is an isotype; *Tibouchina asperifolia* Cogn. (Landim 759) is accepted by The Plant List (2013) and by Melastomataceae.Net (2013); and *Pisonia cordifolia* Mart. ex J.A.Schmidt is an unresolved name in The Plant List (2013) (http://www.theplantlist.org/tpl/record/kew-2552380).

The most speciose families (Figure 1), Fabaceae (33 species), Rubiaceae (24 species), Myrtaceae (23 species) and Melastomataceae (15 species), account for 30% of the species in the *Mata do Crasto*. These four families are amongst the nine most diverse families in the Atlantic Forest (Stehmann et al. 2009). In a study of Atlantic Forest in southern Bahia, Ubatuba (SP) and Porto Alegre (Rio Grande do Sul) these families were also important but the Fabaceae are more speciose in the *Mata do Crasto* than in either of these areas and the Myrtaceae, proportionally, less important (Leitão Filho, 1987). However, in a wider and more recent survey of Atlantic Forest, Oliveira-Filho & Fontes' (2000) conclusions were more similar to those reported here. According to their results, the four most speciose families in the *Mata do Crasto* are also the five most speciose families in lowland pluvial Atlantic forests, considering the Fabaceae as a single family (*sensu* APG III, Reveal & Chase 2011). The apparent similarity of the *Mata do Crasto* to other areas should be interpreted with caution since the database used by Oliveira-Filho & Fontes (2000) did not consider areas north of southern Bahia. Differences in collection effort and subtle alterations in methodologies, together with differential attention to forest strata can also influence richness results and bias comparisons of family richness.

In the *Mata do Crasto*, there are 33 species in 20 genera in the Fabaceae, the second most speciose family in the Atlantic Forest domain (Stehmann et al. 2009), corresponding to 26% and 36%, respectively, of the total numbers of species and genera known in Sergipe (Lima et al. 2013). In surveys of the northeast (Rodal et al. 2005, Barbosa et al., 2011) and in the southeast (Ivanauskas & Rodrigues 2000, Peixoto et al. 2004, Zipparro et al. 2005, Rolim et al. 2006) regions of the Atlantic Forest, the Fabaceae is usually the most speciose family.

The most speciose genera of Fabaceae in the *Mata do Crasto* were *Inga* and *Senna* (four and six species, respectively). *Inga* is the eighth most speciose genus in lowland pluvial Atlantic forest (Stehmann et al. 2009) and one of the two Fabaceae genera included in the 21 most diverse genera in these communities by Oliveira-Filho & Fontes (2000). Physiognomically, *Tachigali densiflora* (Benth.) L.F. Gomes da Silva & H.C. Lima, a large emergent tree very characteristic of the Sergipe Atlantic Forest remnants is a prominent component; this Caesalpinoid Legume occurs in Minas Gerais and then northwards in all the coastal states up to northeastern Paraíba (Lima et al. 2013).

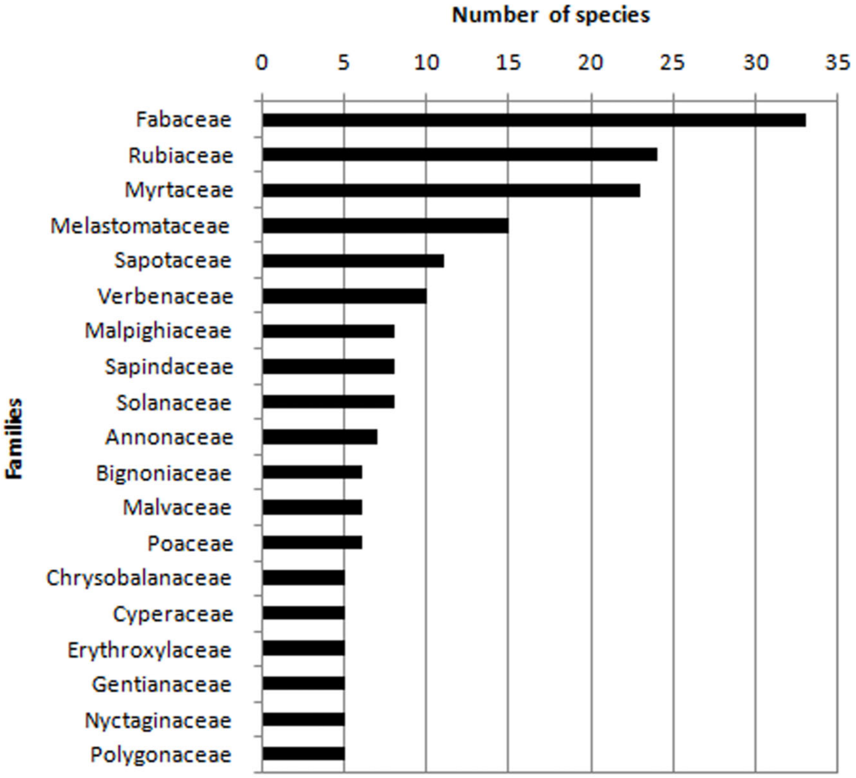

Figure 1. Angiosperm families with five or more species found in the *Mata do Crasto* Atlantic Rainforest remnant, Santa Luzia do Itanhy, Sergipe, Brazil.

The Rubiaceae is the second most speciose family in the *Mata do Crasto*, with 24 species in 12 genera; 61% and 46% of the total number of Rubiaceae species and genera, respectively, recorded from Sergipe (Barbosa et al. 2013). This family is the ninth most speciose in Atlantic Forest (Stehmann et al. 2009) and the third most speciose in lowland Atlantic pluvial forest (Oliveira-Filho & Fontes 2000). *Psychotria* and *Borreria* were the richest genera (seven and four species, respectively).

Seven genera and 23 species of Myrtaceae were recorded from the *Mata do Crasto*. Although eight genera and 35 species of Myrtaceae are cited from Sergipe in the Lista de Espécies do Brasil (Sobral et al. 2013), recent compilations increase these numbers up to ten genera and 60 species (Proença et al. 2013) . The 23 species of Myrtaceae recorded in this forest remnant correspond to 38% of this latter total. *Myrcia* (nine species), *Eugenia* (five species) and *Campomanesia* (four species) are the most diverse genera. Amongst the genera with most species in lowland pluvial Atlantic forests, *Eugenia* and *Myrcia* are two of the most speciose (70 and 37 species, respectively). *Marlierea*, represented in the *Mata do Crasto* by a single species, *M. excoriata*, is the sixth most speciose (22 species; Oliveira-Filho & Fontes 2000).

Myrtaceae is the third most speciose family in the *Mata do Crasto*, although it was the sixth most speciose family in the Atlantic Forest domain (Stehmann et al. 2009) and the most speciose in lowland pluvial Atlantic Forest (Oliveira-Filho & Fontes 2000). This family appears to be most important in the Southeastern Atlantic forests (Tabarelli & Mantovani 1999, Zipparro et al. 2005, Ivanauskas & Rodrigues, 2000, Peixoto et al. 2004, Rolim et al. 2006).

In the northern sector, Myrtaceae seems to be less important: it was forth most speciose family in a seasonal lowland forest near the coast of Pernambuco (Rodal et al. 2005) and was not even listed amongst the six most speciose families in a survey in coastal Paraíba (Pereira & Alves 2006) or in a study in Alagoas (Oliveira et al. 2005), and it was only seventh in three areas of montane Atlantic forest in southern Bahia (Amorim et al. 2009). However, a survey of an area of lowland Atlantic Forest in Pernambuco (Amorim & Alves 2011) reported the same number of species of Myrtaceae as in this study. Although the distance between the two areas is less than 600 km, these two areas together have 35 species of Myrtaceae, of which 11 were shared.

In a study using *Myrcia* as an indicator genus of local biodiversity hotspots within the Atlantic Forest domain (Murray-Smith et al. 2008), the Atlantic Forest was subdivided in squares of 1° latitude x 1° longitude, to which nine levels of richness were allocated, based on the number of *Myrcia* species present, with level 1 the poorest ("0-1 species") and level 9 the richest ("29-49 species"). Although the square in which the *Mata do Crasto* is found (11-12° S x 37-38° W) was classified in their study as level 3 ("5-8 species"), our data, associated with additional collections from the ASE herbarium, have shown that this square actually has at least 13 species of *Myrcia* and should have been classified in the intermediate level 5 ("12-14 species"). These findings reinforce the relevance of the present study results for the current analyses of the biodiversity distribution pattern in the Brazilian Atlantic Rainforest.

Habits

Most of the species collected in the *Mata do Crasto* belong to the tree/shrub layer, followed by the subshrub/herb layer. Higher percentages of species in the tree layer were registered in

Atlantic Forest fragments in north-eastern and south-eastern Brazil (Table 2), accounting for over half the species in Pernambuco and São Paulo. In a study carried out in another type of forest found in the Brazilian northeast, a fragment of montane forest in the municipality of Brejo da Madre de Deus, in Pernambuco (Nascimento, Rodal & Silva 2012), the tree habit was also the best represented (50% of all species).

It was proposed by Gentry & Dodson (1987) that trees contribute relatively little towards the high species diversity in tropical forests, and that is partially confirmed by the significant percentage of lianas, herbaceous climbers and herbs found in this study. Richards (1996) emphasizes the preponderance of woody phanerophytes in tropical rainforests (includes trees as well as shrubs and climbers) and the importance of epiphyte species over ground herbs, stressing, however, the difficulties in comparing life-form spectra from different studies.

A smaller comparative importance of climbers and epiphytes might be expected in the *Mata do Crasto*, and in forests of the northeast, in general, due to the smaller total rainfall, higher seasonality and high inter-annual variation in precipitation. In fact, the importance of epiphytes in the *Mata do Crasto* is lower than in almost all other areas with which it was compared in Table 2, suggesting that the quantity and annual distribution of rainfall may limit establishment of epiphytes in this forest fragment. On the other hand, percentages of climbers and lianas are similar to those of forest fragments in Bahia. Although species of epiphytes are sometimes eliminated from the forests with increased disturbance by man, some species may flourish under these conditions (Hietz et al. 2006). Likewise, lianes may be favored by the more open forest canopy that often results from selective cutting and other forms of disturbance (Schnitzer & Bongers 2002).

However, it is possible that the relative importance of non arboreal species may still remain underestimated in many floristic surveys (Linares-Palomino et al. 2009). Although collecting tall trees may be a difficult task, the difficulty in identifying vegetative stage of lianas and epiphytes specimens in the field, and, sometimes, the requirement of specialized equipment to collect them, it is possible that these life forms are yet insufficiently sampled in the *Mata do Crasto*. Future efforts should concentrate on this layer to strengthen conservation planning that covers the whole diversity of tropical forests, and not only of the tree stratum (Gentry, 1992).

Taxonomic diversity and distinction. Few published floristic studies are comparable to the *Mata do Crasto* study, encompassing the whole Angiosperm community of a significant remnant of lowland ombrophilous Forest. Most floristic inventories found in Northeastern states include only woody plants and/or were undertaken in different forest types, such as montane, caducifolius and/or inland forests. Only three comparable studies have been found in states of Pernambuco (Rodal et. al 2005) and Alagoas (Oliveira et al. 2005), both north of the São Francisco River, and one in Bahia (Amorim et al. 2008), that is South of the São Francisco River.

A total of 1,457 angiosperm species were recorded across the four sites. The Bahia and Alagoas studies were both the most species-rich and comprehensive, with more than one fragment and several different phytophysiognomies included (Table 3). The Bahia study, undertaken in 9,000 ha of protected area in the *REBIO de Una*, included adjacent *florestas de tabuleiro* (*restingas litorâneas,* a kind of maritime forest). The Alagoas site covered 8,000 ha, including dozens of Atlantic Forest fragments of various sizes and different degrees of human perturbation (Oliveira et al. 2005). Our study in the *Mata do Crasto*, covering a single fragment of 1,000 ha, ranked third in number of species, while the smallest fragment (81 ha), in Pernambuco (Santos et al. 2001 cited by Rodal et al. 2005), was the one in which the smallest number of species was recorded. The large differences in sampled area amongst three of these studies likely influence the numbers of species recorded. Study area size is strongly correlated with the number of species recorded as large areas are more likely to include

Table 2. Comparison between habit distributions of Angiosperm species in the *Mata do Crasto*, Santa Luzia do Itanhy, Sergipe, and in other Atlantic Forest studies. Values are in percentages. BA = Bahia; PE = Pernambuco; SE = Sergipe; SP = São Paulo.

Locality, State	Environment (altitude)	Tree	Shrub	Sub-shrub	Herb	Epiphyte	Climber	Parasite/ Saprophyte	Reference
Mata do Toró, PE	Lowland seasonal Forest (<140 m.s.m.)	59,9	18,3	2,0	9,4	2,0	8,4		Rodal et al. 2005
Usina Serra Grande, PE	Open ombrophilous forest	38,4	14,6	6,8	24,5	3,2	12,0	0,5	Oliveira, Grillo, Tabarelli 2005
Crasto, SE	**Lowland ombrophilous forest**	**39,3**	**21,2**	**4,0**	**18,4**	**0,6**	**15,6**		**This study**
REBIO Una, BA	Submontane and lowland pluvial forest	40,7	9,1	0,0	19,2	12,3	17,3	1,4	Amorim et al. 2008
Serra Bonita, BA	Montane ombrophilous forest	43,7		-	20,4	21,1	14,8		Amorim et al. 2009
Pedra Lascada, BA	Montane ombrophilous forest	49,6		-	18,2	24,0	8,2		Amorim et al. 2009
Serra das Lontras, BA	Montane ombrophilous forest (400-1000 m.s.m.)	49,5		-	16,2	22,3	12		Amorim et al. 2009
Intervales, SP	Submontane ombrophilous forest	57,1	9,2	-	9,4	12,6	10,3		Zipparro et al. 2005

Table 3. Angiosperm taxa richness and distribution in selected floristic inventories in lowland Atlantic Forest remnants in Northeastern Brazil. AL = Alagoas; BA = Bahia; PE = Pernambuco; SE = Sergipe.

	PE[1]	**AL[2]**	**SE[3]**	**BA[4]**
No. of morphoespecies*	195	627	321	932
No. of species#	179	529	295	830
Determination to species level (%)	91.8	84.4	91.1	89.1
No. of genera	136	100	83	114
No. of families	57	372	188	429
No. of species/No. of genera	1.3	5.3	3.6	7.3
No. of species/No. of families	3.1	1.4	1.6	1.9
No. of exclusive species	85	306	151	629
% of exclusive species	47.5	57.8	51.0	75.8
Average Taxonomic Distinctness (?+)	3.882	3.907	3.882	3.899
Confidence interval Δ^+ – upper limit	3.883	3.893	3.888	3.895
Confidence interval Δ^+ – lower limit	3.916	3.909	3.913	3.907

[1]Rodal et al. 2005; [2]Oliveira, Grillo & Tabarelli 2005; [3]This study; [4]Amorim et al. 2008

* taxa listed in the selected articles; #taxa determined to species level

different habitats, thereby increasing species richness (Primack & Rodrigues 2001).

Little difference in average taxonomic distinction between the four selected lowland Northeastern Atlantic Forest studies was found, values of Δ^+ found varying between 3.88 and 3.91 (Table 3). Unfortunately, there are no other Atlantic Forest studies in which measures of taxonomic diversity have been calculated for the complete list of angiosperm species of a region, what may hinder further comparisons. Webbs (2000) study was apparently the first to apply measures of taxonomic diversity and distinctness to angiosperms, analyzing tree species of tropical forests in Borneo. But, with the exception of the work of Dominguez et al. (2010), comparing angiosperm floras in the Hawaiian and Canarian archipelagos, no other study was found encompassing the whole angiosperm flora present in an area.

Measures of diversity that incorporate phylogenetic distance among species are thought to be better than more traditional measures (Cianciaruso, Silva & Batalha 2009). Measures of taxonomic diversity and distinction include a dimension of phylogenetic diversity that is more closely related to functional diversity than species richness. Such indices are apparently less sensitive to sample size than conventional ecological indices, such as richness and equitability. They also appear independent of sampling effort, permitting comparisons among studies with different degrees of sampling effort. However, identification influences all indices and it is critical that care is taken that this is done as completely and as accurately as possible (Clarke & Warwick 1998, 1999). Identification is a problem in families where species are notoriously hard to distinguish (e.g., Myrtaceae) and incomplete identification of such families is frequent in floristic studies due to the cryptic nature of distinguishing characters (McVaugh 1968, Landrum and Kawasaki 1997), what did not happen is this study, where all Myrtaceae taxa are identified at species level.

Our values of Δ^+ are, however, close to those calculated (3.73 - 3.77) by Gorenstein (2009) for trees in a submontane ombrophilous forest, at altitudes between 30 and 1,003 m, within the Atlantic Forest domain in São Paulo. Lower Δ^+ values were found in four Ugandan phytophysiognomies, varying from 2.41, in dry woodland, to 2.79, in dry thicket woodland (Gwali et al. 2010); these data were also based only on the woody flora, using three taxonomic levels (Family, Genus and Species).

The high similarity among the Taxonomic Distinctiness indices between these four areas was unexpected, especially since they differ to each other in total number of families, genera and species, and that all four had many exclusive species (47-75%). Given its intermediate position, both geographically and in size, between the larger (and richer) Bahia and Alagoas sites, the relatively high proportion (51%) of species uniqueness at the *Mata do Crasto* site is striking. Although physiognomically similar, this data suggests Northeastern Atlantic forests are not floristically uniform.

Usually, large areas have a greater proportion of species per genus and species per family than small areas. In our study, however, the highest proportions of species per family (3.1) were found in Pernambuco, the smallest area; conversely, the number of species per genera (1.3) in this fragment was much lower than elsewhere. Values of species per family for our study (1.6) were between the Alagoas (1.4) and Bahia (1.9) studies; this value thus follows a geographic gradient diminishing northwards. In species per family, however, the *Mata do Crasto* value (3.6) was lower than either the Bahia (7.3) or Alagoas studies (5.3) that included more than one fragment and forest type.

