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Density of ocelots in a semiarid environment in northeastern Brazil

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Abstract: Ocelots play a key role in ecological communities as mesopredators affecting the lower trophic level and other mesopredators. They show great variability in ecological traits across their distribution, but knowledge of this species is missing in several regions where it occurs. Here, we present the first study of ocelot in the Brazilian semiarid of Caatinga. Arid habitats might keep carnivore population density low and therefore vulnerable to environmental shocks and to human-induced changes, at risk of local extinction. To assess their population status, we used camera traps between September 2009 and January 2010. We estimated the density of ocelots using a spatially explicit capture-recapture method (SECR) to be 3.16 ± 0.46 individuals per 100 km^2. This is a low-density estimate for ocelots, which might reflect the harsh conditions of the arid habitat. A longer population study of the ocelot can answer if this low population density is enough for a long-term persistence of this species in this and other arid environments.

Keywords: *Arid environments, Brazil, Density, Ocelot, SECR.*

Densidade da jaguatirica em um ambiente semiárido no nordeste do Brasil

Resumo: Jaguatiricas possuem um papel fundamental em comunidades ecológicas como mesopredadores, afetando níveis tróficos inferiores e também outros mesopredadores. Esta espécie possui uma grande variabilidade em suas características ecológicas em toda a sua distribuição, no entanto, o conhecimento desta espécie possui lacunas em vários locais onde ela ocorre. Neste trabalho, nós apresentamos o primeiro estudo desta espécie no semiárido brasileiro da Caatinga. Ambientes áridos podem afetar negativamente as espécies carnívoras e, aliado a alterações antrópicas, esta espécie pode ser levada a extinção local se sua densidade populacional é baixa. Portanto, para verificar o nível populacional da jaguatirica em uma região protegida da Caatinga, instalamos armadilhas fotográficas, entre setembro de 2009 e janeiro de 2010. Com os dados obtidos, calculamos a densidade desta espécie através de métodos espacialmente explícitos (SECR). A densidade estimada da jaguatirica foi de 3.16 ± 0.46 indivíduos por 100 km^2. Esta estimativa é muito baixa para esta espécie, o que pode ser um reflexo das condições áridas deste ambiente. Um estudo populacional de maior duração pode ajudar a responder se esta baixa densidade é o suficiente para a persistência desta espécie a longo prazo tanto neste, quanto em outros ambientes áridos onde ela ocorre.

Palavras-chave: *Ambientes áridos, Brasil, Densidade, Jaguatirica, SECR.*

Introduction

The ocelot (*Leopardus pardalis*) occurs from southern Texas to north Argentina (Murray & Gardner 1997) in open environments, flood plains, dry coniferous forests, and rainforests (Emmons & Feer 1997). Besides the existence of many studies focused on this species through its distribution (de Villa Meza et al. 2002, Haines et al. 2005, Maffei & Noss 2008, Kolowski & Alonso 2010), very few have addressed this species in arid habitats (Laack 1991, González et al. 2003, Harveson et al. 2004, Maffei et al. 2005).

Ocelot densities vary across its distribution, ranging from 2.3 to 75.2 individuals per 100 km^2 (Table 1) and are thought to decrease with lower precipitation and increasing distance from the equator (Di Bitetti et al. 2008). This is because a lower precipitation may decrease productivity (Chesson et al. 2004) which in turn, might decrease carnivore prey densities (Herfindal et al. 2005, Pettorelli et al. 2009, Sandom et al. 2013), and higher latitudes often correlates with a lower precipitation (Prince & Goward 1995, Di Bitetti et al. 2008). However, arid environments might present different challenges to species in those regions.

The semiarid of the Caatinga, in northeastern Brazil (Figure 1), for instance, is a harsh environment where ocelots occurs (Oliveira & Cassaro 2005). This region has a high annual mean temperature (26º to 30º) and the lowest precipitation (300-1,000 mm/year) of Brazil (Prado 2008). Furthermore, this habitat is under heavily negative human induced changes like deforestation for ranches and plantations (Castelletti et al. 2004). However, there is almost no knowledge of ocelots' population status in the Caatinga.

Ocelots are ecologically important as mesopredators, not only affecting prey species, but potentially other carnivore species as well (de Oliveira & Pereira 2013), it is essential to conduct studies in this region where not only the ocelot, but also others species, faces a harsh environment that is being severely modified by human activities (Leal et al. 2008). Therefore, this study aims to contribute to the knowledge of ocelot populations in arid habitats by estimating its abundance and density in one of the few conservation units in the Caatinga (Leal et al. 2008).

Material and Methods

The study was conducted at the Serra da Capivara National Park (SCNP), in southern Piauí state (Figure 1), covering an area of 1,291 km^2 (FUMDHAM 1994). Local mean annual rainfall is approximately 644 mm with temperatures ranging from 12-45ºC and annual mean of 26ºC (Pellerin 1991). To make up for the lack of permanent natural water sources, the park's administration conducts artificial water hole management in which a water truck fills, periodically, artificial ponds distributed in the park.