Shared species between studies was surprisingly low: only 15 species (1%) were common to all four studies, even when possible synonyms were accounted for. Conversely, the number of species exclusive to a single study was very high varying from 85 exclusive species (47%) in Pernambuco to 629 (76%) in Bahia. The Alagoas study and our study showed intermediate values; Alagoas had a higher number of exclusive species (306) than the *Mata do Crasto* (151), but the percentages of exclusive species were similar (58 and 51%, respectively). Exclusive species thus seem to diminish approximately northwards.

The results were also analyzed considering the São Francisco River (SF) as a potential dispersal barrier. Two hundred and fifteen species (15%) had distributions that crossed the São Francisco river (i.e., that are shared between all, three or two studies that crossed the river). The percentage of exclusive species in the studies south of the São Francisco River (Alagoas and Bahia) is nearly twice (822 species, 56%) that of those North of the river (420 species, 29%); however, these results may be influenced by the different number of fragment and forest types included in these studies (Oliveira, Grillo, & Tabarelli 2005, Amorim et al. 2008). A quantitative association analysis is beyond the scope of this study but it is noteworthy that although Fabaceae was the most speciose family in the three distribution classes (widespread, SF-south, and SP-south), Rubiaceae was the second most important family only amongst the SF-south species (55) and widespread species (19), and was substituted by the Orchidaceae (33 species) in the SF-north species. It was also observed that SF-south species were distributed in more families (114) than either SF-north species (90 families) or widespread species (67 families).

Conclusion

This study has contributed an additional 96 species to the Sergipe flora, and increased knowledge of their geographic distribution and that of other species in the Atlantic forests of the Northeast. Northeastern Atlantic Forest fragments subject to somewhat similar environmental characteristics may have significantly different floristic compositions, and a high proportion of exclusive species, although taxonomic diversity appears to be relatively stable. Considering the strong level of anthropogenic pressure on the northeastern Atlantic Forest remnants, it is possible that much of its native diversity has already been lost, particularly rare species and the ones that are most sensitive to habitat alteration, thus creating false "disjunctions" in their distributions. Other possibilities are that many species have spatial or temporal casuistic mosaic-like distribution patterns, or that the existence of many continuous, but regional, species is responsible for the observed pattern. Additional floristic inventories in Atlantic Forest fragments, particularly, but not exclusively, in the Northeast are needed to clarify individual species' distribution patterns and also forest type distribution patterns.

Studies that increase comprehension of structure, function and environmental causes are necessary to ensure the effective conservation of Atlantic forests. To be effective, these should occur at a rate that preempts the accelerating rates of deforestation. Many threats, and their synergies, lead to a decline in populations of Neotropical tree species, which can produce chains of events that influence ecological services (Tabarelli, Silva & Gascon 2004). Such considerations have lead to some authors questioning the conservation value of small forest fragments for long-term Atlantic Forest preservation (Tabarelli, Mantovani & Peres 1999). In Pernambuco, for example, almost half of the fragments analyzed in the south of the state had an area above 10 ha, but only 7% were above 100 ha (Ranta et al. 1998). This highlights the importance of the *Mata do Crasto*, an Atlantic Forest fragment of ca. 1,000 ha, for the effective conservation of the floristic and faunistic diversity of the northeastern Atlantic Forest.

Therefore, the first of the recommendations made by Landim & Landrum (2002) regarding the knowledge of Sergipe's flora, increasing sampling effort, remains valid, but the last two ones must not be forgotten: the urgent need to study Brazil's Northeastern flora, including herbarium material, and a simultaneous investment in taxonomic training. In this context, the first volume of the Flora de Sergipe (Prata et al. 2013) is an important contribution. In order to understand species richness and distribution in Sergipe, other rainforest fragments (in the municipalities of Indiaroba, Itaporanga d'Ajuda, São Cristóvão and Japaratuba) are also being studied and inventoried.

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inventory

Checklist of tidepool fishes from Jericoacoara National Park, southwestern Atlantic, with additional ecological information

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MACHADO, F.S., MACIEIRA, R.M., ZULUAGA GÓMEZ, M.A., COSTA, A.F., MESQUITA, E.M.C., GIARRIZZO T. **Checklist of tidepool fishes from Jericoacoara National Park, southwestern Atlantic, with additional ecological information.** Biota Neotropica. 15(1): e20140111. http://dx.doi.org/10.1590/1676-06032015011114

Abstract: Ichthyofauna from 29 tidepools in Jericoacoara National Park (Ceará State, Brazil) was sampled. A total of 733 fishes, comprising 16 species belonging to 12 families, was collected. The three most abundant species were the frillfin goby *Bathygobius soporator*, the sergeant-major *Abudefduf saxatilis* and the molly miller *Scartella cristata*. An invasive species from the Indo-Pacific, the Muzzled blenny *Omobranchus punctatus*, was also recorded. The known geographic distribution of the blenny *Hypleurochilus fissicornis* was extended approximately 2,500 km northward. These findings highlight the lack of knowledge of the rocky intertidal ecosystems along the Brazilian coast, an area that needs more sampling effort and ecological data.
Keywords: *rockpools, reef, intertidal zone, fish community, rocky shore.*

MACHADO, F.S., MACIEIRA, R.M., ZULUAGA GÓMEZ, M.A., COSTA, A.F., MESQUITA, E.M.C., GIARRIZZO T. **Inventário dos peixes de poças de mare do Parque Nacional de Jericoacoara, Atlântico sudoeste, com informações ecológicas adicionais.** Biota Neotropica. 15(1): e20140111. http://dx.doi.org/10.1590/1676-06032015011114

Resumo: Um total de 733 espécimes de peixes, pertencentes a 16 espécies (12 famílias), foi capturado em 29 poças de maré no Parque Nacional de Jericoacoara (Ceará, Brasil). As espécies mais numericamente abundantes foram o amboré *Bathygobius soporator*, o sargentinho *Abudefduf saxatilis* e o macaco-verde *Scartella cristata.* Uma espécie invasora originária do Indo-Pacífico, *Omobranchus punctatus*, foi registrada para a área. A ocorrência de *Hypleurochilus fissicornis* permitiu expandir sua distribuição geográfica em cerca de 2.500 km ao norte. Esses resultados demostram que diversos aspectos relacionados a ictiofauna do ecossistema entremarés em substrato consolidado ainda permanecem pouco estudados no Brasil, e portanto, mais levantamentos da biodiversidade e dados ecológicos são necessários.
Keywords: *recife, zona de entremaré, costão rochoso, espécie invasora.*

Introduction

Historically, intertidal ecosystems have been explored by humans (Horn et al. 1999, Mobley & McCallum 2001, Mannino & Thomas 2002, Thompson et al. 2002, Steele & Klein 2008), and remain an important provider of resources. Seafood, honey, traditional medicine, tannins, timber and firewood are some of the intertidal ecosystem goods used by humans (Addessi 1994, Moberg & Rönnbäck 2003, Fletcher et al. 2012). However, the biodiversity and ecological processes of some intertidal ecosystems, such as tidepools, remain understudied in many countries (Norton & Cook 1999, Prochazka et al. 1999), despite the long history of exploitation of these systems. For example, approximately six references (*i.e.*, Rosa et al. 1997, Barreiros et al. 2004, Macieira & Joyeux 2009, 2011, Nunes et al. 2011, Macieira et al. 2014; excluding thesis, gray literature and works using visual census sampling methods) investigated the ecological aspects of Brazilian tidepool fishes. Although, fishes are an important component of many aquatic ecosystem (Holmlund & Hammer 1999) and one of the most exploited live marine resources (King 2007). The historical increase of the coastal human population, and its economic activities (*e.g.*, ports, industry, fishery, exploitation of oil and gas), pose a threat the intertidal ecosystem. The increase and diversification of anthropogenic impacts (*e.g.*, eutrophication, habitat loss, introduced species, oil spills, pollution), have resulted in a loss of biodiversity and its functions and, consequently, a reduction or interruption of the ecosystems' services (Thompson et al. 2002, Moberg & Rönnbäck 2003, Halpern et al. 2008, Cardinale et al. 2012). Thus, assessing the biodiversity and understanding the ecological processes of coastal ecosystems through the monitoring of marine communities, where basic information (*e.g.*, the list of species) are lacking is essential to ensure the systems' health. This study presents the first checklist for the tidepool fishes from Jericoacoara National Park. In addition, estimations of body size, density and biomass are provided, and the patterns of species geographic distribution and one range extension are discussed.

Materials and Methods

1. *Study Area*

The Jericoacoara National Park is located in Ceará State in northeastern Brazil (2°47'S, 40°30'W), with an area of 8,416 ha composed of a mosaic of landscapes (*i.e.*, cliffs, mangroves, sandy beaches, sandy dunes and rocky intertidal shore; Figure 1). In the northern part, the intertidal zone is dominated by a beachrock formation, and diversified sessile fauna and flora (*i.e.*, ascidians, corals, macroalgae and sponges) partially cover the rocky shore and the tidepools (Figure 2). The regional climate is tropical semi-arid (mean: 27°C temperature, 989 mm rainfall); during the dry season the trade winds are more intense (reaching 15 m/s). The coastal circulation is driven by the North Brazil current and by semidiurnal mesotides (Meireles 2011, MMA 2011).

2. *Data collection*

Samples were collected with the permission of the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) and Sistema de Autorização e Informação em Biodiversidade (SISBIO), license number 35625. Sampling was conducted during daytime, at low tide of the spring tide, in September 2012. Twenty-nine tidepools (without connectivity to the sea or other pools during the ebb tide) were randomly sampled in a surveyed area of 3.32 km^2 (Figure 1). The physicochemical parameters of water and morphological characteristics were measured in each pool. Temperature, pH and salinity were measured with a mercury thermometer (± 0.1°C precision), a ClolorpHast tape (± 1) and an optical refractometer (Model: Q767; ± 0.1), respectively. Rugosity was measured by the chain-and-tape technique (Wilding et al. 2010) and was replicated three times per pool to obtain a mean value. The topography and bathymetry of the rockpool were surveyed using a 20 cm × 20 cm grid for the measurement of its depth within each square. With this information, the area and volume of each pool were calculated by kriging the data points in ArcGIS software. The substrate composition of each tidepool was estimated following Cox (2007), and categorized as sand (grain size < 1 mm), gravel (≤ 50 mm) and rock (> 50mm). The sum of all categories corresponded to 100% of the substrate composition. The ichthyofauna was sampled using hand nets, and application of an alcohol clove-oil solution to the pool's water (Griffiths 2000, Ackerman & Bellwood 2002, Cunha & Rosa 2006). The specimens were fixed in 10% formalin, preserved in 70% alcohol, and subsequently, measured total length (TL) and total weight (WT) with a precision of 0.1 mm and 0.01 g, respectively. Density and biomass were expressed as the number of individuals and weight (g) per volume of pool (m^3), respectively. Voucher specimens were deposited in the fish collection at the ichthyological collection of the Grupo de Ecologia Aquática (GEA.ICT), and the numbers are given in the appendix. The species were categorized by their degree of residency in pool habitats as permanent residents, opportunists, and transients following Macieira & Joyeux (2011). Zoogeographical affinities of the tidepool fishes in Jericoacoara National Park were analyzed, and the species were categorized by their geographic distribution (modified from Luiz Jr. et al. 2008) into the following categories: CA = Central Atlantic (St. Paul's Rocks, Ascension and St. Helena); SW = Southwestern Atlantic (Argentinian and Brazilian province-*sensu* Briggs & Bowen 2012); TA = Trans-Atlantic (both sides of the Atlantic Ocean); and WA = Western Atlantic (in the western north and south

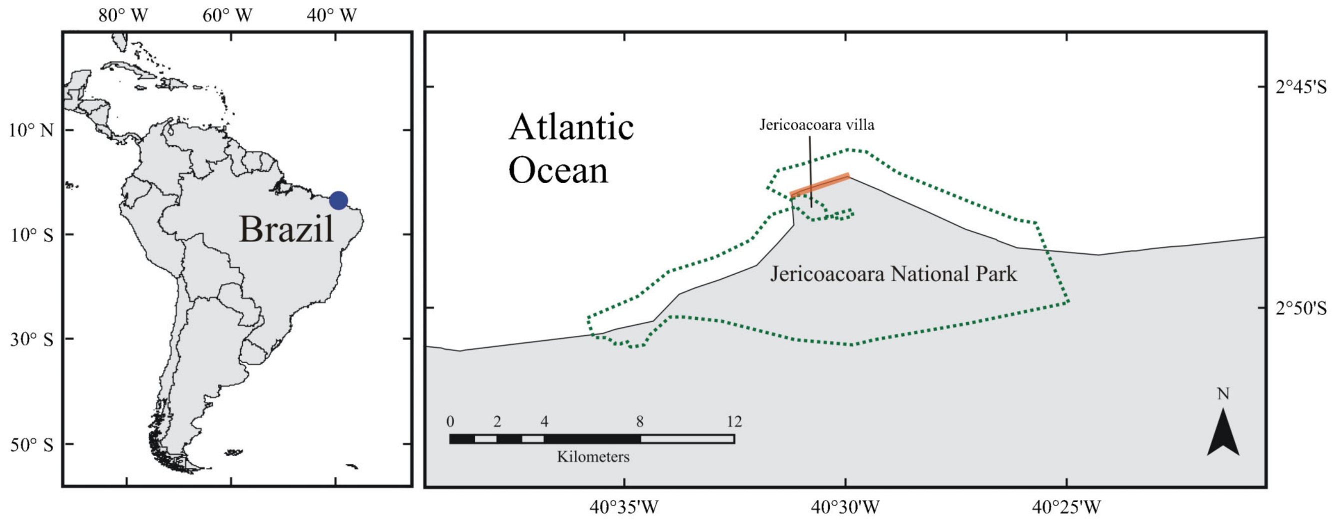

Figure 1. Geographic position of Jericoacoara National Park (blue circle) in the southwestern Atlantic. Delineation of the protected area on the Brazilian coast (dotted green line), and the area sampled (orange area).

Figure 2. Landscapes of the rocky intertidal zone at ebb tide at Jericoacoara National Park, Brazil. (A-B) Beachrock formation at intertidal zone; (C-D) Details of the rockpools. Photos: Tommaso Giarrizzo.

Atlantic). A single species *Omobranchus punctatus* (Valenciennes 1836) was not evaluated for geographic distribution because it is classified as an exotic species.

Results

The rockpools were similar in physicochemical parameters of water but quite different in their morphological characteristics (Table 1). Temperature was the most variable physicochemical parameter, and the pH differences were minor.

A total of 733 individuals, comprising 16 species belonging to 12 families, was captured at Jericoacoara National Park (Table 2 and Figure 3). The mean (± SD) density and biomass were 143.96 ± 203.86 ind. m^{-3} and 24.61 ± 31.16 g m^{-3}, respectively, and the mean size (TL) was 53.2 ± 2.82 mm (range 8.0 – 451.0 mm). Except for the green moray *Gymnothorax funebris* Ranzani 1839, the community was composed of small species or juveniles of medium-sized species. The family Blenniidae was the most specious (three species) in this site, with the others composed of only one or two species. The frillfin goby *Bathygobius soporator* (Valenciennes 1837) (n = 183), molly miller *Scartella cristata* (Linnaeus 1758) (173), sergeant-major *Abudefduf saxatilis* (Linnaeus 1758) (122), twin-spotted frillfin *Bathygobius geminatus* Tornabene, Baldwin & Pezold 2010 (73) and blenny *Malacoctenus delalandei* (Valenciennes 1836) (72) were the most representative species (85% of the total caught). These same five species showed highest density, but biomass (g m^{-3}) was more expressive for *S. cristata* (mean ± standard deviation 143.1 ± 422.7), *B. soporator* (120.9 ± 187.7), *A. saxatilis* (51.52 ± 116.3), dog snapper *Lutjanus jocu* (Bloch & Schneider 1801) (47.81 ± 236.95) and *G. funebris* (20.75 ± 82.19). Among these, only *A.*

Table 1. Mean ± standard deviation (N = 29), minimum and maximum values of the environmental parameters of tidepools at Jericoacoara National Park, Ceará State, Brazil.

Environmental parameters	Mean ± standard deviation	Minimum	Maximum
Physicochemical parameters			
pH	8.6 ± 0.1	8.5	9.0
Salinity	35.6 ± 0.6	35.0	37.0
Temperature (°C)	27.8 ± 1.7	24.5	30.5
Morphological characteristics			
Area (m^2)	4.8 ± 4.3	0.50	20.1
Sand Coverage (%)	34.6 ± 27.7	0.0	100.0
Rock Coverage (%)	40.6 ± 24.8	0.0	83.0
Gravel Coverage (%)	24.8 ± 24.9	0.0	100.0
Rugosity	1.6 ± 0.5	1.1	3.3
Volume (m^3)	0.3 ± 0.2	0.01	1.30

Table 2. Taxonomic list, number of individuals, geographic distribution, range, mean and standard deviation (S.D.) for size (total length), density and biomass of the intertidal fishes recorded at Jericoacoara National Park, Brazil. The classification follows Nelson (2006), Labridae follows Westneat & Alfaro (2005). * = New record. Geographic distribution categories: CA = Central Atlantic; SW = Southwestern Atlantic; TA = Trans-Atlantic; and WA = Western Atlantic.