We deployed 70 camera trap stations between September 1st 2009 and January 19th 2010 in roads and trails inside the park (Figure 1). We chose to install the stations in this way because several studies have demonstrated that big cats (Emmons 1988, Carbone & Christie 2001, Maffei et al. 2005) and ocelots (Trolle & Kéry 2005) have higher capture rates on roads and

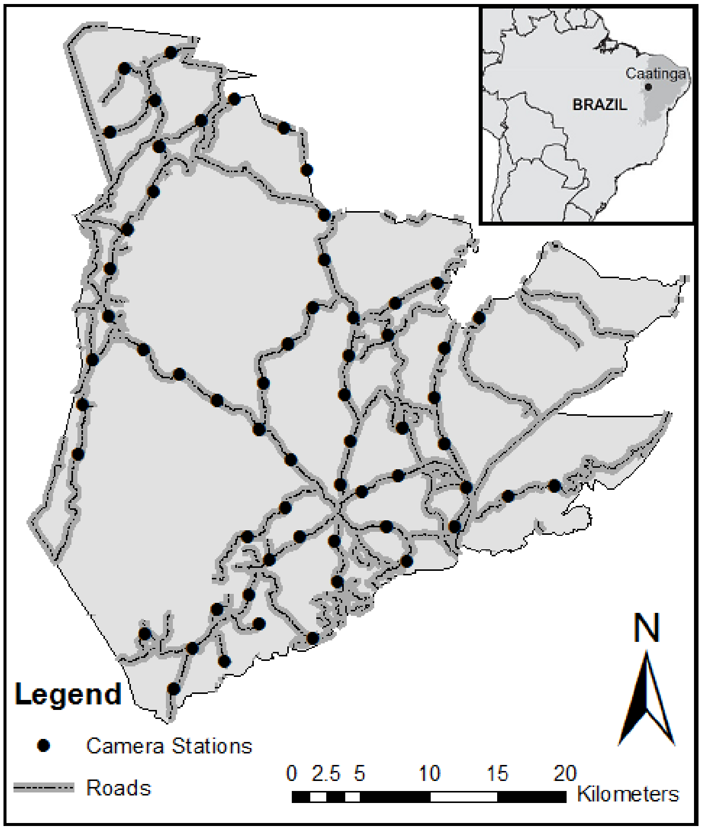

Figure 01. Map of Serra da Capivara National Park with camera locations.

Table 1. Ocelot density estimated in different studies and regions

Country	Habitat	Density (individuals/ 100 km^2)	Method[1]	Source
Peru	Amazon Forest	75,2	Non-spatial	Kolowski & Alonso (2010)
Brazil	Pantanal	56,4	Non-spatial	Trolle & Kery (2003)
Bolivia	Chaco dry forest	1.6-51.7	Spatially-explicit	Noss et al. (2012)
Peru	Amazon Forest	43,5	Non-spatial	Kolowski & Alonso (2010)
U. S. A.	Coastal grasslands	30	Non-spatial	Haines et al. (2006)
Belize	Tropical Rainforest	25,88	Non-spatial	Dillon & Kelly (2007)
Brazil	Atlantic Forest	21	Non-spatial	Fusco-Costa et al. (2010)
Argentina	Atlantic Forest	19,99	Non-spatial	Di Bitetti et al (2006)
Argentina	Atlantic Forest	13,36	Non-spatial	Di Bitetti et al (2006)
Argentina	Atlantic Forest	12,84	Non-spatial	Di Bitetti et al (2006)
Belize	Tropical Rainforest	12,61	Non-spatial	Dillon & Kelly (2008)
Argentina	Atlantic Forest	7,71	Non-spatial	Di Bitetti et al (2006)
Mexico	Sonora Desert	5,7	Non-spatial	González et al (2003)
Brazil	Caatinga	3,16	Spatially-explicit	This study
Brazil	Atlantic Forest	4	Non-spatial	Goulart et al. (2009)
Belize	Tropical Pine Forest	2.3-3.8	Non-spatial	Dillon & Kelly (2007)

[1] Density estimation method: Spatially-Explicity Capture-Recapture (SECR) or Non-spatial methods.

trails than on forested habitats. Additionally, the dense thorny vegetation and dramatic relief present in the park made it very difficult to install trap stations in other areas. Each station had two cameras (LeafRiver – Leaf River Outdoor Products, Taylorville, MS, US) facing each other in order to photograph both sides of the animal, which facilitates posterior individual identification. Cameras were set to operate continuously, with a 5-minute delay between consecutive photos. Each trap was spaced from the others by a mean distance of 2.9 ± 0.4 km (SD). Like other ocelot studies (Maffei et al. 2005, Di Bitetti et al. 2006, Maffei & Noss 2008), the present study was originally designed for jaguars (Silveira et al. 2009) and we opportunistically gathered important data on ocelots.

To estimate density we applied spatially explicit capture-recapture (SECR) Maximum-likelihood methods (Borchers & Efford 2008) implemented in software R 3.0.1 through the package "secr" (Efford 2011). These models estimates the density ($\hat{D}$), assuming the existence of a relation of the animal detection probability to the distance (d) from each animal home range center. This follows a two-parameters function, $g(d)$, with g_0 being the detection probability when $d = 0$, and a spatial scale σ, related to home range diameter (O'Brien & Kinnaird 2011). We considered six models with different effects on detection: (1) No variation in detection [$g_0(.)\sigma(.)$], (2) variation after the first capture [$g_0(b)\sigma(.)$], (3) variation with time [$g_0(T)\sigma(.)$], (4) differences between sexes [$g_0(sex)\sigma(.)$] (5) The conjoint effect of sex and time [$g_0(sex+T)\sigma(.)$] and (6) behavior and time [$g_0(b+T)\sigma(.)$]. We selected between models by using the Akaike Information Criterion adjusted for small samples (AICc).

Results

We registered 316 pictures of ocelots comprising 51 individuals. (Two researchers identified each picture independently). It is possible to identify sex easily in ocelot's pictures due the conspicuousness of the male's scrotum, and we found a sex ratio of 1.5:1 males to females (31 males and 20 females). We found 38 individuals (74.5%) at more than one station, 27 at more than two (52.9%) and 11 individuals (21.5%) had no recaptures (i.e. registered at only one photograph). There were also several pictures of juveniles and cubs; however, we did not include them in the analysis because we could not identify them individually. Model selection highlighted the difference between sexes on detection probability (Table 2), consistent with other studies that find ocelots are a territorial species with variation in home range and activity between sexes (Dillon & Kelly 2008). The highest-ranked model estimated 3.16 ± 0.46 ocelots/100 km^2.

Discussion

Ocelot density in our study area was at the lower end for this species in relation to other regions (Table 1), which could make this population especially prone to environmental changes – man made or not – and local extinction (Purvis et al. 2000). Several characteristics of this arid region could be affecting ocelot populations. The first environmental factor that might play a role keeping this ocelot population at lower levels is the low productivity. In some regions, low productivity can limit prey species (East 1984, McNaughton et al. 1989), which in turn may suppresses carnivore populations, because of the lower density of prey (Carbone & Gittleman 2002). This bottom-up effect, was hypothesized to be a main driver of ocelot density throughout its distribution (Di Bitetti et al. 2008). However, dry environments may affect ocelots adversely. Other studies on ocelots densities in arid regions estimated highly varying densities: 1.6 to 51.7 ocelots/100 km^2 in the Bolivian dry forests (Noss et al. 2012), 30 ocelots/100 km^2 in Texas (Haines et al. 2006) and 5.7 ocelots/100 km^2 .In Sonora, Mexico (González et al. 2003).

Table 2. Model selection results for different density models.

Model	AICc	ΔAICc	AIC weight
[g(sex)σ(.)]	1998,5	0	0,67
[g(sex + T)σ(.)]	2000,1	1,56	0,3
[g(b)σ(.)]	2005,7	7,24	0,01
[g(b + T)σ(.)]	2008,5	10,06	0
[g(.)σ(.)]	2012,1	13,64	0

It is also interesting to note that the lowest density estimated for ocelots (2.3 individuals per 100 km^2) comes from a tropical pine forest in Belize (Dillon & Kelly 2007). These same authors, however, found a higher ocelot density in forests that were not pine-dominated (25 individuals per 100 km^2). Hence, vegetation structure may play an important role of this carnivore density across different regions. In our study, we estimated a low density in a region with a low productivity in an area with a dense vegetation structure, suggesting that in arid environments the productivity is a strong factor for ocelot density. However, we observed a high presence of rock cavies (*Kerodon rupestris*) during our survey. If this small rodent is an important part of ocelot's diet in this site, we do not believe low productivity is a main factor affecting ocelot density here. Unfortunately, the number of ocelot studies in arid regions are insufficient to verify a connection between productivity and density, as suggested by previously (Di Bitetti et al. 2008).

Several other factors may be relevant in arid landscapes. The interaction with other carnivore species can affect a species population (Palomares & Caro 1999, Caro & Stoner 2003, Dayan & Simberloff 2005, Donadio & Buskirk 2006). Ocelots co-occur with Jaguars and Pumas in the SCNP. These apex carnivores have a relatively high density in this park (Silveira et al. 2009) and they might negatively affect ocelot densities through intraguild killing (Ritchie & Johnson 2009).

Continuous monitoring of this species would help elucidate whether this low density is the natural state of ocelots in the Caatinga or whether the population is declining. Even if the density remains constant during different years, it is still a very low estimative and likely to be subject to local extinction with environmental changes or increase in human activities in the region. This study provides background for future research concerning ocelots in these and other arid habitats.