Family and species	N	Geographic distribution	Total Length (mm)		Density	Biomass
			Min. – Max.	Mean ± S.D.	Fish m^{-3} ± S.D.	g m^{-3} ± S.D.
Muraenidae						
Gymnothorax funebris Ranzani, 1839	2	WA	358 – 451	404.5	0.24	20.75
Ophichthidae						
Ahlia egmontis (Jordan, 1884)	1	WA	167	-	0.27	0.29
Mugilidae						
Mugil curema Valenciennes, 1836	3	WA	26 – 31	28.7 ± 2.5	0.46 ± 1.75	0.09 ± 0.35
Lutjanidae						
Lutjanus jocu (Bloch & Schneider, 1801)	9	TA	44 –113	82.8 ± 19.1	5.24 ± 25.97	47.81 ± 236.95
Haemulidae						
Haemulon parra (Desmarest, 1823)	6	WA	65 – 99	86.0 ± 12.2	0.54 ± 2.93	3.81 ± 20.50
Pomacentridae						
Abudefduf saxatilis (Linnaeus, 1758)	122	TA	16 – 113	48.4 ± 21.2	21.10 ± 38.14	51.52 ± 116.33
Labridae						
Sparisoma frondosum (Agassiz, 1831)	1	TA	158	-	0.27	19.22
Blenniidae						
Hypleurochilus fissicornis (Quoy & Gaimard, 1824) *	66	SW	15 – 56	28.5 ± 8.00	6.23 ± 17.28	2.01 ± 5.74
Omobranchus punctatus (Valenciennes, 1836)	11	Exotic	13 – 73	54.7 ± 16.3	3.49 ± 11.72	3.75 ± 12.74
Scartella cristata (Linnaeus, 1758)	173	TA	23 – 100	56.6 ± 17.4	54.02 ± 166.7	143.1 ± 422.7
Labrisomidae						
Labrisomus nuchipinnis (Quoy & Gaimard, 1824)	6	TA	31 – 148	76.2 ± 38.9	0.54 ± 1.87	6.24 ± 29.89
Malacoctenus delalandei (Valenciennes, 1836)	72	WA	23 – 65	44.6 ± 9.40	8.58 ± 17.93	9.85 ± 20.90
Gobiesocidae						
Gobiesox barbatulus Starks, 1913	3	WA	43 – 44	43.3 ± 0.60	0.27 ± 1.47	0.30 ± 1.59
Gobiidae						
Bathygobius geminatus Tornabene, Baldwin & Pezold, 2010	73	WA	16 – 69	38.2 ± 11.6	14.65 ± 38.34	8.66 ± 15.24
*Bathygobius soporato*r (Valenciennes, 1837)	183	WA	8 – 105	63.6 ± 18.4	24.86 ± 36.16	120.9 ± 187.7
Acanthuridae						
Acanthurus chirurgus (Bloch, 1787)	2	WA / CA	50 – 73	61.5	0.18	0.64

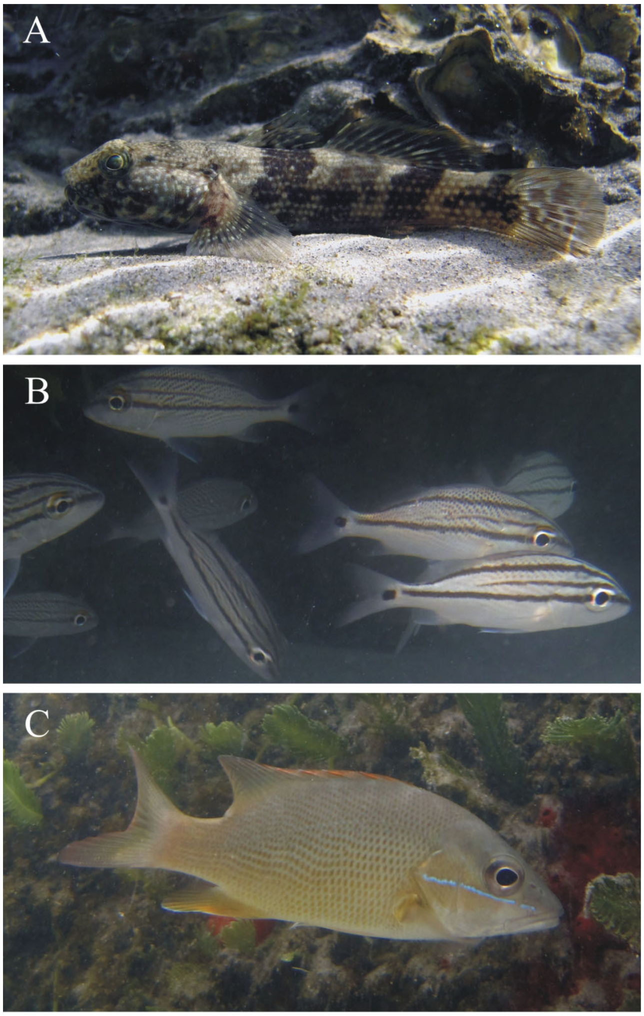

Figure 3. Some fish species of the rockpools at Jericoacoara National Park, Brazil. (A) *Bathygobius soporator*, (B) school of *Haemulon parra*, (C) *Lutjanus jocu*. Photos: Tommaso Giarrizzo.

saxatilis and *L. jocu* were not considered permanent resident of rockpools. The occurrence of the muzzled blenny *Omobranchus punctatus* is reported for the first time in the state of Ceará (Jericoacoara National Park), where 11 specimens were collected in this survey, with a mean density of 3.49 (± 11.72) ind. m^{-3} and a biomass 3.75 g m^{-3} (± 12.74). The occurrence of the blenny *Hypleurochilus fissicornis* (Quoy & Gaimard 1824) at Jericoacoara National Park extends the known distribution of this species by approximately 2,500 km northward. The previously known geographic distribution of this species was 20°S (Brazil) to 40°S (Argentina) and covered approximately 3,000 km (Menezes & Figueiredo 1985, Irigoyen & Galván 2009, Rangel & Guimarães 2010). A total of 66 *H. fissicornis* were captured with a mean density and biomass of 6.23 (± 17.28) ind. m^{-3} and 2.01 (± 5.74) g m^{-3}, respectively.

The geographic distribution of the tidepool fishes from Jericoacoara National Park demonstrates that half of all species (8) were distributed exclusively in the western Atlantic, five occurred on both sides of the Atlantic Ocean, and the other four species had distinct distribution ranges. However, only the molly miller *S. cristata* had a wide distribution in the Atlantic Ocean and the Mediterranean Sea.

Discussion

The homogeneity in physicochemical parameters of water between tidepools, indicates a similar physiological stress condition for the tidepool communities. A strong variability was detected in the morphological characteristics that could indicate an ecosystem with many types of microhabitats, and may denote a diversified spectrum of niches (Mouillot et al. 2007, Macieira & Joyeux 2011). These features seem to be associated to flat reefs (*e.g.*, Macieira & Joyeux 2011) or rocky shores, with discrete difference in height between pools, in areas where the intertidal zone daily inundated by the sea.

The composition of the tidepool fish community in Jericoacoara National Park is similar to other areas in Brazil, but the richness is lower than expected compared with sites in northeastern Brazil (*e.g.*, Cabo Branco, Paraiba state with 40 species, Rosa et al. 1997). Given that our sampling effort was concentrated in a unique sampling event, the present species list provides relevant information exclusively for permanent resident fish (*e.g.*, 10 resident fish species in our study *vs.* 13 resident fish species in Cabo Branco, Rosa et al. 1997, in two pools sampled 24 times). Only with high temporal resolution sampling designs (*e.g.*, monthly samples), could be achieved the record of opportunistic and transient fishes. Furthermore, difference in the number of species could be explained by several environmental factors such as structural complexity (Davis 2000, Griffiths et al. 2006, Rojas & Ojeda 2010), morphology of pools (Mahon & Mahon 1994, Macieira & Joyeux 2011), substrate cover (Bennett & Griffith 1984, Davis 2000, Arakaki & Tokeshi 2011), vertical position (Gibson 1972, Barton 1982, Davis 2000, Castellanos-Galindo et al. 2005, Cox et al. 2010) and exposure to waves (Gibson 1972, Grossman 1982). For example, the tidepools in Cabo Branco (see Rosa et al. 1997) are about 80-266 times voluminous than the sampled pools in Jericoacoara. According to Mahon & Mahon (1994), there is a positive correlation between the abundance / richness of species and volume of pool. Furthermore, the non-resident fish commonly use these large pools (Mahon & Mahon 1994, Macieira & Joyeux 2011), which are absent in the intertidal zone of Jericoacoara National Park. The synergetic interaction of these factors modulates the intertidal fish community since they act as a species filter (Macieira & Joyeux 2011), and the many combinations of factors result in different types of communities. Thus, only with standardized sampling design with high spatio-temporal resolution and similar quantitative methodologies could be possible to understand how the local and regional ecological drivers influence the fish assemblages in tidepool ecosystems.

The classic permanent resident fish families in tidepools, Blenniidae and Gobiidae (Prochazka et al. 1999), were expressive in terms of the number of species (31.25% of all species) and dominant in abundance (69.03% of all caught), density (73.25% of the total mean density) and biomass (65.48% of the total mean biomass). The success of these families in occupying the intertidal ecosystem is related to morphological, physiological and behavioral specialized adaptations to intertidal life (Gibson 1986, Evans et al. 1999, Gibson 1999, Horn et al. 1999, Martin & Bridges 1999). These adaptations allow occupancy an ample spectrum of niches and improve the capacity to compete for resources (*e.g.*, food, shelter and nest site). Alternatively, the opportunists and transient species (*i.e.*, generally without adaptation to intertidal life) are segregated to a specific type of pool (usually with large volume) with less stressful physiological conditions, but with an increase in the risk of predation and in the number of competitors (Mahon & Mahon 1994, Macieira & Joyeux 2011). The presence of juveniles of non-resident species could indicate the use of the tidepools as a nursery site and highlights the importance of this ecosystem to marine fishes (Gibson & Yoshiyama 1999, Hernández et al. 2002, Krück et al. 2009). Future studies are needed to evaluate the dependence on pools by non-resident species, mainly those that are fishery-targeted species [*e.g.*, *L. jocu*, *Mugil curema* Valenciennes 1836 and *Sparisoma frondosum* (Agassiz 1831)].

The analysis of the geographic distribution demonstrated an absence of endemic species, and the fishes were widely distributed. There are approximately 7 endemic species along the Brazilian coast (excluding oceanic islands; R.M. Macieira personal communication), but the absence of these endemic species in the Jericoacoara pools could be due to the sampling effort, because some species are rare and thus require a greater effort to capture (*e.g.*, *Letharchus aliculatus* McCosker 1974; R.M. Macieira personal communication). Most of these species have high microhabitat specificity and the morphological structure of tidepools in Jericoacoara National Park may not be adequate.

Biological invasions are an actual and growing threat to ecosystems health (Pimentel 2011), and understanding the process, implications and consequences of invasions is key to minimizing their effects. The exotic species *O. punctatus* is native to the Indo-Pacific (Springer & Gomon 1975) but is widely dispersed along the Brazilian coast in stabilized populations (*e.g.*, Bahia, Maranhão, Pará, Piauí, Rio de Janeiro and Santa Catarina) (Gerhardinger et al. 2006, Lasso-Alcalá et al. 2011). However, biological (*e.g.*, fecundity, growth) and ecological (*e.g.*, niche, food habits) data about this invasion are still lacking. At Jericoacoara National Park, the presence of this exotic species during its entire life (*i.e.*, juveniles to adults were caught *sensu* Froese & Pauly 2014 - Life-history tool) and some characteristics such as small size, negative buoyancy, compressed body form, thigmotaxy, saltated swimming and cryptic behavior (Gibson 1986), permits it to be classified as a permanent resident. In addition, the density and biomass were comparable to others species (*e.g.*, *H. fissicornis* and *M. delalandei*). Thus, *O. punctatus* has good potential to compete for resources with native species, especially the permanent resident species that use specific and limited resources as nest sites and shelter / rest areas. The effects of introduction cannot be completely evaluated because preterit data are absent, but simulations and ecological models could provide an interesting perspective of the invasion process.

In conclusion, the present work provides the first list of tidepool fishes from Jericoacoara National Park. Despite the lack of occurrence of endemic species and limited representatively of opportunistic and transient fishes, this work illustrates how a small concentrated effort can help fill the lack of knowledge and provide useful information to implement the management plan for this protected area. To promote the native biodiversity and maintain the presence of current species, we recommend (1) additional study in the area to determine the effects of the exotic species *O. punctatus* on native species, (2) long-term ecological research to monitor the ecosystem health (considering the low coast of sampling tidepool fishes and the importance of this component to system), and (3) modeling the effects of anthropogenic impacts on the food web by the modification of functional diversity.

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Appendix

Museum vouchers of specimens from the Jericoacoara National Park, deposited in the ichthyological collection of the Grupo de Ecologia Aquática (GEA.ICT). Species arranged in alphabetical order. *Abudefduf saxatilis* GEA.ICT#01694; *Acanthurus chirurgus* GEA.ICT#00071; *Ahlia egmontis* GEA.ICT#00019; *Bathygobius geminatus* GEA.ICT#00325; *Bathygobius soporator* GEA.ICT#00382; *Gobiesox barbatulus* GEA.ICT#00166; *Gymnothorax funebris* GEA.ICT#00293; *Haemulon parra* GEA.ICT#00293; *Hypleurochilus fissicornis* GEA.ICT#01693; *Labrisomus nuchipinnis* GEA.ICT#00410; *Lutjanus jocu*: GEA.ICT#00186; *Malacoctenus delalandei* GEA.ICT#00158; *Mugil curema* GEA.ICT#01692; *Omobranchus punctatus* GEA.ICT#01691; *Scartella cristata* GEA.ICT#00253; *Sparisoma frondosum* GEA.ICT#01690.

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short communication

Analysis of the error associated with the subsampling of Chironomidae in an intermittent stream of semi-arid Brazil

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Abstract: Chironomidae is a common family in freshwaters, often occurring at high densities, which hinders the processing of large samples, given that time and labor are usually limited. The present study aims at evaluating the extent of the error related with the subsampling of Chironomidae from a larger sample with regard to the size of the individuals between a sample and the subsample. A total of 9195 chironomids were collected from three sites in an intermittent stream. Samples were taken using a D-shaped net (250 µm) on eight occasions. Individuals from each sample were homogenized in a gridded Petri dish and coordinates from lines and columns were randomly drawn. Individuals from the assigned coordinates were selected until 100 individuals or 10% of the sample were chosen. Comparisons were made between the proportion of larger ($\geq$5mm) and smaller individuals (<5mm) between the samples and subsamples, and it was established the correlation between the size of the error and the size of the sample, using the rank coefficient of Spearman. The highest error observed was 12.7%, meaning that the difference in larger individuals between the sample and subsample reached that value. However on six of the eight samples the error was below 3%. Spearman correlation showed no significance between the error observed and the size of the sample (ρ=0.38, p=0.35), meaning that larger samples will not yield larger error associated with the size of the individuals. The present study indicates that the subsampling technique used is capable of drawing a random subset of individuals from a sample of chironomids with regard to their size. This technique can be used in ecological or biomonitoring studies in order to reduce sample processing time without creating a bias in the analysis.
Keywords: *temporary pools, sampling effort, aquatic insects.*

FARIAS, R.L., ALENCAR, T.F.B., LIMA, J.A.S., MEDEIROS, E.S.F. **Análise do erro associado com a subamostragem de Chironomidae em um rio intermitente do semiárido do Brasil.** Biota Neotropica. 15(1): e20140039. http://dx.doi.org/10.1590/1676-06032015003914

Resumo: Chironomidae é uma família comum em águas doces, frequentemente ocorrendo em altas densidades, o que dificulta o processamento de amostras para estudos ecológicos, dado que o tempo e recursos são geralmente limitados. O presente estudo tem como objetivo avaliar a dimensão do erro relacionado com a subamostragem de Chironomidae em relação ao tamanho de indivíduos entre a amostra e a subamostra. Um total de 9195 quironomídeos foi coletado de três sítios em um rio intermitente. As amostras foram tomadas usando uma rede tipo D (250 µm) em oito ocasiões. Os indivíduos de cada amostra foram homogeneizados em uma placa de Petri quadriculada e as coordenadas de linhas e colunas foram sorteadas. Indivíduos das coordenadas atribuídas foram selecionados até que 100 indivíduos ou 10% da amostra fossem escolhidos. Comparações foram feitas entre a proporção de indivíduos grandes ($\geq$ 5mm) e pequenos (<5mm) entre amostras e subamostras e foi estabelecida a correlação entre o tamanho do erro e o tamanho da amostra, utilizando o coeficiente por rank de Spearman. A maior diferença de indivíduos grandes entre amostra e subamostra (erro) foi de 12,7%. No entanto, em seis das oito amostras o erro foi inferior a 3%. Correlação de Spearman não mostrou significância entre o erro observado e o tamanho da amostra (ρ = 0,38; p = 0,35), o que significa que amostras maiores não produziram maior erro relacionado com o tamanho dos indivíduos. O presente estudo indica que a técnica de subamostragem utilizada é capaz de extrair um subconjunto aleatório de tamanho de indivíduos a partir de uma amostra de Chironomidae. Essa técnica pode ser usada em estudos ecológicos ou de biomonitoramento a fim de reduzir o tempo de processamento das amostras sem criar um viés na análise.
Palavras-chave: *poças temporárias, esforço amostral, insetos aquáticos.*

Introduction

The Chironomidae family is a common taxon in freshwaters, frequently occurring in high densities and richness in several aquatic environments including Brazilian semi-arid streams (Trivinho-Strixino 2011, Rocha et al. 2012, Carvalho et al. 2013). These organisms are important colonizers of the sediment and aquatic vegetation, contributing with the breakdown of organic matter. They have a wide range of survival mechanisms, being either physiological/morphological or behavioral, which enables their existence in unfavorable conditions of temperature, pH, salinity and dissolved oxygen (Weber 1980). These characteristics make the Chironomidae family an important indicator for the environmental conditions, being used as a tool in biomonitoring studies (Rosenberg 1998).

The identification of their aquatic larval stage is made through the preparation of semipermanent slides for the observation of characters mostly in their head (Trivinho-Strixino 2011). Only then, individuals can be counted and the data used for ecological studies of community structure (Farias et al. 2012). This process is both labor and time-consuming, which often makes the counting of all individuals an unrealistic demand for laboratory work. Even though this has been argued to be the most appropriate approach to studies with benthic invertebrates (Baker & Huggins 2005), resource limitation and individuals numbers reaching the thousands often demand the subsampling of larger samples (Courtemanch 1996, Baker & Huggins 2005, Anderson & Ferrington 2012).

The basic advantages of subsampling is the reduction in effort on counting and identifying individuals which enables processing a greater number of samples. The latter is especially important in intermittent streams, because they require to incorporate both temporal and spatial natural variation. Furthermore, in unequal sample sizes, subsampling may be used as a way of correcting for the sample size and at the same time understand a larger portion of the variation in the community (Sebastien et al. 1988, King & Richardson 2002, Baker & Huggins 2005, Bouchard & Ferrington 2011).

Associated with unequal sample sizes, chironomids themselves present diverse morphotypes (Trivinho-Strixino 2011) leading to different individuals sizes. Subsampling techniques applied to individuals after sorting can create bias in the subsample since larger individuals or morphotypes will tend to be more readily picked than smaller ones. To enable unbiased randomization, individuals must be numbered and these numbers randomly drawn. In large samples with thousands of organisms this is unfeasible. Therefore we propose an alternative method where one spreads individuals in a gridded Petri dish and randomly draw coordinates (lines and columns) in order to sort individuals. Since larger individuals will occupy more squares in the grid, and thus have a greater chance of being selected, a test for the size of this bias is necessary. Therefore, the present study (1) quantifies the existence and proportion of the error related with chironomid size between a sample and its subsample and (2) determines if this error increases in larger samples.

Material and Methods

Chironomids were collected from three different sites on the Ipanema River, an intermittent river in semi-arid Brazil. Two sites were collected three times (April, July and October 2007) and one site was collected twice (April and July 2007) (Table 1). At each sampling, the sediment was taken using a D-shaped net (40 cm wide and 250 µm mesh). Since water flow was nil or low, the net was dragged for 40 cm at a depth of 2.5 cm (representing a volume of 40 x 40 x 2.5 cm). The depth of the sample was approximate, based on a measuring rod attached to the frame of the net. Three drags were performed for each sampling occasion and these were later pooled together and are henceforth referred to as a "sample". Thus, a total of 8 samples were used in the present study. Samples were fixed in 4% formalin in the field and taken to the laboratory where they were preserved in 70% alcohol. Since sampling in the present study was performed at different sites and occasions, the number of individuals varied for each sample (see Table 1). This natural variation was used to test for the correlation between the size of the error and the size of the sample.

At the laboratory, all Chironomidae on each sample were sorted and counted before proceeding to subsampling. Subsampling was adapted from the fixed fraction and fixed count methods (Baker & Huggins 2005). The chironomid of a sample was homogenized on a gridded Petri dish with each square measuring 1x1 mm. Each column and line of the grid was numbered and then line and column numbers were randomly drawn. Individuals from the assigned 1 mm^2 coordinates were selected. This process was repeated until approximately 10% of the individuals of the sample were chosen; these represent a subsample. Samples with less than 1000 individuals had approximately 100 individuals randomly sorted. We refer to this technique as an *a posteriori* subsampling. That is, not taking a subsample of the sediment collected and then identifying all chironomids in that subsample, but instead, sorting all chironomids from the sample and then taking a subsample of the individuals for identification.

Comparisons were made between the proportion of larger ($\geq$5mm) and smaller individuals ($<$5mm) between the samples and subsamples. These size classes were based on preliminary analysis to identify larger larvae morphotypes (e.g. *Chironomus*, *Dicrotendipes*, *Coelotanypus* and *Ablabesmyia*) in comparison with smaller ones (e.g. *Lauterborniella* and *Saetheria*) for the study area.

It was established the correlation between the size of the error (difference in proportion of larger individuals between sample and subsample) and the size of the sample, using the rank coefficient of Spearman (α=0.05) (Sheridan & Lyndall 2001).

Results and Discussion

A total of 9195 individuals were collected from the eight study sites (Table 1). The highest difference in larger individuals between the sample and the subsample was 12.7% (Site 1 April). However, on six of the eight samples this error was below 3%. The lowest variation was observed at the Site 3 in October, where 1.3% of the chironomids in the sample were larger than 5mm and this value for the subsample was 1.8%, showing a difference of only 0.5%. Spearman correlation showed no significance between the error observed and the size of the sample (ρ=0.38, p=0.35), meaning that larger samples will not yield larger error associated with the size of the individuals.

Ideally, subsampling should reduce laboratory work and yield nonbiased and representative data, in order to reliably

Table 1. Proportional difference in individuals between the sample and subsample (%) for larger (⩾5mm) and smaller (<5mm) Chironomidae in three sites from an intermittent river of semi-arid Brazil.

Sites	Sample size < 5mm	Sample size ≥ 5mm	Subsample size <5mm	Subsample size ≥5mm	Difference in individuals between the sample and subsample (%)
Site 1 April					
N	986	53	134	29	
%	94.9	5.1	82.2	17.8	12.7
Site 1 July					
N	518	59	120	15	
%	89.8	10.2	88.9	11.1	0.9
Site 1 October					
N	1476	63	359	27	
%	95.9	4.1	93.0	7.0	2.9
Site 2 April					
N	584	26	110	7	
%	95.7	4.3	94.0	6.0	1.7
Site 2 July					
N	614	16	66	3	
%	97.5	2.5	95.7	4.3	1.8
Site 3 April					
N	2486	54	259	23	
%	97.9	2.1	91.8	8.2	6.1
Site 3 July					
N	766	4	84	1	
%	99.5	0.5	98.8	1.2	0.7
Site 3 October					
N	1470	20	162	3	
%	98.7	1.3	98.2	1.8	0.5

represent the community being studied (Wrona et al. 1982, Barbour & Gerritsen 1996). In the present study, we tested mostly the error related to chironomid size, from the sample to the subsample. We assume that an *a posteriori* subsampling would have as major drawback the tendency to select larger more easily viewed individuals, resulting from the fact that they occupy a larger area than smaller individuals. A clear advantage, however, is that the researcher has the number of the individuals sorted from the sample and can "return" to that if subsampling produce spurious results. More importantly, the total N of the sample is available for the researcher which in itself is an important information on the efficacy of the data generated by the subsampling procedure. In smaller samples, say up to 1000 individuals, all individuals may be counted and identified, but in larger samples (see Carvalho et al. 2013 and the present study), subsampling a proportion of the total number will increase overall sampling effort but also efficiency of the subsample as number of individuals increase. This is shown in the present study by the low difference in chironomid size between the sample and the subsample and by the lack of correlation between chironomid size related error and the size of the sample.

We showed in the present study that the subsampling technique used is capable of drawing a randomized subset of individuals from a sample of chironomids. This indicates that the technique tested for *a posteriori* sorting of individuals from a sample has the same probability of collecting larger or smaller individuals when compared with the original method of collection (in this case the D-shaped net). That means that larger individuals (or morphotypes) are not overestimated in relation to smaller ones, and that this is achieved regardless of the number of individuals in a sample.

Not surprisingly, in recent years a growing number of research groups have been implementing subsampling methods in their collection protocols (Carter & Resh 2001, McCord et al. 2007, Petkovska & Urbanic 2010, Anderson & Ferrington 2012). However, it is important to ensure that such subsampling methods are representative of the sample and the study area, and that they are being interpreted bearing in mind the limitations of the subsampling technique (Farias et al. 2012, Ligeiro et al. 2012). In the Brazilian semi-arid streams, larger morphotypes are represented mostly by *Chironomus*, *Dicrotendipes* and *Clinotanypus* (e.g. Farias et al. 2012, Rocha et al. 2012). Nonetheless, other systems report other types of chironomids and consequently different larger morphotypes, such as *Cryptochironomus*, *Axarus* and *Alotanypus* (e.g. Stenert et al. 2012, Floss et al. 2012, Molozzi et al. 2011). Thus, even though the technique used in this study is of general application, it is important to perform pilot studies before the actual sampling and subsampling in order to understand the composition of the chironomid fauna and adjust the cut off value between large and small morphotypes in accordance with the local fauna.

We suggest the utilization of *a posteriori* subsampling in the laboratory in studies with large sample sizes collected from spatially and/or temporally variable aquatic systems, but emphasize the need for assessing the degree of randomness in the subsampling technique used and estimation of the error involved.

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Aquatic Oligochaeta (Annelida: Clitellata) from State of São Paulo, Brazil: Diversity and Occurrence review

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GORNI, G., PEIRÓ, D.F., SANCHES, N. **Aquatic Oligochaeta (Annelida: Clitellata) from State of São Paulo, Brazil: Diversity and Occurrence review.** Biota Neotropica. 15(1): e20140063. http://dx.doi.org/10.1590/1676-06032015006314

Abstract: More than 5.000 species are described to Class Oligochaeta, and approximately 1650 aquatic species are recognized around the world. Knowledge regarding abundance and composition of limnic oligochaetes can be used as an indicator of water and sediment quality. Thus, this paper aims to summarize all published data on aquatic Oligochaeta from State of São Paulo (Brazil), in order to establish a cheklist of microdrili from the State. The list emphasizes the diversity of limnic oligochaetes and provides a general overview of their distribution and also ecological aspects. Were examined the bibliographical data on São Paulo aquatic Oligochaeta, including species catalogs and taxonomic and ecological literature. Were analyzed a total of 34 academic researches, 32 journal papers and two taxonomic catalogs. This analysis resulted in a list of 75 valid species, distributed in 24 genera and five families. This amount of taxa corresponds to 4.5% of the aquatic Oligochaeta worldwide valid species, and about 87% of the Brazilian species.
Keywords: *Limnic oligochaetes, Species list, Occurrence, São Paulo.*

GORNI, G., PEIRÓ, D.F., SANCHES, N. **Oligochaeta aquático (Annelida: Clitellata) do Estado de São Paulo: Revisão da Diversidade e Ocorrência.** Biota Neotropica. 15(1): e20140063. http://dx.doi.org/10.1590/1676-06032015006314

Resumo: Mais de 5.000 espécies são descritas para a Classe Oligochaeta e aproximadamente 1650 espécies aquáticas são reconhecidas em todo o mundo. O conhecimento sobre a composição e abundância de oligoquetos límnicos pode ser um indicador de qualidade da água e/ou sedimento. Assim, este trabalho teve como objetivo reunir todas as informações publicadas sobre Oligochaeta aquático do Estado de São Paulo (Brasil), a fim de estabelecer uma lista de táxons de microdrili registrados. A lista destaca a diversidade de oligoquetos límnicos e fornece uma visão geral de sua distribuição e aspectos ecológicos. Para isso, foram examinados dados bibliográficos de Oligochaeta aquáticos em São Paulo, incluindo catálogos de espécies, bem como artigos sobre taxonomia e de ecologia. Foram analisados ??o total de 34 trabalhos acadêmicos, sendo 32 artigos e dois catálogos taxonômicos. Esta análise resultou em uma lista de 75 espécies válidas, distribuídas em 24 gêneros e cinco famílias. Este montante corresponde a 4,5% das espécies de Oligochaeta aquático registradas no mundo, e aproximadamente 87 % das espécies brasileiras.
Palavras-chave: *Oligoquetos límnicos, Lista de espécies, Ocorrência, São Paulo.*

Introduction

The Class Oligochaeta is included into the Phylum Annelida, together with Hirudinea and Polychaeta. The main characteristic of the phylum is the metameric body construction. It means the body is subdivided in similar segments (or "rings") arranged along the antero-posterior axis of the body (Righi 2002).

More than 5.000 species are described to Oligochaeta. The majority of them are terrestrial earthworms (megadrile). Being relatively low the number of freshwater, semi terrestrial or marine forms (microdrile). Approximately 1650 aquatic Oligochaeta are recognized as valid species around the world (Martin et al. 2008). In Brazil the number of valid species is around 86, excluding the Enchytraeidae Family (Christoffersen 2007). In continental aquatic environments the abundance and composition of Oligochaeta can be an indicator for water and sediment quality (Lafont 1984, Marchese & Drago 1999, Alves & Strixino 2000).

The knowledge about the Brazilian freshwater Oligochaeta is very fragmented and incomplete, even these organisms being very common in continental aquatic environments (Timm et al. 2001). However, the publication of books in the eighties - specifically focused on the identification of oligochaetes in Brazil and South America (Righi 1984, Brinkhurst & Marchese 1989, respectively) – encouraged researches as Takeda (1999, 2001), Montanholi-Martins & Takeda (1999, 2001), Alves & Lucca (2000), Alves & Strixino (2000), Pamplin et al. (2005), Alves et al. (2006, 2008), Gorni & Alves (2008a, 2008b, 2012), Martins & Alves (2010) and Rodrigues et al. (2013a, 2013b), which have broadened the knowledge on taxonomic and ecological aspects of these worms in Brazil.

The objective of this paper is to summarize all published data on aquatic Oligochaeta from State of São Paulo (Brazil), in order to establish a checklist of known microdrili taxa from the State. The list emphasizes the diversity of limnic oligochaetes and provides a general overview of their distribution and also ecological aspects.

Material and methods

Were examined the bibliographical data on São Paulo aquatic Oligochaeta, including species catalog, and taxonomic and ecological literature. The literature was surveyed by searching academic databases (Scopus, Scielo, and Google Scholar), and the scientific publications with reports of limnic oligochaetes. Aiming covering the greatest number of publications, were consulted academic papers published from 1942 through 2014.

Results and discussion

A total of 34 studies about São Paulo aquatic Oligochaeta were analyzed, including 32 journal papers and 2 taxonomic catalogs. The list of taxa includes 75 valid species, distributed in 24 genera and five families. This amount of species corresponds to 4.5% of the aquatic Oligochaeta worldwide valid species, and about 87% of the Brazilian species (Christoffersen 2007, Martin et al. 2008). This checklist is shown below, divided into families, genera and species, following alphabetical order.

Checklist and classification

Aelosomatidae

***Aelosoma aerum* Marcus, 1944**

Records: ecological remarks

São Paulo: Serra da Cantareira streams associated with the bryophyte *Dumortiera* sp. (Marcus 1944).

***Aelosoma corderoi* Du Bois Reymond Marcus, 1944**

Records:

São Paulo: Tietê River (Du Bois Reymond Marcus 1944).

***Aelosoma evelinae* Marcus, 1944**

Records: ecological remarks

São Paulo: Pinheiros River, sediment (Marcus 1944).

***Aelosoma gertae* Marcus, 1944**

Records: ecological remarks

São Paulo: associated with the aquatic macrophyte *Eichhornia crassipes* (Marcus 1944).

***Aelosoma headleyi* Beddard, 1888**

Records: ecological remarks

São Paulo: associated with the aquatic macrophyte *Eichhornia crassipes* (Marcus 1944).

***Aelosoma hemprichi* Ehrenberg, 1831**

Records: ecological remarks

São Paulo: University of São Paulo Campus associated with the Bromeliaceae (Marcus 1944).

***Aelosoma sawayai* Marcus, 1944**

Records:

São Paulo and Mogi das Cruzes (Marcus 1944).

***Aelosoma travancorense* Aiyer, 1926**

Records:

São Paulo, Mogi das Cruzes and Pirassununga (Marcus 1944).

***Aelosoma viride* Stephenson, 1911**

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment and associated with the Bromeliaceae (Marcus 1944).

Alluroididae

***Brinkhurstia americana* (Brinkhurst, 1964)**

Records: ecological remarks

Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, sediment of Ponte Nova and Bariri Dams (Pamplin et al. 2005). Araraquara: Pinheirinho Stream, sediment (Alves et al. 2006).

Naididae

***Allodero lutzi* (Michaelsen, 1926)**

Dero (Allodero) lutzi, Righi 1984: 26-27.

Records:

São Paulo (Righi 1984).

***Allonais chelata* (Marcus, 1944)**

Records: ecological remarks

Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007).

***Allonais inaequalis* (Stephenson, 1911)**

Records: ecological remarks

Araraquara: Pinheirinho Stream, sediment (Alves et al. 2006), and Cruzes Stream, associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007), and in Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Allonais paraguayensis paraguayensis* (Michaelsen, 1905)**

Nais paraguayensis, Marcus 1943: 23-31.

Allonais paraguayensis, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533; Alves & De Lucca 2000: 115; Corbi & Trivinho-Strixino 2002: 38; Pamplin et al. 2005: 67; Janke & Trivinho-Strixino 2007: 112; Gorni & Alves 2008b: 163; Gorni & Alves 2012: 107.

Allonais lairdi, Pamplin et al. 2005: 67.

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment and Pirassununga: Mogi-Guaçu River and Cachoeira de Emas Reservoir, sediment (Marcus 1943). Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000). Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and

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Bariri Dams, sediment (Pamplin et al. 2005). São Carlos: Fazzari Stream, leaf litter (Janke & Trivinho-Strixino 2007). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

Amphichaeta leydigi **Tauber, 1879**

Records:

Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008).

Aulodrilus limnobius **Bretscher, 1899**

Records: ecological remarks

São Paulo: Pinheiros River, sediment (Marcus 1944). Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008). Campos do Jordão: Galharada and Serrote Streams, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

Aulodrilus pigueti **Kowalewski, 1914**

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000). Luiz Antonio: Mogi-Guaçu River, sediment (Alves & Strixino 2003).

Aulophorus borellii **(Michaelsen, 1900)**

Dero (Aulophorus) borellii, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533; Alves & De Lucca 2000: 115.

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000). Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000).

Aulophorus carteri **Stephenson, 1931**

Dero (Aulophorus) carteri, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533.

Records: ecological remarks

Pirassununga: Mogi-Guaçu River, Cachoeira de Emas Reservoir, sediment (Marcus 1943). Luiz Antônio: Mogi-Guaçu River, associated with aquatic macrophytes, *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000).

Aulophorus costatus **Du Bois-Reymond Marcus, 1944**

Dero (Aulophorus) costatus, Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262.

Records: ecological remarks

Américo Brasiliense: Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

Aulophorus furcatus **(O. F. Müller, 1774)**

Dero (Aulophorus) furcatus, Pamplin et al. 2005: 67; Gorni & Alves 2006: 1060; Suriani et al. 2007: 420-421.

Records: ecological remarks

São Paulo: sediment of Pinheiros and Tietê Rivers tributaries (Marcus 1943). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Araraquara: Cruzes Stream, associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment (Suriani et al. 2007).

Aulophorus hymanae **(Naidu, 1962)**

Dero (Aulophorus) hymanae, Suriani et al. 2007: 420-421.

Records: ecological remarks

Promissão: Tietê River, sediment of Promissão Reservoir, Buritama: Tietê River, Nova Avanhandava Reservoir, sediment. Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007).

Aulophorus lodeni **(Brinkhurst, 1986)**

Dero (Aulophorus) lodeni, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533; Corbi & Trivinho-Strixino 2002: 38; Pamplin et al. 2005: 67; Suriani et al. 2007: 420-421.

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment. Ibitinga: Tietê River, Ibitinga Reservoir, sediment. Promissão: Tietê River, Promissão Reservoir, sediment. Buritama: Tietê River, Nova Avanhandava Reservoir, sediment. Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007).

Aulophorus superterrenus **Michaelsen, 1912**

Records: ecological remarks

São Paulo and Campinas: associated with the epiphytic *Vriesea* sp. (Bromeliaceae) (Marcus 1943).