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Galls of *Cecidoses eremita* Curtis and *Eucecidoses minutanus* Brèthes (Lepidoptera: Cecidosidae) in Magdalena, Buenos Aires Province: preliminary study and associated fauna

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LOETTI, V., VALVERDE, A., RUBEL, D.N. **Galls of *Cecidoses eremita* Curtis and *Eucecidoses minutanus* Brèthes (Lepidoptera: Cecidosidae) in Magdalena, Buenos Aires Province: preliminary study and associated fauna.** Biota Neotropica. 16(4): e20160161. http://dx.doi.org/10.1590/1676-0611-BN-2016-0161

Abstract: In Argentina, five galling species of the family Cecidosidae (Lepidoptera), including *Cecidoses eremita* Curtis and *Eucecidoses minutanus* Brèthes, have been cited. This note reports a preliminary study of their galls in “molles” (*Schinus longifolius* (Lindl.) Speg.) of Magdalena (Buenos Aires, Argentina). In April 2013, galls of *C. eremita* and *E. minutanus* were censused in randomly selected “molles”. In April and December 2013, randomly selected galls were then collected and transported to our laboratory in hermetic bags, and conserved at -18 ºC until examination. Maximum diameter and wall thickness of collected galls were measured. About 84% of the observed “molles” (103/123) had galls of *C. eremita* and/or *E. minutanus*. The median of galls per tree was 12 (Q1=6; Q3=22). *Eucecidoses minutanus* had galls with smaller diameter ($U_{11;53}$= 583; P<0.05) and thinner wall ($U_{10;52}$=506.5; P<0..05) than *C. eremita*. In open galls, we found Pseudoescorpionida, Araneae (Segestriidae and Salticidae), and larvae of Lepidoptera and Hymenoptera. Within closed galls, we found adults of Torymidae and Chalcidoidea, and larvae of Ichneumonoidea.

Keywords: *Schinus longifolius, native forest, parasitoid, Ichneumonoidea, Torymidae.*

Agallas de *Cecidoses eremita* Curtis y *Eucecidoses minutanus* Brèthes (Lepidoptera: Cecidosidae) en Magdalena, Prov. de Buenos Aires: muestreo preliminar y fauna asociada

Resumen: En Argentina se registran cinco especies cecidógenas de la familia Cecidosidae (Lepidoptera), entre ellas *Cecidoses eremita* Curtis y *Eucecidoses minutanus* Brèthes. Se reporta un estudio preliminar de agallas de estas dos especies en “molles” (*Schinus longifolius* (Lindl.) Speg.) de Magdalena (Buenos Aires). En abril de 2013 se censaron las agallas de *C. eremita* y *E. minutanus* en molles seleccionados al azar. En abril y diciembre de 2013, se colectaron mediante muestreo aleatorio agallas de ambas especies, se trasladaron en bolsas herméticas y se conservaron a -18 ºC hasta ser examinadas. Se midieron el diámetro máximo y el grosor de la pared. Un 84% de los molles observados (103/123) presentaron agallas de *C. eremita* y/o *E. minutanus*. La mediana de agallas cerradas por árbol fue 12 (Q1=6 y Q3=22). Las agallas de *E. minutanus* presentaron un diámetro menor ($U_{11;53}$= 583; P<0,05) y una pared más delgada ($U_{10;52}$=506,5; P<0,05) que las de *C. eremita*. Los organismos asociados a las agallas abiertas fueron Pseudoescorpionida, Araneae (Segestriidae y Salticidae), y larvas de Lepidoptera y de Hymenoptera. Dentro de las agallas cerradas se encontraron adultos de Torymidae y de Chalcidoidea, y larvas de Ichneumonoidea.

Palabras clave: *Schinus longifolius, bosque nativo, parasitoide, Ichneumonoidea, Torymidae.*

Introduction

Gall formation in plant tissues is induced by galling organisms, mainly insects. The response to the stimulus from gall-making insects is the development of a specific morphological structure originated by hypertrophy (abnormal growth) and hyperplasia (increase in cell size). This structure or gall provides food and shelter for the gall-inducing organism (Nieves-Aldrey 1998, Stone & Schönrogge 2003, Albert et al. 2011, Dias et al. 2013). Galls also show associated fauna of parasitoids and inquiline species (Pujade-Villar & Ros-Farré 1998, Askew et al. 2013, Kuzmanich et al. 2015).

In South America, most studies have been carried out in Brazil. In Argentina, the first lists of gall-inducing organisms and their associated fauna were published in 1916 and 1917 by Brèthes and Jörgensen respectively. These first lists named five gall-inducing species of the family Cecidosidae (Incurvarioidea, Lepidoptera) in trees of the genus *Schinus* Linneo (Anacardiaceae): *Cecidoses eremita* Curtis, *Eucecidoses* *minutanus* Brèthes, *Dicranoses congregatella* Brèthes, *Dicranoses capsulifex* Kieffer and Jörgensen and *Oliera argentiniana* Brèthes.

The galls of *C. eremita* and *E. minutanus*, named "matecitos" or "tabaneras" by inhabitants of Buenos Aires Province, are globose stem galls and smooth surface and glabrous. The colour is firstly green and brown later. They have a single spherical larval chamber, and an operculum that can be open or closed when it is covered by an opercular cap (see Figure 1). These galls are found in large numbers in the branches of *Schinus longifolius* (Lindl.) Speg. (Jörgensen 1917).