Bothrioneurum americanum **Beddard, 1894**

Records: ecological remarks

Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005).

Bothrioneurum iris **Beddard, 1901**

Records: ecological remarks

São Paulo: leaf litter of Tietê River (Marcus 1942).

Bothrioneurum vejdovskyanum **Stolc, 1886**

Bothrioneurum pyrrhum, Marcus 1942: 201-205.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1942).

Branchiura sowerbyi **Beddard, 1892**

Branchiura sowwerbyi, Alves & Strixino 2003: 4; Dornfeld et al. 2006: 193; Fusari & Fonseca-Gessner 2006: 93; Pamplin et al. 2006: 126.

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000, Alves & Strixino 2003). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Americana: Atibaia River, Salto Grande Dam, sediment (Dornfeld et al. 2006). Americana: Americana Dam, sediment (Pamplin et al. 2006). São Carlos: Monjolinho Dam, sediment (Fusari & Fonseca-Gessner 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment; Bariri: Tietê River, Bariri Reservoir, sediment; Ibitinga: Tietê River, Ibitinga Reservoir, sediment; Promissão: Tietê River, Promissão Reservoir, sediment; Buritama: Tietê River, Nova Avanhandava Reservoir, sediment and Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007).

Chaetogaster diaphanus **(Gruithuisen, 1828)**

Records: ecological remarks

Araraquara: Cruzes Stream, associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

Chaetogaster diastrophus **(Gruithuisen, 1828)**

Records: ecological remarks

São Paulo and Campinas: Tietê River sediment and associated with Bromeliaceae (Marcus 1943). Ipeúna: Cantagalo and Lapa Streams, associated with the Odonata larvae *Elasmothemis cannacrioides* and *Mnesarete* sp. (Corbi et al. 2004). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a). Campos do Jordão: Galharada and Serrote Streams, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Chaetogaster langi* Bretscher, 1896**

Chaetogaster parvus, Marcus 1943: 15.

Chaetogaster spongillae, Marcus 1943: 16.

Records: ecological remarks

São Paulo: Pinheiros River, sediment. Águas de São Pedro: Piracicaba River Basin, Araquá River sediment and Southern State of São Paulo: Ribeira de Iguape River, associated with the sponge *Ephydatia crateriformis* (Marcus 1943).

***Chaetogaster limnaei limnaei* K. Von Baer, 1827**

Records: ecological remarks

São Paulo: associated with the gastropod *Australorbis* sp. (Du Bois-Reymond Marcus 1947).

***Dero botrytis* Marcus, 1943**

Dero (Dero) botrytis, Pamplin et al. 2005: 67.

Records: ecological remarks

São Paulo: São Paulo University Campus (Marcus 1943). Águas de São Pedro: Piracicaba River Basin, sediment of Limoeiro Dam (Marcus 1944). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005).

***Dero digitata* (O.F. Müller, 1773)**

Dero (Dero) digitata, Alves & De Lucca 2000: 115; Pamplin et al. 2005: 67; Gorni & Alves 2006: 1060; Alves & Gorni 2007: 409; Suriani et al. 2007: 420-421.

Records: ecological remarks

Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005) Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Bariri: Tietê River, Bariri Reservoir, sediment (Suriani et al. 2007).

***Dero evelinae* Marcus, 1943**

Dero (Dero) evelinae, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533; Pamplin et al. 2005: 67; Fusari & Fonseca-Gessner 2006: 93; Suriani et al. 2007: 420-421; Alves & Gorni 2007: 409.

Records: ecological remarks

São Paulo: University of São Paulo Campus (Marcus 1943). Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). São Carlos: Fazzari Dam, sediment (Fusari & Fonseca-Gessner 2006). Bariri: Tietê River, Bariri Reservoir, sediment (Suriani et al. 2007). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007).

***Dero multibranchiata* Stieren, 1892**

Dero (Dero) multibranchiata, Corbi & Trivinho-Strixino 2002: 38; Pamplin et al. 2005: 67; Suriani et al. 2007: 420-421.

Records: ecological remarks

Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Bariri: Tietê River, Bariri Reservoir, sediment (Suriani et al. 2007).

***Dero nivea* Aiyer, 1930**

Dero (Dero) nivea, Correia & Trivinho-Strixino 1998: 41; Trivinho-Strixino et al. 2000: 533; Alves & Strixino 2000: 177; Corbi & Trivinho-Strixino 2002: 38; Pamplin et al. 2005: 67; Gorni & Alves 2006: 1060; Suriani et al. 2007: 420-421; Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262.

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000), and sediment (Alves & Strixino 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment; Bariri: Tietê River, Bariri Reservoir, sediment (Suriani et al. 2007). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Dero obtusa* D'Udekem, 1855**

Dero (Dero) obtusa, Alves & De Lucca 2000: 115; Corbi & Trivinho-Strixino 2002: 38; Pamplin et al. 2005: 67;Gorni & Alves 2006: 1060; Suriani et al. 2007: 420-421; Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262.

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment (Marcus 1943). Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Araraquara: Cruzes Stream, associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment (Suriani et al. 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Dero pectinata* Aiyer, 1930**

Dero (Dero) pectinata, Pamplin et al. 2005: 67; Suriani et al. 2007: 420-421.

Records: ecological remarks

Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Ibitinga: Tietê River, Ibitinga Reservoir, sediment (Suriani et al. 2007).

***Dero plumosa* Naidu, 1962**

Dero (Dero) plumosa, Alves & Strixino 2000: 177.

Records: ecological remarks

Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000).

***Dero raviensis* (Stephenson, 1914)**

Dero (Dero) raviensis, Alves et al. 2006: 434; Gorni & Alves 2006: 1060; Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262.

Records: ecological remarks

Araraquara: Pinheirinho Stream, sediment and associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006).

São Carlos: Monjolinho River, sediment (Alves et al. 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Dero sawayai* Marcus, 1943**

Dero (Dero) sawayai, Gorni & Alves 2006: 1060; Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262.

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment (Marcus 1943). Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Haemonais waldvogeli* Bretscher, 1900**

Records: ecological remarks

Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005, Suriani et al. 2007). Araraquara: Pinheirinho Stream, sediment (Alves et al. 2006), and associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006).

***Jolydrilus jaulus* Marcus, 1965**

Records: ecological remarks

Cananéia and Cubatão: mangrove sediment (Marcus 1965).

***Limnodrilus hoffmeisteri* Claparède, 1862**

Limnodrilus hoffmeisteri f. divergens, Marcus 1942: 169-174.

Limnodrilus hoffmeisteri f. parva, Marcus 1942: 167-169.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1942). Pirituba (Mendes et al. 1951). Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000, Alves & Strixino 2003). Araraquara: Pinheirinho, Santa Clara and àgua Branca Streams, sediment (Alves & De Lucca 2000, Alves et al. 2006). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). São Carlos: Monjolinho River, sediment (Alves et al. 2006, Fusari & Fonseca-Gessner 2006). Ribeirão Preto: Pardo River, sediment of Monte Alegre Lake (Cleto-Filho & Arcifa 2006). Americana: Atibaia River, Salto Grande Dam, sediment (Dornfeld et al. 2006). Americana: Americana Dam, sediment (Pamplin et al. 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment; Bariri: Tietê River, Bariri Reservoir, sediment. Ibitinga: Tietê River, Ibitinga Reservoir, sediment; Promissão: Tietê River, Promissão Reservoir, sediment; Buritama: Tietê River, Nova Avanhandava Reservoir, sediment and Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007). Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008). Campos do Jordão: Galharada and Serrote Streams, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Limnodrilus neotropicus* Černosvitov, 1939**

Records: ecological remarks

Araraquara: Água Branca Stream, sediment (Alves et al. 2006). São Carlos: Gouveia Stream, sediment (Alves et al. 2006). Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008).

***Limnodrilus udekemianus* Claparède, 1862**

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1942). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). São Carlos: Monjolinho River, sediment (Alves et al. 2006). Buritama: Tietê River, Nova Avanhandava Reservoir, sediment (Suriani et al. 2007). Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007).

***Monopylephorus parvus* Ditlevsen, 1904**

Records: ecological remarks

Cananéia: mangrove sediment (Marcus 1965).

***Nais communis* Piguet, 1906**

Nais communis f. magenta, Marcus 1943: 23.

Records: ecological remarks

Southern State of São Paulo: Ribeira de Iguape River, associated with the sponge *Ephydatia crateriformis* (Marcus 1943). São Paulo: Tietê River and Pinheiros River tributaries, sediment (Marcus 1943). Luiz Antônio: Mogi-Guaçu River, associated with aquatic macrophytes (Trivinho-Strixino et al. 2000). Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000), and associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). São Carlos: Jacaré-Guaçu River, associated with the sponge *Radiospongilla amazonensis* (Corbi et al. 2005), and Monjolinho River, sediment (Alves et al. 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Jacaré-Pepira River, associated with the bryophytes *Fissidens* sp. and *Philonotis* sp. (Gorni & Alves 2007), and Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a). Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008). Campos do Jordão: Campo do Meio and Galharada Streams, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Nais elinguis* O. F. Müller, 1774**

Records: ecological remarks

Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006).

***Nais pardalis* Piguet, 1906**

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment (Marcus 1943). Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006).

***Nais variabilis* Piguet, 1906**

Records: ecological remarks

Ipeúna: Cantagalo and Lapa Streams, associated with the Odonata larvae *Elasmothemis cannacrioides* and *Mnesarete* sp. (Corbi et al. 2004). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni and Alves 2008b, Gorni & Alves 2012).

***Paranais evelinae* (Marcus, 1965)**

Wapsa evelinae, Marcus 1965: 63.

Records: ecological remarks

Cananéia: mangrove sediment (Marcus 1965).

***Pristina aequiseta aequiseta* Bourne, 1891**

Pristina aequiseta, Marcus 1943: 104-106, Alves et al. 2006: 434, Gorni & Alves 2008a: 262.

Pristina evelinae, Marcus 1943: 112-125.

Records: ecological remarks

São Paulo: Pinheiros River tributaries, sediment; Pirassununga: Mogi-Guaçu River, Cachoeira de Emas Reservoir, sediment and Águas de São Pedro: Piracicaba River Basin, Araquá River, sediment (Marcus 1943). Southern

State of São Paulo: Ribeira de Iguape River, associated with the sponge *Ephydatia crateriformis* (Marcus 1943). Araraquara: Água Branca Stream, sediment (Alves et al. 2006). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Pristina americana* Cernosvitov, 1937**

Pristinella longidentata, Alves & Strixino 2000: 177; Gorni & Alves 2008b: 163.

Pristina (Pristinella) longidentata, Gorni & Alves 2012: 107.

Records: ecological remarks

São Paulo: Pinheiros and Tietê Rivers, sediment (Marcus 1943). Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000). Araraquara: Pinheirinho and Santa Clara Streams, sediment (Alves & De Lucca 2000). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). São Carlos: Monjolinho River, sediment (Alves et al. 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment; Bariri: Tietê River, Bariri Reservoir, sediment; Ibitinga: Tietê River, Ibitinga Reservoir, sediment; Promissão: Tietê River, Promissão Reservoir, sediment; Buritama: Tietê River, Nova Avanhandava Reservoir, sediment and Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b).

***Pristina biserrata* Chen, 1940**

Records: ecological remarks

Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007), and with the sponge *Metania spinata* (Gorni & Alves 2008a). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b).

***Pristina breviseta* Bourne, 1891**

Naidium breviseta, Marcus 1943: 128-129.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1943). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). São Carlos: Fazzari Dam, sediment (Fusari & Fonseca-Gessner 2006).

***Pristina longiseta* Ehrenberg, 1828**

Pristina leidyi, Alves & Strixino 2003: 4; Gorni & Alves 2006: 1060; Alves & Gorni 2007: 409; Gorni & Alves 2008a: 262; Gorni & Alves 2008b: 163; Gorni & Alves 2012: 107.

Records: ecological remarks

Southern State of São Paulo: Ribeira de Iguape River, associated with the sponge *Ephydatia crateriformis*, and Águas de São Pedro: Piracicaba River Basin, Araquá River, sediment (Marcus 1943). Luiz Antonio: Mogi-Guaçu River, sediment (Alves & Strixino 2003). Araraquara: associated with the gastropod *Pomacea bridgesii* (Gorni & Alves 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007), and with the sponge *Metania spinata* (Gorni & Alves 2008a). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina macrochaeta* Stephenson, 1931**

Records: ecological remarks

São Paulo: Pinheiros River, sediment (Marcus 1943). Campinas: Atibaia River, sediment (Marcus 1944). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007), and with the sponge *Metania spinata* (Gorni & Alves 2008a).

***Pristina menoni* (Aiyer, 1929)**

Pristinella menoni, Alves et al. 2006: 434; Gorni & Alves 2007: 519.

Records: ecological remarks

Araraquara: Pinheirinho Stream, sediment (Alves et al. 2006). Brotas: Jacaré-Pepira River, associated with the bryophytes *Fissidens* sp. and *Philonotis* sp. (Gorni & Alves 2007).

***Pristina notopoda* Černosvitov, 1937**

Pristinella notopora, Gorni & Alves 2008b: 163.

Pristina (Pristinella) notopora, Gorni & Alves 2012: 107.

Records: ecological remarks

Campos do Jordão: Campo do Meio, Galharada and Serrote Streams, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina osborni* (Walton, 1906)**

Naidium minutum, Marcus 1943: 129-130.

Pristinella osborni, Alves & Gorni 2007: 409; Alves et al. 2008: 71.

Pristinella minuta, Gorni & Alves 2008b: 163.

Pristina (Pristinella) minuta, Gorni & Alves 2012: 107.

Records: ecological remarks

Águas de São Pedro: Piracicaba River Basin, Araquá River, sediment (Marcus 1943). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Ribeirão Grande: Intervales State Park Streams (Alves et al. 2008). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina proboscidea* Beddard, 1896**

Records: ecological remarks

São Carlos: Jacaré-Guaçu River, associated with the sponge *Radiospongilla amazonensis* (Corbi et al. 2005). Araraquara: Água Branca Stream, sediment (Alves et al. 2006). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007). Brotas: Lagoa Dourada Dam, associated with the sponge *Metania spinata* (Gorni & Alves 2008a). Campos do Jordão: Galharada Stream, sediment and leaf litter (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina rosea* (Piguet, 1906)**

Naidium roseum, Marcus 1943: 130-132; Marcus 1944: 50.

Pristinella jenkinae, Alves et al. 2006: 434; Fusari & Fonseca-Gessner 2006: 93; Gorni & Alves 2007: 519; Gorni & Alves 2008b: 163; Gorni & Alves 2012: 107.

Records: ecological remarks

São Paulo: University of São Paulo Campus, and Pinheiros River tributaries, sediment (Marcus 1943), Tietê River, associated with the plant *Calathea* sp. (Marcus 1944). Araraquara: Pinheirinho and Água Branca Streams, sediment (Alves et al. 2006). São Carlos: Gouveia Stream, sediment (Alves et al. 2006), and Monjolinho Dam, sediment (Fusari & Fonseca-Gessner 2006). Brotas: Jacaré-Pepira River, associated with the bryophytes *Fissidens* sp. and *Philonotis* sp. (Gorni & Alves 2007). Campos do Jordão: Campo do Meio Stream, Galharada and Serrote Streams, leaf litter and sediment (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina sima* (Marcus, 1944)**

Naidium simum, Marcus 1944: 68-69.

Pristinella sima, Gorni & Alves 2008b: 163.

Pristina (Pristinella) sima, Gorni & Alves 2012: 107.

Records: ecological remarks

São Paulo: associated with the bryophyte *Dumortiera* sp. (Marcus 1944). Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000). Campos do Jordão: Galharada and Serrote Streams, leaf litter and sediment (Gorni & Alves 2008b, Gorni & Alves 2012).

***Pristina synclites* Stephenson, 1925**

Records: ecological remarks

Araraquara: Pinheirinho Stream, sediment (Alves et al. 2006). São Carlos: Monjolinho River, sediment (Alves et al. 2006, Fusari & Fonseca-Gessner 2006).

***Slavina appendiculata* (D'Udekem, 1855)**

Records: ecological remarks

São Carlos: Gouveia Stream, sediment (Alves et al. 2006).

***Slavina evelinae* (Marcus, 1942)**

Peloscolex evelinae, Marcus 1942: 157-159.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1942). Luiz Antônio: Mogi-Guaçu River, associated with the aquatic macrophyte *Scirpus cubensis* (Correia & Trivinho-Strixino 1998, Trivinho-Strixino et al. 2000). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005, Suriani et al. 2007). Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007).

***Slavina isochaeta* Černosvitov, 1939**

Records: ecological remarks

Luiz Antonio: Mogi-Guaçu River, sediment (Alves & Strixino 2003).

***Slavina sawayai* Marcus, 1944**

Records: ecological remarks

Águas de São Pedro: Piracicaba River Basin, Araquá River, sediment (Marcus 1944).

***Stylaria lacustris* (Linnaeus, 1767)**

Records: ecological remarks

Brotas and Américo Brasiliense: Lagoa Dourada and Anhumas Stream Dams, associated with aquatic macrophytes (Alves & Gorni 2007).

***Tectidrilus gabriellae* Du Bois-Reymond Marcus, 1950**

Peloscolex gabriellae, Du Bois-Reymond Marcus 1950: 1.

Records:

São Sebastião (Du Bois-Reymond Marcus 1950).

***Tubifex tubifex tubifex* (O. F. Müller, 1774)**

Tubifex (Tubifex) tubifex, Marcus 1942: 198-200.

Tubifex tubifex, Alves & Strixino 2000: 177; Alves et al. 2006: 434.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1942). Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000). São Carlos: Monjolinho River, sediment (Alves et al. 2006).

Narapidae

***Narapa bonettoi* Righi & Varela, 1983**

Records: ecological remarks

São Carlos: Gouveia Stream, sediment (Alves et al. 2006).

OPISTOCYSTIDAE

***Opistocysta funiculus* Cordero, 1948**

Opistocysta flagellum, Marcus 1944: 69-70.

Records: ecological remarks

São Paulo: Tietê River, sediment (Marcus 1944). Luiz Antônio: Mogi-Guaçu River, sediment (Alves & Strixino 2000, Alves & Strixino 2003). Américo Brasiliense: Anhumas Stream Dam, sediment (Corbi & Trivinho-Strixino 2002). Salesópolis and Bariri: Tietê River, Ponte Nova and Bariri Dams, sediment (Pamplin et al. 2005). Americana: Atibaia River, Salto Grande Dam, sediment (Dornfeld et al. 2006), and in Americana Dam (Pamplin et al. 2006). Barra Bonita: Tietê River, Barra Bonita Reservoir, sediment; Ibitinga: Tietê River, Ibitinga Reservoir, sediment; Buritama: Tietê River, Nova Avanhandava Reservoir, sediment; Pereira Barreto: Tietê River, Três Irmãos Reservoir, sediment (Suriani et al. 2007).

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Euastrum and *Micrasterias* (family Desmidiaceae) in lentic tropical ecosystem, Brazil

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SILVA, F.K.L., FELISBERTO, S.A. ***Euastrum*** **and** ***Micrasterias*** **(family Desmidiaceae) in lentic tropical ecosystem, Brazil.** Biota Neotropica. 15(1): e20140079. dx.doi.org/10.1590/1676-06032015007914

Abstract: This study aimed to perform the taxonomic survey of *Euastrum* and *Micrasterias* in a lentic tropical environment, seeking to contribute to the knowledge on biodiversity and geographical distribution of the Zygnemaphyceae. Conducted at the Samambaia Reservoir, ten samples were collected in the dry season (24/09/10 and 04/11/10) and ten in the rainy season (06/01/11 and 02/03/11). Periphyton was sampled from stems of aquatic plants (Cyperaceae), which were in the marginal area of the reservoir. With the floristic survey, 22 taxa were identified representing the genus *Euastrum* (9) and *Micrasterias* (13), of these 16 are new records for the State of Goiás. In relation the frequency of occurrence and the seasonal period, 19 taxa were classified in the rare category and three in common, nine species were recorded during the dry season, while four only in the rainy season.

Keywords: *desmids, periphyton, sazonal, taxonomy, Zygnemaphyceae.*

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Resumo: Este estudo objetivou o levantamento taxonômico de *Euastrum* e *Micrasterias* em um ambiente tropical lêntico, visando contribuir para o conhecimento da biodiversidade e distribuição geográfica de Zygnemaphyceae. Realizado na Represa Samambaia, dez amostras foram coletadas no período seco (24/09/10 e 04/11/10) e dez no período chuvoso (06/01/11 e 02/03/11). O perifíton foi amostrado de pecíolos de plantas aquáticas (Cyperaceae) que se encontravam na região litorânea da represa. Com o levantamento florístico foram identificados 22 táxons representantes dos gêneros *Euastrum* (nove) e *Micrasterias* (13), destes, 16 são novas citações para o Estado de Goiás. Em relação à freqüência de ocorrência e ao período sazonal, 19 táxons foram enquadrados na categoria raro e três em comum, nove espécies foram registrados para o período seco, enquanto quatro somente na estação chuvosa.

Palavras-chave: *desmídias, perifíton, sazonal, taxonomia, Zygnemaphyceae.*

Introduction

Although of relatively discreets, algae have a great importance in the freshwater environment, both ecologically terms as in relation to human use of natural resources (Bellinger & Sigee 2010). The number of species recognized probably underestimates the actual number of existing species, since many habitats and regions are not extensively sampled (Stevenson et al. 1996).

When algae lives with bacteria, fungi, protozoa and micro-crustaceans, they form the periphyton, a complex community of microorganisms with organic or inorganic debris adhered and associated to a natural or artificial, living or dead substrate (Wetzel 1983). Thus the periphyton serves as a microcosm which occurs simultaneously in their bioderme, autotrophic and heterotrophic internal processes (Wetzel 1983). Still, periphyton is the food basis for the trophic chains because is rich in proteins, vitamins and minerals important for many organisms, as well as represents an effective participation in the recycling of various inorganic nutrients and photosynthetic production, since most of their components are algae (Wetzel 1983).

Periphytic algae are of interest because these organisms play an important role in both lotic and lentic water bodies because as primary producers (Lam & Lei 1999), they are a protein food source and shelter for many invertebrates and fishes (Cattaneo & Kalf 1978). And is this important and complex community that we can find the green algae belonging to the class Zygnemaphyceae and covering two orders, the Desmidiales and Zygnematales.

In Desmidiales, among four families (Gonatozygaceae, Peniaceae, Closteriaceae and Desmidiaceae) according to the classification of Mix (1972) proved by McCourt et al. (2000) using analysis of molecular biology, the Desmidiaceae family is the largest in number of genus and species. Most species of this family have a median constriction that defines the narrow isthmus, which connects the two halves of cell (Brook 1981, Coesel 1996), for example, the genus *Euastrum* and *Micrasterias* target in this study. Another point, is that the species of this order are found in oligo-mesotrophic aquatic environments (Coesel 1996, Gerrath 2003).

Taxonomic papers that specifically address the genus *Euastrum* and *Micrasterias* are more common to the State of

Paraná (Moresco et al. 2009, Felisberto & Rodrigues 2011), Rio de Janeiro (Sophia 1989), São Paulo (Bicudo & Sormus 1982, Sormus & Bicudo 1997), Bahia (Oliveira et al. 2009, Oliveira et al. 2011) and Amazonas (Martins 1986, Melo et al. 2009). In Goiás, Felisberto & Rodrigues (2002) have studied both genus with the periphyton of Corumbá Reservoir.

This study aims to conduct a taxonomic survey of the species of genus *Euastrum* and *Micrasterias* of periphyton in two periods (dry and rainy) in the Samambaia Reservoir. In this way, we hope contribute to the knowledge in terms of biodiversity and new records for the Midwest and consequently to Brazil.

Material and methods

The study area (16 ° 35’S, 49 ° 16’W, Figure 1) is located in Campus II of the Federal University of Goiás in Goiânia-GO, Central West region of Brazil.

The Samambaia Reservoir was constructed in 1972 by damming the stream Samambaia (Brandão & Kravchenko 1997), it has an average depth of 3.5 m and was characterized as an environment oligo to mesotrophic (Nogueira 1999). This reservoir has been built to the purpose of fish farming experiments of Federal University of Goiás (UFG) and later went on to supply the entire university campus through the company of Goiás Sanitation S/A (Saneago), although there are significant point sources and diffuse of pollutants (Nogueira 1999).

Sampling stations were abbreviated as P1 = the island, P2 = near the Saneago house, P3 = next to the nascent, P4 = beside of the forest and P5 = bar near the road to the dam.

The characterization of drought and rain was based on climatological daily data rainfall obtained through newsletters from the Evapopluviometric Station of Goiânia, located in the School of Agronomy and Food Engineering, UFG, distant about 600 m of the study area. The climate in the study area is considered as tropical by according to Köppen classification (Peel et al. 2007).

Periphyton was collected from stems of aquatic plants (Cyperaceae) that were in the marginal area of the reservoir (Three petioles per sample point), five sampling points in the study area. Twenty samples were collected, ten in the dry season (24/09/10 and 04/11/10) and ten in the rainy season (06/01/11 and 02/03/11).

The periphytic substrate material was removed with the aid of a razor blade followed by distilled water jets. After scraping, the material was transferred to vials, preserved and fixed with Transeau solution (Bicudo & Menezes 2006).

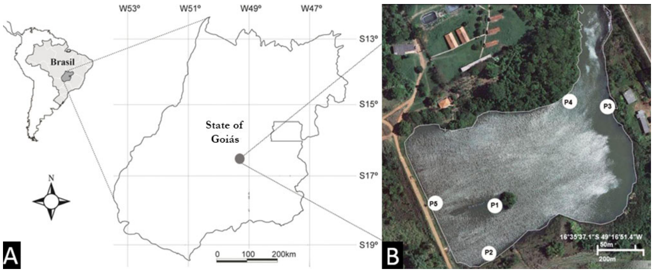

Figure 1. Location map of the Samambaia Reservoir (A). Sampling stations of the Samambaia Reservoir (B): P1 to P5. Source: Souza et al. (2014).

The samples are deposited in the herbarium collection of the Federal University of Goiás, Goiânia-GO under the numbering 47324-47349.

The samples were analyzed between slide and cover slip in the preparation of 10 temporary blades per sample. The capture images of subjects was processed with the aid of the optical microscope ZEISS brand (model Axioskop 40) and a digital camera coupled by the optical system of the microscope.

Identification of taxa was made by the morphological and morphometric characteristics of the cells, which were obtained by the optical microscope at the increase of 40x and 100x, and consultation to the specialized literature base, including articles, reviews and monographs. It was observed, when possible, the three views necessary for taxonomic identification of the desmids: frontal, lateral and apical. For the taxonomic classification, it was followed the recommendation of Bicudo & Menezes (2006).

The frequency of occurrence, in percent, was calculated considering the presence and absence of the taxon in the sampling stations and divided by the total number of taxa sampled. The categories used were: Rare ($\leq$ 10%), Common ($>$ 10% $\leq$ 30%) and Constant ($>$ 30%), adapted from Guille (1970).

Results and discussion

Finalized the taxonomic survey of the genus studied, a total of 22 taxa of *Euastrum* (9) and *Micrasterias* (13) were identified.

Euastrum Ehrenberg ex Ralfs 1848

Cells isolated, oval, trapezoid to quadrilateral, usually longer than broad, deep median incision; semicells usually 3-lobed, two lateral lobes, the polar generally have an apical notch and is more deeply incised around the margin, smooth cell wall; semicell with a relatively narrow isthmus (Bicudo & Menezes 2006).

Euastrum abruptum Nordstedt, Vid. Medd. Naturh. Foren. Kjöbenhavn, III (14/15): 217. Pl. 2, fig. 3. 1869 (1870). (Figure 2a)

Cell longer than wide (71 x 45 μm; isthmus: 13 μm); deep median constriction, fully enclosed central sine, trapezoidal semicell, slender, 3-lobed, interlobar incisions U-shaped open, deep; lateral lobes of an semicell separated by semi-quadrangular incisions of the lateral lobes of the other semicell, deep; polar lobe with oval sinus, margins of lobes with a closely wavy process.

Geographical distribution in the State of Goiás: Förster (1964, 1969).

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P2, 01/III/2011, Felisberto *et al.* 18 (UFG 47341).

Among the taxa identified, *Euastrum abruptum* can be easily confused with *Euastrum evolutum*. This is because they share a slight resemblance in the form of their semicell, which are trapezoidal. When carefully observed, they can be distinguished by the length of their cells, *Euastrum abruptum* is larger and thinner than *Euastrum evolutum*. The lateral lobes of a semicell are separated by semi-quadrangular incisions of lateral lobes of the other semicell, and the polar lobe has an oval sinus, characteristics there are not analyzed in *Euastrum evolutum*, in which the lateral lobes do not have incisions that separate them of the lateral lobe of the other semicell, and the lobe apex has a V-shaped sinus, instead of oval.

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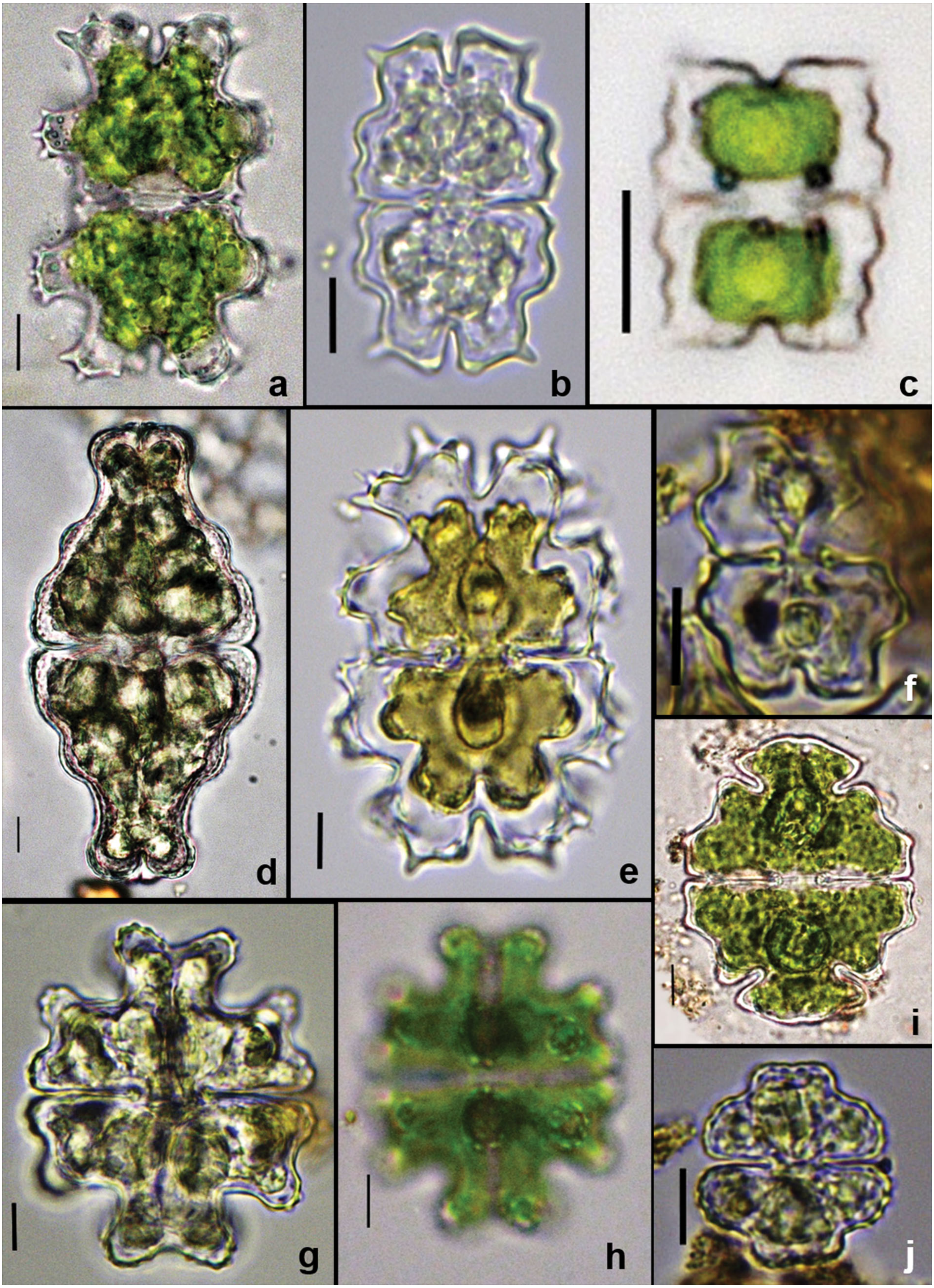

Figure 2: *Euastrum* of the Samambaia Reservoir. **Fig. 2a.** *Euastrum abruptum* Nordstedt. **Fig. 2b.** *E. bidentatum* Nägeli. **Fig. 2c.** *E. denticulatum* Gay. **Fig. 2d.** *E. didelta* (Turpin) Ralfs var. *quadriceps* (Nordstedt) Krieger. **Fig. 2e.** *E. evolutum* Scott & Croasdale. **Fig. 2f.** *E. gayanum* De Toni var. *angulatum* Krieger. **Fig. 2g and 2h.** *E. gemmatum* (Brébisson) Brébisson ex Ralfs var. *gemmatum* (Fig. 2h, focus on ornamental wall). **Fig. 2i.** *E. subintegrum* Nordstedt var. *brasiliense* Grönblad. **Fig. 2j.** *E. subornatum* West & Westvar. *brasiliense* Borge. Scale bar = 10 µm.

Euastrum bidentatum Nägeli, Einzelliger Algen, 1849: 122, pl. 7 D: figs 1a-f. (Figure 2b)

Cell longer than wide (31-34 x 19-21 µm; isthmus: 4-5 µm); deep median constriction, almost completely closed, slightly open at the ends; semi-elliptical semicell, 3-lobed, shallow interlobar incisions; lateral lobes ends with apex with slight indentations; polar lobe with deep V-shaped sinus; angular margins of the polar lobe with a closely wavy process.

Geographical distribution in the State of Goiás: First quote of species occurrence in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P1, 24/IX/2010, Felisberto et al. 1 (UFG 47324); P2, 24/IX/2010, Felisberto et al. 2 (UFG 47325); P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P2, 04/XI/2010, Felisberto et al. 8 (UFG 47331); P5, 01/III/2011, Felisberto et al. 21 (UFG 47344).

Euastrum bidentatum shows a deep incision at the apex of each of its semicells and is adorned with small projections, almost thorny, which are arranged in particular, at the contours areas of the semicell curvatures.

Euastrum denticulatum Gay, Bull. Soc. Bot. France 31: 335. 1884. (Figure 2c)

Cell slightly longer than wide (22-29 x 19-22 µm; isthmus: 5-6 µm); deep median constriction, almost completely enclosed, slightly open at the ends; semicell semi-quadrangular, 3-lobed, interlobar incisions shallow; lateral lobes ends with a convex apex; polar lobe with a semioval deep sinus; straight apical margin of the polar lobe, and angular margins with small processes.

Geographical distribution in the State of Goiás: Felisberto & Rodrigues (2002).

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P1, 04/XI/2010, Felisberto *et al.* 7 (UFG 47330); P3, 01/III/2011, Felisberto *et al.* 19 (UFG 47342); P5, 01/III/2011, Felisberto *et al.* 21 (UFG 47344).

The taxa *Euastrum denticulatum* and *Euastrum gayanum* var. *angulatum* have cells with sizes very close and your frontal lobes exhibit slightly convex sum its thus, can easily be confused when they observed more closely. However, the semicell of *E. denticulatum* is semi-quadrangular, unlike *E. gayanum* var. *angulatum*, whose semicell is semiretangular, and the sine is fully enclosed in *E. gayanum* var. *angulatum*, whereas in *E. denticulatum* is slightly open at the edges. Still, the polar lobe has apical margin straight in *E. denticulatum*, while in *E. gayanum* var. *angulatum* is slightly wavy.