The parasitoids reported for *C. eremita* are the Hymenoptera *Austrodolops eremitae* Blanchard (Ichneumonoidea, Braconidae) (Blanchard 1936), *Cecidopimpla ronnai* Brèthes (Ichneumonoidea, Ichneumonidae) (Brèthes 1920), *Rhynchodontomerus inclusus* Jörgensen et Kieffer (Chalcidoidea, Torymidae) (De Santis & Esquivel 1966), *Eudecatoma cecidosiphaga* Brèthes (Chalcidoidea, Eurytomidae) (Gates 2014), *Torymus cecidicolus* Brèthes (Chalcidoidea, Torymidae) and *Brasema willei* (Chalcidoidea, Eupelmidae) (Burks et al. 2005). Little is known about the biology and ecology of these gall-inducing species. There are no reports about the parasitoidism intensity in the natural populations or of their associated fauna (Moreira et al. 2012, Kuzmanich et al. 2015). *Eucecidoses minutanus* appears only in fauna catalogs, and to our knowledge, there are no reports on this species, except for a Congress communication that analyzes the morphological and genetic diversity between individuals of different sites (Brentano et al. 2012).

The aim of this communication is to report a preliminary survey of the abundance of galls produced by *E. minutanus* and *C. eremita* and the results of the examination of galls collected from different individuals of "molle" (*Schinus longifolius* (Lindl.) Speg.) located in an area of conserved native forest ("talar") at the Magdalena District, Buenos Aires Province, Argentina.

Material and Methods

The study was carried out in the El Destino Reserve, Magdalena District, Buenos Aires Province (35º 8'S, 57º 23'W). This Reserve is located in the Pampa Deprimida, a plaine with dominant grassland and few forest. The annual mean temperature is 15ºC and the annual mean rainfall 970 mm.

In April 2013, the galls of *C. eremita* and *E. minutanus* were censused until two meters high in 123 randomly selected trees in a patch with conserved native forest ("talar").

The censused trees were selected through a systematic sampling with k=2, and were marked with a code number.

For the census, the galls were classified as open (without opercular cap) or closed (with opercular cap). Additionally, in April and December 2013, *E. minutanus* and *C. eremita* galls were randomly collected and examined. The collection method consisted of three stages: first, 32 trees (16 trees in April and 16 in December) were selected using a table of random numbers; second, two branches of each tree were selected. For the selection of branches, we used a random number between 1 and 5 and selected the branches with equal number by counting the branches from the soil to the crown. Finally, we collected the first gall observed by visually inspecting the branch from the trunk to its distal end.

Collected galls were transported to the laboratory in hermetic bags, and conserved at -18ºC until examined. The diameter and the wall thickness were measured in each gall by means of a calliper. The wall thickness was measured after a cut at sagittal plane of the gall by a mini saw.

The inside of galls was examined with a stereoscopic microscope. The observed organisms were kept in alcohol 70% until their identification.

The data of the diameter and wall thickness in the galls of both species were tested using Shapiro Wilk test for normality (Shapiro & Wilk 1965). Differences between the galls of both species in the diameter and wall thickness were tested using the Wilcoxon rank sum test (non-parametric data, Siegel & Castellan 1995).

Results

Results showed that 84% of the observed "molles" (103/123) had galls of *C. eremita* and/or *E. minutanus*. No galls were observed in any of the nine saplings (lower than 1.70 m) randomly selected among the 123 "molles" sampled. The percentage of closed galls per tree varied between 0% and 100% (median= 46.0%, Q1=26.9%; Q3=62.3%). The median of closed galls per tree was 12 (Q1=6; Q3=22).

Figure 1. Galls of *C. eremita* (a) and *E. minutanus* (b) in *Schinus longifolius*, Magdalena, Buenos Aires.

Table 1. Maximum diameter and wall thickness from collected galls of *Eucecidoses minutanus* and *Cecidoses eremita*, Magdalena, Buenos Aires Province, 2013.

	n	**Median (first quartile-third quartile)**	
		Diameter (cm)	**Thickness (mm)**
E. minutanus	11	0.7 (0.5 – 0.7)	0.8 (0.5 – 1.1)
C. eremita	53	1.4 (1.3 – 1.5)	3.0 (3.0 – 3.8)

Table 2. Number of examinated galls of *Eucecidoses minutanus* y *Cecidoses eremita* and their content, Magdalena, Buenos Aires Province, 2013.

	Galls				
	Open		**Closed**		
	Empty	**Organisms associated**	**Empty**	**Presence of pupa**	**Others organisms**
E. minutanus	6	2	1	1	1
C. eremita	14	8	3	21	7

A total of 64 galls were collected and examined, 11 of *E. minutanus* and 53 of *C. eremita*. The diameter and the wall thickness were significantly different between both species. The galls of *E. minutanus* showed a lower diameter ($U_{11;53}$= 583.0; P<0.05) and a lower wall thickness ($U_{10;52}$=506.5; P<0.05) than the galls of *C. eremita* (Table 1). This result did not vary when only the open galls were included ($U_{21;8}$= 168.0; P<0.01 for the diameter and $U_{21;8}$= 163.0; P<0.01 for the thickness).

The gall numbers of each species with presence of the original pupa or other organisms are shown in Table 2. In the open galls of *E. minutanus* with presence of other organisms, we observed an exuvia of Pseudoescorpionida and a larva of suborder Symphyta (Hymenoptera). In the open galls of *C. eremita*, we found three spiders: one specimen of *Ariadna boesenbergi* Keyserling 1877 (Segestriidae), one specimen of the family Salticidae (Hernán Iuri, personal communication), and a group of spiders recently hatched that could not be identified. Another open gall held a Lepidoptera larva and four galls held arthropod remains that could not be identified by their degree of decomposition.