Euastrum didelta (Turpin) Ralfs var. ***quadriceps*** (Nordstedt) Willi Krieger in Kolkwitz, Rabenh. Krypt. -Fl., ed. 2. 13(1): 520; pl. 67, fig. 8–10. 1937. (Figure 2d)

Cell much longer than wide (112 x 57 µm; isthmus: 16 µm); deep median constriction, almost completely enclosed, slightly open at the ends; trapezoidal semicell, almost indistinct lobes, interlobar incisions flatly concave; lateral lobes ends with a slight indentations at the apices; polar lobe with truncated apex, forming a lip; thick cell wall and adorned with punctuations.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328).

Euastrum didelta var. *quadriceps* differs from the typical variety by having three protrusions well marked just above the isthmus and coarse scores in the cell wall.

Euastrum evolutum (Nordstedt) West & G.S.West var. evolutum, Trans. Linn. Soc. London, Bot. 5: 243, 1896. (Figure 2e)

Cell longer than wide (49-60 x 30-38 µm; isthmus: 7-12 µm); deep median constriction, almost completely enclosed, slightly open at the ends; trapezoidal semicell, robust, 3-lobed, interlobar deep incisions, U-shaped open; lateral and polar lobes with deep recesses in the apex; polar lobe with a deep sinus, V-shaped; margins of lobes with many closely corrugated processes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P1, 04/XI/2010, Felisberto et al. 7 (UFG 47330); P2, 04/XI/2010, Felisberto et al. 8 (UFG 47331); P3, 04/XI/2010, Felisberto et al. 9 (UFG 47332); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333); P1, 06/I/2011, Felisberto et al. 12 (UFG 47335); P2, 06/I/2011, Felisberto et al. 13 (UFG 47336): P3, 06/I/2011, Felisberto et al. 14 (UFG 47337); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341); P5, 01/III/2011, Felisberto et al. 21 (UFG 47344).

Euastrum gayanum de Toni var. ***angulatum*** Krieger, Desm. Ber. Deutsch. Bot. Ges. 63 (2): 37, fig. 3. 1950. (Figure 2f)

Cell slightly longer than wide (20-30 x 16-25 µm; isthmus: 3?4 µm); deep median constriction, fully enclosed; semiretangular semicell, 3-lobed, interlobar incisions very shallow; lateral lobes with slightly convex apices; polar lobe with flatly semioval sinus; apical margin of the polar lobe slightly wavy and angular margins with small processes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 24/IX/2010, Felisberto et al. 3 (UFG 47326).

Euastrum gemmatum (Brébisson) Brébisson *ex* Ralfs var. ***gemmatum***, Brit. Desmid.: 87; pl. 14, fig. 4. 1848. (Figure 2g-h)

Cell longer than wide (51-54 x 41-47 µm; isthmus: 10-13 µm); deep median constriction, almost completely closed, slightly open at ends; semicircle semicell, 3-lobed, interlobar deep incisions, U-shaped open; lateral and polar lobes with deep recesses in the apices; apical margins of the lobes convex; semicell with 3 circular tumescence quite evident in the region between the frontal lobes; the lateral largest than the side, prominent, ornamented with 2 rings of rounded granules; ornamented wall with granules.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 24/IX/2010, Felisberto et al. 3 (UFG 47326); P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P4, 04/IX/2010, Felisberto et al. 10 (UFG 47333); P5, 04/IX/2010, Felisberto et al. 11 (UFG 47334); P2, 06/I/2011, Felisberto et al. 13 (UFG 47336); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341).

Euastrum subintegrum Nordstedt var. ***brasiliense*** Grönblad, Acta Soc. Sci. Fenn. 2(6): 14; pl. 4, fig. 69, 70. 1945. (Figure 2i)

Cell longer than wide (60-87 x 47-65 µm; isthmus: 9-14 µm); deep median constriction, almost completely enclosed, slightly open at the ends; trapezoidal semicell, 3-lobed, interlobar incisions deep lanceolate; lateral lobes with deep recesses in the apices; convex polar lobe; rounded angular margins; semicell with tumescence circular lateral, prominent, ornamented with 2 rings of rounded granules; smooth cell wall.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir Samambaia P3, 06/I/2011, Felisberto et al. 9 (UFG

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47332); P4, 06/I/2011, Felisberto et al. 10 (UFG 47333); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341).

Euastrum subintegrum var. *brasiliense* is differentiated from the others taxa found in the Samambaia Reservoir, by having a convex polar lobe with rounded angles and especially for presenting the semicell face with only a single central tumescence, prominent and ornate with two rings of rounded granules, which also differentiate from *Euastrum gemmatum* var. *monocylum* that displays three tumescences.

Euastrum subornatum West & G.S.West var. ***brasiliense*** Borge, Ark. Bot. 1: 114; pl. 5, fig. 6. 1903. (Figure 2j)

Cell slightly longer than wide (39-49 x 35-44 μm; isthmus: 10-12 μm); deep median constriction, central linear sine, fully open, opening to the isthmus; trapezoidal semicell, 3-lobed, interlobar incisions flatly concave; lateral lobes rounded; slightly truncated polar lobe; semicell with tumescence in the midline of the lateral lobes formed by a single ring of granules; cell wall ornate with granules.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P4, 04/IX/2010, Felisberto et al. 10 (UFG 47333); P1, 01/III/2011, Felisberto et al. 17 (UFG 47340).

The slightly truncated polar lobe, cell with linear and fully open sinus and the tumescence of semicell face with only a single ring of granules, distinguish it from the others taxa sampled.

Micrasterias Agardh ex Ralfs 1848

Isolated cells to *pseudofilamentous* (*Micrasterias foliacea*), circular to elliptical, deep median constriction; semicells 3-5-lobed, with four deep incisions in the axis of the cell; polar lobe lengthy to expanded, never divided into lobules, unlike the lateral which have divisions into lobules; cell wall smooth to ornamented (Bicudo & Menezes 2006).

Micrasterias abrupta West & G.S.West, Trans. Linn. Soc. London, Bot. 5: 241, pl. 14, figs. 13-16, 1896. (Figure 3a)

Cell as wide as long (51-54 x 49-52 μm; isthmus: 10-12 μm); deep median constriction, sine closed near the central isthmus and open at the ends; semioval semicell, 5-lobed; interlobular incisions basally lanceolate, open, slight between the lateral lobes and deep between the polar lobes and lateral; lateral lobes with two bifurcations, bidenticulate apices; polar lobe with an inverted deltoid, with bidenticulate angles, apical margin straight; polar lobe greater than the lateral.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328); P4, 04/IX/2010, Felisberto et al. 10 (UFG 47333).

Micrasterias abrupta and *Micrasterias truncata* var. *pusilla* are visually similar, cells are as wide as long, have a central sine closed near the isthmus and is open at the ends, but the semicell of *Micrasterias abrupta* have a semioval format and its polar lobe has an apical straight edge with bidenticulate angles, in contrast the *Micrasterias truncata* var. *pusilla* have its semicell with semi-orbicular shape and polar lobe with a convex apical margin and acuminate angles.

Micrasterias borgei Krieger *In* Rabenhorst, Kryptogamen-Fl. Deutschl. 13(2):86, pl. 128, fig. 1-4. 1939. (Figure 3b)

Cell longer than wide (225 x 206 μm; isthmus: 32-40 μm); deep median constriction, center sine closed, slightly open at the ends; semi-elliptical semicell, 5-lobed, robust lobes; polar lobe with incision opened a little more than half of its length; incisions between the lateral lobes opened and deep, U or V-shaped; lateral lobes with consecutive bifurcations till the apex, slightly curved denticles polar lobe with a deep sinus, apex divided into two bidenticulate divergent lobes, central denticles slenderly facing the sinus; polar lobe greater and more robust than the laterals.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P5, 06/I/2011, Felisberto et al. 16 (UFG 47339); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341).

Micrasterias foliacea Bailey ex Ralfs var. ***foliacea*** Brit. Desmidieae 210, pl. 35, fig. 3. 1848. (Figure 3c)

Cell wider than long (59-69 x 90 μm; isthmus: 14-15 μm); cells forming pseudofilaments that cling to each other by the poles; deep median constriction, central sine open; semirectangular semicell, 5-lobed; open and deep interlobular incisions, misshapen; lateral lobes asymmetrically bifurcate, only one lobule near the polar lobe have an integrate apex; apical margins of the lateral lobes bidenticulate with an openly deltoid sinus; polar lobe with deep incision, semi quadratic, chamfered angles; polar lobe slightly bigger than the lateral lobes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 04/XI/2010, Felisberto et al. 9 (UFG 47332); P4, 06/I/2011, Felisberto et al. 15 (UFG 47338); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341).

Micrasterias foliacea is easily distinguishable from the others taxa belonging to the *Micrasterias* genus, by their cells form pseudofilaments, which adhere to each other through their poles. An interesting feature is that only one lobule of the lateral lobes have an integrate apex, and the same is close to the polar lobe with chamfered angles.

Micrasterias furcata C. Agardh ex Ralfs, Desmidieae 73, pl. 9, fig. 2. 1848. (Figure 3d-f)

Cell longer than wide (126-156 x 103-124 μm; isthmus: 18-19 μm); deep median constriction, central sine closed near the isthmus and open at the ends; semi-elliptical semicell, 5-lobed, robust lobes; polar lobe with open incision a little more than half of its length; incisions between the lateral lobes opened and deep, U or V-shaped; lateral lobes with consecutive bifurcations, polar lobe with semicircular sinus, apex divided into two divergent lobules bidenticulate, slightly curved denticles; polar lobe bigger and more robust than the lateral lobes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328); P1, 04/XI/2010, Felisberto et al. 7 (UFG 47330); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333); P1, 06/I/2011, Felisberto et al. 12 (UFG 47335); P2, 06/I/2011, Felisberto et al. 13 (UFG 47336); P1, 01/III/2011, Felisberto et al. 17 (UFG 47340); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341); P4, 01/III/2011, Felisberto et al. 20 (UFG 47343); P5, 01/III/2011, Felisberto et al. 21 (UFG 47344).

Individuals of *Micrasterias furcata* that were analyzed for the Samambaia Reservoir showed some differences when compared. There was morphological variation in incisions between lobes and between the lobules, some exhibited the

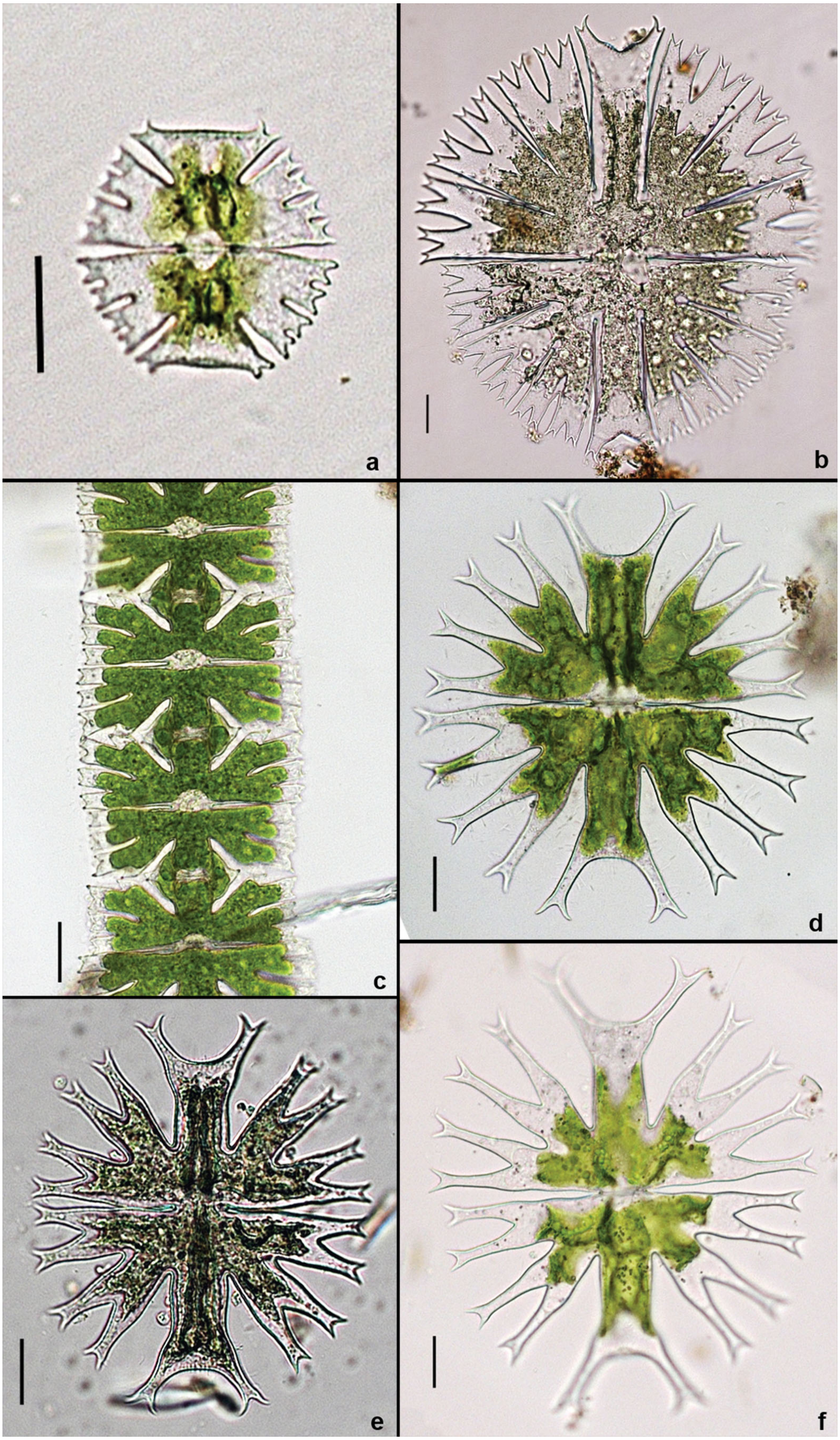

Figure 3: *Micrasterias* of the Samambaia Reservoir. **Fig. 3a.** *Micrasterias abrupta* West & West. **Fig. 3b.** *M. borgei* Krieger. **Fig. 3c.** *M. foliacea* Bailey ex Ralfs. **Fig. 3d, 3e and 3f.** *M. furcata* Agardh ex Ralfs (Fig. 3e and 3f.: morphological expressions of the typical variety). Scale bar = 10μm.

polar lobe longest and others shorter and wider. Lateral lobes sometimes were thin, but in some cases, the lobes were more robust.

Micrasterias laticeps Nordstedt var. ***laticeps***, Vidensk. Medd. Naturh. Foren. 1869 (14-15): 220. 1870. (Figure 4a)

Cell wider than long (109-161 x 127-190 µm; isthmus: 21-42 µm); deep median constriction, central sine closed near the isthmus and then opened; semi-orbicular semicell, 3-lobed; interlobular incisions opened and deep, V-shaped; apices of the lateral and polar lobes facing to the opening of the sine, polar lobes bigger than the lateral lobes, angles of the polar lobe acuminated and lateral lobes bidenticulate.

Geographical distribution in the State of Goiás: Förster (1964).

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 24/IX/2010, Felisberto et al. 3 (UFG 47326); P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328); P3, 04/XI/2010, Felisberto et al. 9 (UFG 47332).

Micrasterias laticeps Nordstedt var. ***acuminata*** Krieger, *In* Rabenhorst, Kryptogamen-Fl. Deutschl. 13(2):14, pl.98, fig. 2. 1939. (Figure 4b)

Cell wider than long (60-84 x 79-107 µm; isthmus: 14-16 µm); deep median constriction, center sine closed near the isthmus and then opened; semi-orbicular semicell, 3-lobed; open and deep interlobular incisions, V-shaped; apices of the lateral and polar lobes facing to the opening of the sine, polar lobe bigger than the lateral lobes, lobes with acuminate angles.

Geographical distribution in the State of Goiás: Förster (1964).

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P5, 04/XI/2010, Felisberto et al. 11 (UFG 47334).

Micrasterias laticeps var. *acuminata* resembles with its typical variety, because both have the semicell with semi-orbicular format and the apices of the lateral and polar lobes are facing to the opening of the sine. But the angles of the lobes in *Micrasterias laticeps* var. *acuminata* are all acuminated, which differentiates it from your typical variety that only have the angles of the polar lobe acuminated, having the lateral lobes with angles bidenticulate.

Micrasterias mahabuleshwarensis J. Hobson var. ***mahabuleshwarensis*** Quart. Jour. Microsc. Sci. 1863: 169, fig. p.168. 1863. (Figure 4c-d)

Cell longer than wide (165 x 142 µm; isthmus: 26 µm); deep median constriction, fully open median incision, triangular, 5-lobed semicell; semi-rectangular incisions between the polar lobe and the lateral, open and deep; lateral lobes with pyramidal sinus, divergent lobules with entire apices; polar lobe with divergent processes with entire apices, apical margin of the polar lobe is straight; polar lobe of the same size as the sides; serrated cell margin.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328).

Sampled taxa of the genus *Micrasterias* for the Samambaia Reservoir, *Micrasterias mahabuleshwarensis* is the one cell that displays serrated margin. This taxon also shows the polar lobe sharply projected beyond the side lobes and intra-marginal spines throughout the cell.

Micrasterias pinnatifida (Kützing) ex Ralfs, Brit. Desm., 77. Pl. 10, fig. 3. 1848. (Figure 4e)

Cell wider than long (51-66 x 59-66 µm; isthmus: 11-18 µm); deep median constriction, center sine closed near the isthmus and then open; trapezoidal semicell, 3-lobed, interlobar and deep incisions open, U-shaped; polar lobes and lateral with bidenticulate angles, polar lobes smaller than the lateral lobes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P1, 24/IX/2010, Felisberto et al. 1 (UFG 47324); P3, 24/IX/2010, Felisberto et al. 3 (UFG 47326); P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P5, 24/IX/2010, Felisberto et al. 5 (UFG 47328); P1, 04/XI/2010, Felisberto et al. 7 (UFG 47330); P2, 04/XI/2010, Felisberto et al. 8 (UFG 4731); P3, 04/XI/2010, Felisberto et al. 9 (UFG 47332); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333); P5, 04/XI/2010, Felisberto et al. 11 (UFG 47334); P1, 06/I/2011, Felisberto et al. 12 (UFG 47335); P1, 01/III/2011, Felisberto et al. 17 (UFG 47340); P2, 01/III/2011, Felisberto et al. 18 (UFG 47341); P5, 01/III/2011, Felisberto et al. 21 (UFG 47344).