One of the three closed galls of *E. minutanus* held an adult of the family Torymidae (Hymenoptera) (Juan José Martínez, personal communication) and showed six little holes in its wall. Seven of the 24 closed galls of *C. eremita* held other organisms: three held two or three Ichneumonoidea larvae (Hymenoptera) (Juan José Martínez, personal communication), one held an adult of the family Chalcidoidea (Hymenoptera) and an unidentified larva, and the remaining galls held other insect larvae that could not be identified. All observed galls had only one chamber.

Discussion

Gall inducers show a high level of specificity to their host plants, although some plant species have different galler species (Cuevas-Reyes et al. 2003, Veldtman & McGeoch 2003). *Schinus longifolius* (Lindl.) Speg. and other species of the family Anacardiaceae show several specific galler species. In a survey to identify the gall-inducing insects in the region of the Río de la Plata, 15% of all the gall morphotypes found were observed in *Schinus longifolius* (Lindl.) Speg., a species that would have "super host" characteristics (Veldtman & McGeoch 2003, Kuzmanich et al. 2015). In our study area, galls of four species, including *C. eremita, E. minutanus, D. congregatella* (Lepidoptera: Cecidosidae), and other leaf gallers (possibly family Calophyidae (Psylloidea) (Burckhardt & Basset 2000, Kuzmanich et al. 2015), have been observed in *Schinus longifolius* (Lindl.) Speg. The presence of four galler species and the high percentage of trees with galls could be due to the great abundance of this host tree in the study area (Cuevas Reyes et al. 2004).

Some authors have found an inverse relationship between the gall number and the age of host plant for several leaf gallers, and proposed that young leaves have higher nutrient value than old leaves (Washburn & Cornell 1981, Price et al. 1987, Cuevas Reyes et al. 2004). Although our sampling included few saplings (nine), none of them showed galls of *C. eremita* or *E. minutanus*. Future studies should evaluate the potential relationship between the presence of this species and the age of the host *Schinus longifolius* (Lindl.) Speg.

In this preliminary study, we found that 12.9% of the closed galls of *C. eremita* contained some parasitoid Hymenoptera. The proportion of galls with parasitoids is very variable in space and time. Several galler-host systems have been studied by different authors. Washburn & Cornell (1981) found that the percentages of leaf galls of the cynipid *Xanthoteras politum* (Bassett) with parasitoids varied between 3 and 18%. Wool & Burstein (1991) detected between 13-33% of *Smynthurodes betae (*Aphididae) galls housing parasitoids in different sites. Almeida et al. (2006) detected 2.5% of parasitism by insect parasitoids in galls induced by *Anisodiplosis waltheriae* Maia (Diptera: Cecidomyiidae) while in other Cecidomyiidae Maia & Tavares (2000) observed along 12 months parasitoidism rates between 32- 79% in *Cordiamyia globosa* Maia (Diptera: Cecidomyiidae).

Other organisms were found in open galls, such as Pseudoescorpionida, also had been recorded in Cecydomidae galls (Maia 2001; Maia 2002; Rodrigues et al. 2014; Maia & Carvalho-Fernandes 2016).

The gall abundance in host trees, the morphometric variables of galls and the proportion of galls with parasitoids are original contributions of this study because they may allow comparisons in space and time in the area and because there are no previous reports for the two species studied in the present study. In addition, the "talar" is the only native forest of Buenos Aires Province and an environment with conservation value. Thus, the study of gall-inducing species and their parasitoids or associated organisms becomes important for the design of policies on conservation of biodiversity.

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identification key

Identification key for lycophytes and ferns from the Picinguaba and Santa Virgínia Nuclei, Parque Estadual da Serra do Mar, Ubatuba, SP, Brazil

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Abstract: This work contributes to the knowledge of the fern and lycophytes diversity in the Picinguaba and Santa Virginia Nuclei, Parque Estadual da Serra do Mar (PESM), Ubatuba, São Paulo, Brazil, as well as to provide subsidies to identification of the found taxa in these areas. In total, 30 collecting expeditions were conducted and the vouchers were deposited at UEC Herbarium. We have identified 135 species distributed in 53 genera and 19 families for both areas. The most representative families were Polypodiaceae (28 species) and Dryopteridaceae (19 species), whereas *Asplenium* (12 species), *Blechnum* and *Elaphoglossum* (8 species each) were the most important genera. Epiphytic species predominated (62 overall), probably due to the presence of favorable habitats. Among the taxa, 41 are considered endemic from Brazil, 35 of them endemic to the Brazilian Atlantic Forest. Five species are classified as vulnerable according to the "Official list of endangered species in the State of São Paulo": *Elaphoglossum macahense* (Fée) Rosenst., *Anetium citrifolium* (L.) Splitg., *Asplenium muellerianum* Rosenst., *Cyathea glaziovii* (Fée) Domin, and *Thelypteris angustifolia* (Willd.) Proctor, which emphasizes the importance of preservation areas such as the Parque Estadual da Serra do Mar. An identification key has been elaborated to help with the recognition of these groups in Picinguaba and Santa Virgínia Nuclei.

Keywords: *Floristics, taxonomy, diversity, Atlantic Rain Forest*

Chave de identificação para licófitas e samambaias dos Núcleos Picinguaba e Santa Virgínia, Parque Estadual da Serra do Mar, Ubatuba, SP, Brasil

Resumo: Este trabalho visa contribuir para o conhecimento da diversidade de licófitas e samambaias ocorrentes nos núcleos Picinguaba e Santa Virgínia do Parque Estadual da Serra do Mar (PESM), Ubatuba, SP, Brasil, bem como fornecer subsídios para a identificação dos táxons encontrados nestas áreas. Ao todo, foram realizadas 30 expedições de coleta e o material botânico encontra-se depositado no Herbário UEC. Foram identificadas 135 espécies, 19 famílias e 53 gêneros para as duas áreas. As famílias mais representativas foram Polypodiaceae (28 espécies) e Dryopteridaceae (19 espécies), enquanto *Asplenium* (12 espécies), *Blechnum* e *Elaphoglossum* (8 espécies cada) foram os gêneros melhor representados. As espécies epífitas predominaram (62 ao todo), provavelmente devido à presença de hábitats favoráveis. Dos táxons encontrados, 41 são considerados endêmicos do Brasil, sendo 35 deles endêmicos da Mata Atlântica brasileira; cinco espécies são classificadas como vulneráveis, conforme a "Lista oficial de espécies ameaçadas de extinção no Estado de São Paulo": *Elaphoglossum macahense* (Fée) Rosenst., *Anetium citrifolium* (L.) Splitg., *Asplenium muellerianum* Rosenst., *Cyathea glaziovii* (Fée) Domin e *Thelypteris angustifolia* (Willd.) Proctor, o que ressalta a importância de áreas de preservação como o Parque Estadual da Serra do Mar, no contexto conservacionista. Uma chave de identificação foi elaborada para contribuir no reconhecimento destes grupos nos núcleos Picinguaba e Santa Virgínia.

Palavras-chaves: *florística, taxonomia, diversidade, Floresta Ombrófila Densa Atlântica*

Introduction

The Atlantic Forest is a complex set of ecosystems, with significant importance for harboring a considerable portion of Brazilian biological diversity (Joly et. al., 1999). According to Forzza *et al*. (2012) this vegetation presents 19,335 species of plants and fungi, which contributes substantially to the mega-diversity of the country.

However, studies reveal that only 7.9% of the Atlantic Forest remnants are larger than 100 hectares, a size that would be representative for biodiversity conservation (SOS Atlantic Forest and INPE, 2011). These data reinforce the need to better understand and protect this forest, which is considered one of the major biodiversity hotspots of the Neotropics (Myers *et al*., 2000).

The Serra do Mar (a mountain range within the Atlantic Forest Domain) is located mainly in the Southeastern region of Brazil. It is a primary center of diversity and endemism for lycophytes and ferns (Tryon, 1986), probably because of regional relief features. As amply documented in several previous studies, mountainous areas have favorable environmental conditions for the development of these two groups of plants (see Holttum, 1938; Page, 1979; Tryon 1986; Roos, 1996, and Moran, 2008).

Recently, Prado *et al*. (2015) reported 883 species of ferns and lycophytes in the Brazilian Atlantic Rain Forest. This number surpasses Amazon (with 503 species), Cerrado (269 species), Caatinga (26 species), Pantanal (30 species), and Pampa (eight species). In the Atlantic Rain Forest of São Paulo there are 603 species, distributed in 115 genera and 33 families of ferns and lycophytes. According to Prado (1998), the highest diversity of ferns and lycophytes within this area is found at Serra da Mantiqueira, Serra da Bocaína, Serra do Japi, and Vale do Ribeira.

For similar areas to the current study (i.e., Atlantic Forest mountain slopes in the state of São Paulo), there are the works by Custódio-Filho (1989), Prado & Labiak (2001, 2009); Athayde-Filho *et al*. (2003), Prado (2004), Boldrin & Prado (2007), Salino & Almeida (2008), and Mazziero *et al*. (2015). However, there are no identification keys for the ferns and lycophytes from the Atlantic Forest in northeastern São Paulo.

The Picinguaba and Santa Virgínia Nuclei are located in the Parque Estadual da Serra do Mar, municipalities of Ubatuba, São Luís do Paraitinga, and Cunha, protecting a very well preserved area of Atlantic Forest at northeastern São Paulo. These places harbor a rich flora of lycophytes and ferns and the main objective of this paper is to provide an identification key for determining the species of these groups in these areas.

Material and Methods

Study area: The "Parque Estadual da Serra do Mar" (State Park) represents the largest continuous area of well preserved Atlantic Forest in Brazil, with almost 315 000 ha (3.15^9 m^2) and covering areas from two states, São Paulo and Rio de Janeiro, in the southeast region of the country. This park is divided into 10 conservation units, among them Picinguaba and Santa Virginia.