Micrasterias radiosa Ralfs var. ***radiosa*** Brit. Desm: 72. pl. 8, fig. 3, 1848. (Figure 4f)

Cell as long as wide (111-126 x 105-129 µm; isthmus: 13-16 µm); deep median constriction, central sine almost entirely closed, open only at the ends; semicircular semicell, 5-lobed; polar lobe with linear incision until near of the isthmus; misshapen incisions, slightly open and deep between the polar lobes; lateral lobes with consecutive bifurcations; polar lobe with sinus V-shaped, apex divided into two divergent lobules bidenticulate, polar lobe with the same size as the lateral lobes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P1, 24/IX/2010, Felisberto et al. 1 (UFG 47324); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333); P5, 04/XI/2010, Felisberto et al. 11 (UFG 47334).

Micrasterias radiosa Ralfs var. ***elegantior*** (G.S.West) Croasdale In Prescott et al. Syn. N. Amer. Desm. 2(2): 181, pl. 132, fig. 2-4. 1977. (Figure 5a)

Cell as long as wide (145-150 x 148-149 µm; isthmus: 17-20 µm); deep median constriction, central sine fully opened; semicircular semicell, 5-lobed, slender lobes; polar lobe with open incision until near the isthmus; misshapen incisions, open and deep between the lateral lobes; lateral lobes with consecutive bifurcations, polar lobe with deltoid sinus, apex divided into two divergent lobules, bidenticulate; polar lobe with the same size lateral lobes.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333).

Three taxa within the genus *Micrasterias* are very similar, *Micrasterias radiosa* var. *elegantior*, *Micrasterias radiosa* var. *radiosa* and *Micrasterias radiosa* var. *ornata*, having cells as wide as long and 5-lobed. In *M. radiosa* var. *elegantior* and *M. radiosa* var. *radiosa* the semicell have semicircular shape, already in *M. radiosa* var. *ornata*, the semicell displays the semi-orbicular format, lobes are more robust, when compared with the others two, and their cell wall is studded with large thorns, feature that specifies like *ornata*.

Micrasterias radiosa Ralfs var. ***ornata*** Nordstedt, Vidensk. Meddrdansk naturh. Foren. (14-15): 223, pl. 2, fig. 11. 1870. (Figure 5b-c)

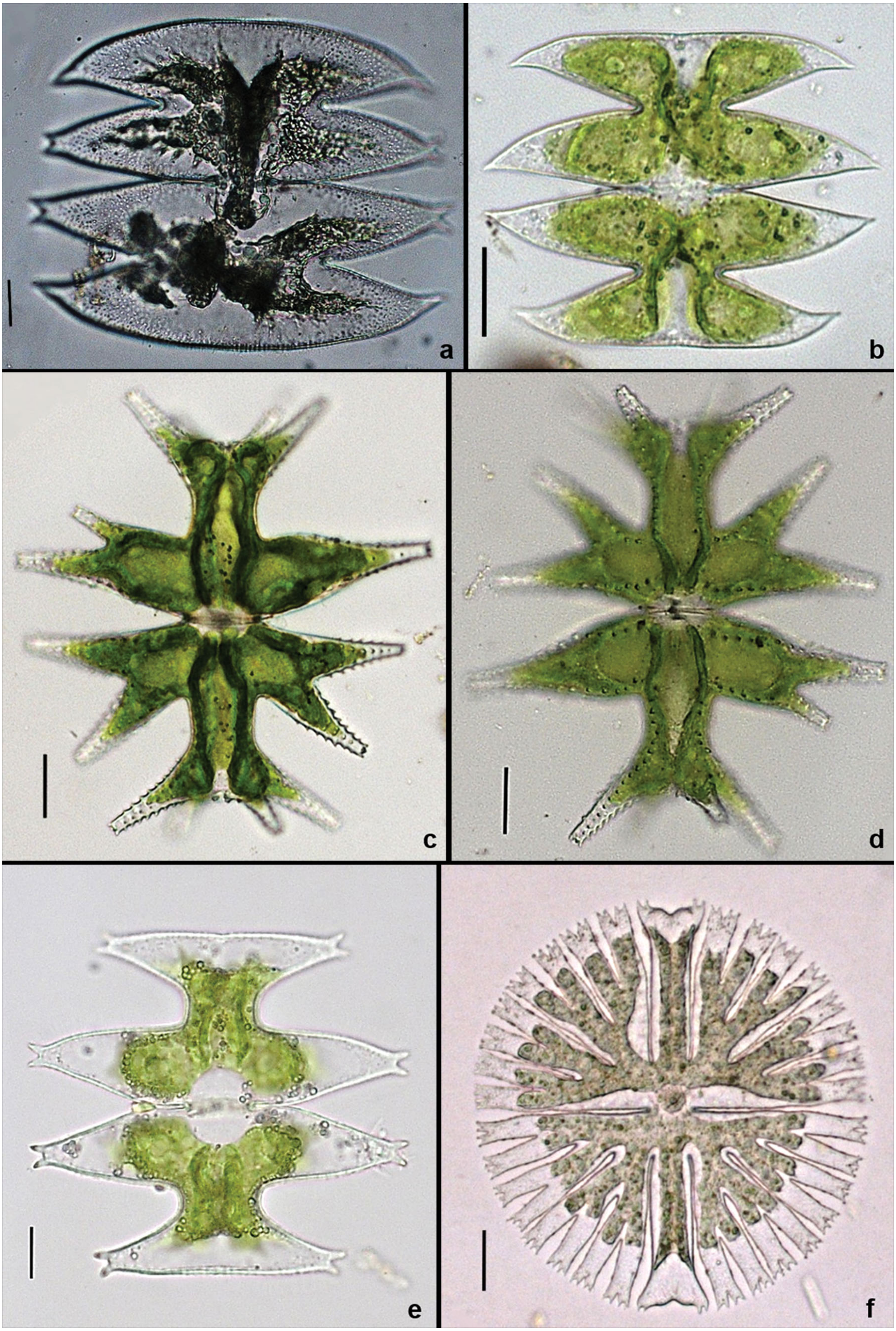

Figure 4: *Micrasterias* of the Samambaia Reservoir. **Fig. 4a.** *Micrasterias laticeps* Nordstedt var. *laticeps.* **Fig. 4b.** *M. laticeps* Nordstedt var. *acuminata* Krieger. **Fig. 4c and 4d.** *M. mahabuleshwarensis* J. Hobson var. *mahabuleshwarensis* (Fig. 4d.: focus on ornamentation of the cell wall). **Fig. 4e.** *Micrasterias pinnatifida* (Kützing) Ralfs. **Fig. 4f.** *M. radiosa* Ralfs var. *radiosa*. Scale bar = 10 µm.

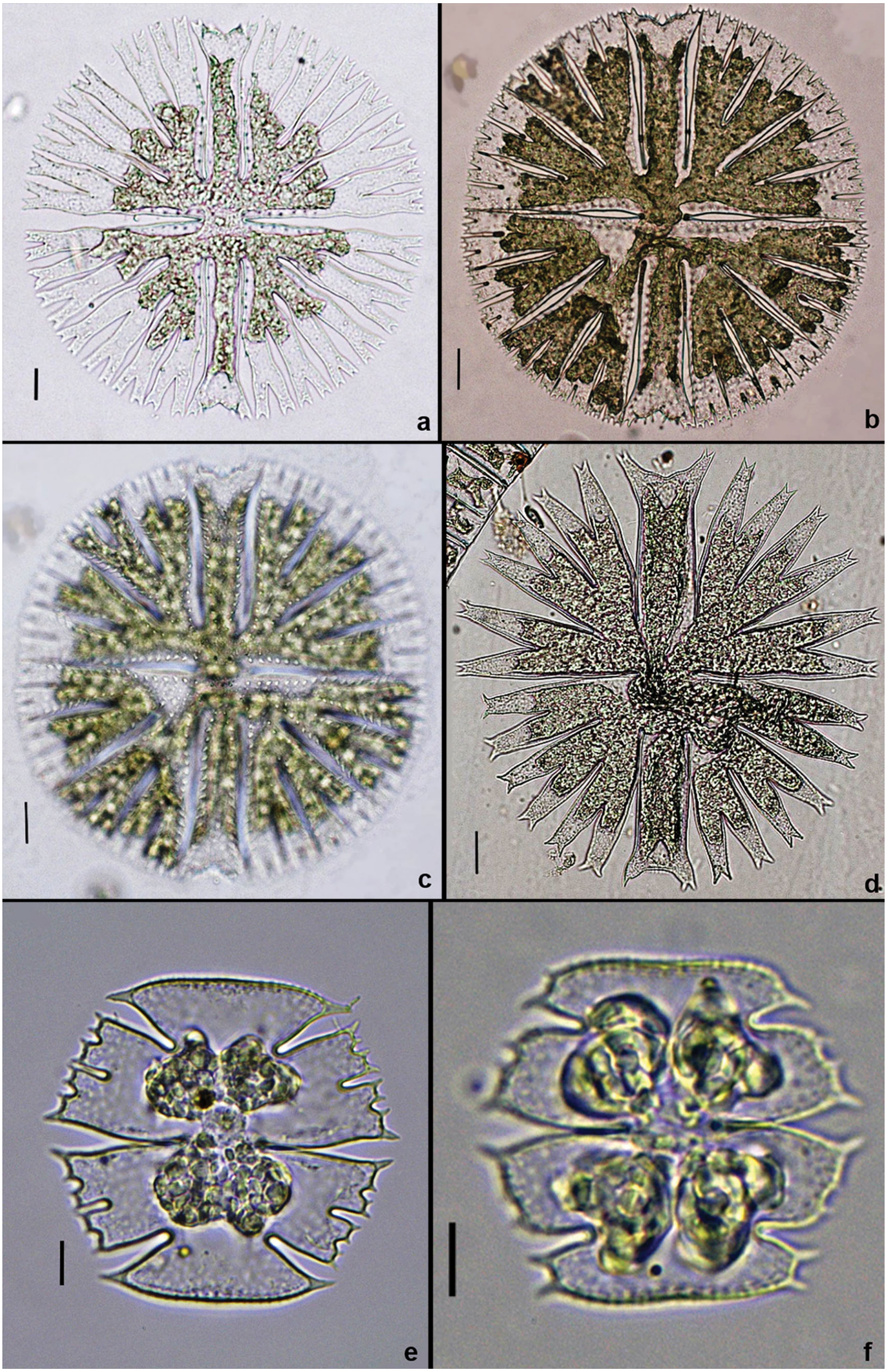

Figure 5: *Micrasterias* of the Samambaia Reservoir. **Fig. 5a.** *M. radiosa* Ralfs var. *elegantior* (G. S. West) Croasdale. **Fig. 5b and 5c.** *M. radiosa* Ralfs var. *ornata* Nordstedt (Fig. 5c: focus on ornamentation of the cell wall). **Fig. 5d.** *M. torreyi* Bailey *ex* Ralfs var. *nordstedtiana* (Hieronymus) Schmidle. **Fig**. **5e and 5f.** *M. truncata* (Corda) Brébisson ex Ralfs var. *pusilla* G. S. West (Fig. 5f.: morphological expression). Scale bar = 10 µm.

Table 1. Frequency of occurrence of the species found in the sampling points of the Samambaia Reservoir in both study periods (C: rain, S: dry, SC: dry and rain, *: absence of species, R: rare, Cm: common and Cs: constant). Freq. = Frequency in %.

Taxa	P1	P2	P3	P4	P5	Freq.
Euastrum abruptum Nordstedt	*	C	*	*	*	1 R
E. bidentatum Nägeli	S	S	*	S	C	5 R
E. denticulatum Gay	S	*	C	*	C	3 R
E. didelta (Turpin) Ralfs var. *quadriceps* (Nordstedt) Krieger	*	*	*	*	S	1 R
E. evolutum (Nordstedt) West & G.S.West var. *evolutum*	SC	SC	SC	S	C	13 Cm
E. gayanum De Toni var. *angulatum* Krieger	*	*	S	*	*	1 R
E. gemmatum (Brébisson) Brébisson *ex* Ralfs var. *gemmatum*	*	C	S	S	S	6 R
E. subintegrum Nordstedt var. *brasiliense* Grönblad	*	C	C	C	*	4 R
E. subornatum West & G.S.West var. *brasiliense* Borge	C	*	*	S	*	2 R
Micrasterias abrupta West & G.S.West	*	*	*	S	S	3 R
M. borgei Krieger	*	C	*	*	C	2 R
Micrasterias foliacea Bailey *ex* Ralfs var. *foliacea*	*	C	S	C	*	17 Cm
M. furcata C. Agardh *ex* Ralfs	SC	C	*	SC	SC	10 R
M. laticeps Nordstedt var. *laticeps*	*	*	S	S	S	3 R
M. laticeps Nordstedt var. *acuminata* Krieger	*	*	*	*	S	1 R
Micrasterias mahabuleshwarensis J. Hobson var. *mahabuleshwarensis*	*	*	*	*	S	1 R
M. pinnatifida (Kützing) *ex* Ralfs	SC	SC	S	S	SC	15 Cm
M. radiosa Ralfs var. *radiosa*	S	*	*	S	S	3 R
M. radiosa Ralfs var. *elegantior* (G. S. West) Croasdale	*	*	*	S	*	2 R
M. radiosa Ralfs var. *ornata* Nordstedt	*	*	S	S	*	2 R
M. torreyi Bailey *ex* Ralfs var. *nordstedtiana* (Hieronymus) Schmidle	*	C	*	*	*	2 R
M. truncata (Corda) Brébisson *ex* Ralfs var. *pusilla* G. S. West	*	*	SC	S	C	5 R

Cell as long as wide (188-227 x 175-216 μm; isthmus: 23-27 μm); deep median constriction, central sine slightly closed, open at the ends; semi-orbicular semicell, 5-lobed, lobes robust compared to the *elegantior* variety; polar lobe with open incision until near the isthmus; misshapen incisions, opened and deep incisions between the lateral lobes; lateral lobes with consecutive bifurcations, polar lobe with sinus V-shaped, apex divided into two bidenticulate divergent lobules; polar lobe with the same size of the lateral lobes; cell wall ornate with big thorns.

Geographical distribution in the State of Goiás: First citation of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 04/XI/2010, Felisberto et al. 9 (UFG 47332); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333).

Micrasterias torreyi Bailey *ex* Ralfs var. ***nordstedtiana*** (Hieronymus) Schmidle, Bot. Jahrb. 26(1–2): 48. 1898. (Figure 5d)

Cell as long as wide (229 x 220 μm; isthmus: 32 μm); deep median constriction, central sine closed near the isthmus and just slightly open at the ends; semicircular semicell, 5-lobed; robust lobes, contour rounded; polar lobe with linear incision until near the isthmus, opened in the ends; opened and deep incisions between the lateral lobes, V-shaped; lateral and polar lobes bifurcated, lobules bidenticulate, divergent lobules in polar lobe; polar lobe with the same size as the lateral lobes.

Geographical distribution in the State of Goiás: First quote of occurrence of species in the Goiás State.

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P2, 01/III/2011, Felisberto et al. 18 (UFG 47341).

For Brazil, the species is cited in other works, but in any of them, there is no illustration or description of the material found (Bicudo & Sormus 1982). Therefore, we can consider this study as the first record of apparel for *Micrasterias torreyi* var. *nordstedtiana* for Goiás.

Micrasterias truncata (Corda) Brébisson *ex* Ralfs var. ***pusilla*** G.S. West, Mém. Soc. Neuchât. Sci. Nat. 5: 1035. pl. 22, fig. 42-43. 1914. (Figure 5e-f)

Cell as wide as long (33-53 x 33-58 μm; isthmus; 11-12 μm); deep median constriction, center sine closed near the isthmus and open at; semi-orbicular semicell, 5-lobed; opened interlobular incisions, basally lanceolate, slight between the lateral lobes and deep between the polar and lateral lobes; lateral lobes bifurcated, bidenticulate apices; inverted deltoid polar lobe with acuminated angles, convex apical margin of the polar lobe; polar lobe wider than the lateral lobes.

Geographical distribution in the State of Goiás: Felisberto & Rodrigues (2002).

Material selected: BRAZIL. GOIÁS: Goiânia, Samambaia Reservoir P3, 24/IX/2010, Felisberto et al. 3 (UFG 47326); P4, 24/IX/2010, Felisberto et al. 4 (UFG 47327); P4, 04/XI/2010, Felisberto et al. 10 (UFG 47333); P1, 06/I/2011, Felisberto et al. 12 (UFG 47335); P3, 01/III/2011, Felisberto et al. 19 (UFG 47342); P5, 01/III/2011, Felisberto et al. 21 (UFG 47344).

Regarding the frequency of occurrence of taxa in the sampled points, we have noticed that most were framed in rare (19) and only three common taxa (Table 1). Regarding the presence and absence of taxa analyzed in the sampling stations, of the 22 taxa identified, 7 were recorded at point P1, 10 on points P2 and P3 , with the highest number of taxa (14) the points P4 and P5. It was observed that only two taxa appeared at all points: *Euastrum evolutum* (Nordstedt) West & G.S.West var. *evolutum* e *Micrasterias pinnatifida* (Kützing) ex Ralfs.

In relation to the exclusivity period, nine taxa were recorded for the dry period (*Euastrum didelta* var. *quadriceps, E. gayanum* var. *angulatum, Micrasterias abrupta, M. laticeps* var. *laticeps, M. laticeps* var. *acuminata, M. mahabuleshwarensis* var. *mahabuleshwarensis, M. radiosa* var. *radiosa, M. radiosa* var. *elegantior* and *M. radiosa* var. *ornata*), while four taxa were found only in the rainy season (*Euastrum abruptum*, *E. subintegrum* var. *brasiliense, Micrasterias borgei* and *M. torrey* var. *nordstedtiana*), as shown in Table 1.

According to Miller et al. (1992), the supply of nutrients to light availability may have a strong impact on communities of algae. Thus, one possible explanation for greater richness in the dry season maybe related to increased stability of the water column and macrophytes (mainly in the marginal region) due to lack of rainfall and consequently lower values of turbidity and higher incidence of light on the body of water.

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