The Santa Virginia Nucleus (SVN) belongs to the municipalities of São Luís do Paraitinga (70% of its area), Cunha (20%), and Ubatuba (10%), at coordinates 23°17'–23°24'S and 45°03'–45°11'W, spanning about 5,000 ha (5^7 m^2) of predominantly Montane Dense Ombrophilous Forest (Veloso *et al*., 1991). Altitudes vary from 850 to 1,100 m, with an average annual temperature of 17° C, and average annual rainfall of 2,300 mm (Salemi, 2009).

The Picinguaba Nucleus (PN) is located in the Municipality of Ubatuba, at coordinates 23°31'–23°34'S and 45°02'–45°05'W, and consists of about 47,500 ha (4,75 m^2), according to SMA (1996). There are different types of vegetations in PN: Pioneer Formations with Marine Influence (Dunes); Pioneer Formations with Fluvial Influence (Caxetal); Pioneer Formations with Fluvial-Marine Influence (Mangrove); Lowland Dense Ombrophilous Forest (Restinga Forest); Submontane Dense Ombrophilous Forest; and Montane Dense Ombrophilous Forest (Assis, 1999). The altitude varies from sea level up to 1,340 m, with an annual average temperature of 22° C, and average annual rainfall exceeding 2,200 mm (Setzer 1966).

The study areas covers four different vegetation types in Atlantic Forest, designated according to Veloso *et al*. (1991) as: Lowland Dense Ombrophilous Forest, (Figure 1 - B, C, D, E, F), Submontane Dense Ombrophilous Forest (Figure 1 - G, H, I, J), Montane Dense Ombrophilous Forest (Figure 1 - K, L, M, N) and Alluvial Dense Ombrophilous Forest (Figure 1 - A). According to observations by Assis (1999), this last area is treated as Restinga Forest in the scope of the Biota FAPESP, Project, nº 03/12595-7.

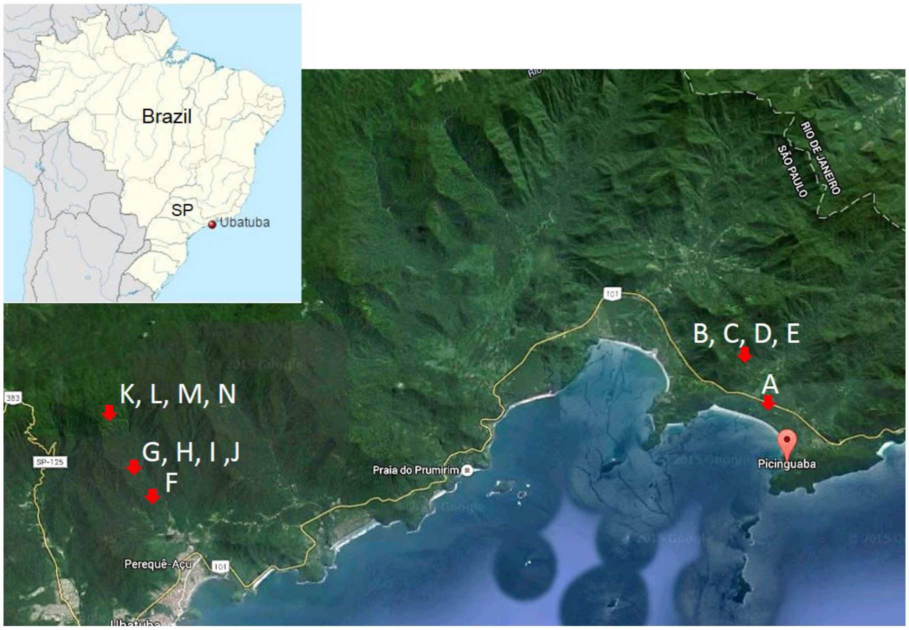

Figure 1. Location of the study areas in the Parque Estadual da Serra do Mar. A= Restinga; B, C, D, E, F= Lowlands Rain Forest; G, H, I, J= Submontane Rain Forest; K, L, M, N= Montane Rain Forest. (Google Earth in 17 Nov 2015).

Sampling design: The lycophyte and fern of the Picinguaba and Santa Virginia Nuclei was investigated along trails, roads, and plots found in these areas. We conducted 23 collecting expeditions in the Picinguaba Nucleus, from 2008 to 2011.Eleven of these expeditions were made to the "Casa da Farinha" (Figure 1 - B, C, D, E), seven to the "Fazenda Capricórnio" (Figure 1 - F, G, H, I, J), and five to the "Praia da Fazenda" areas (Figure 1 - A). Seven expeditions with the same purpose were undertaken in Santa Virginia Nucleus (Figure 1 - K, L, M, N), totaling 30 collecting expeditions in both Nuclei.

The collected material was prepared according to the methodology indicated by Silva (1989). Herbarium vouchers were deposited at UEC. We adopted the classification system by Smith *et al*. (2006, 2008), with changes by Christenhusz *et al*. (2011).

For the geographic distribution, we adopted four basic categories: Pantropical (species of the tropical zones), Tropical America (species of the tropical and subtropical America, including South of the USA), South America (only in South America), and Endemics from Brazil. The distribution of the endemic species was based on Prado *et al*. (2015). The habitat and growth are reported as guilds of the life forms, according to Paciencia (2008).

The identification key here presented was prepared through the observation of the morphological features of adult plants recorded from Picinguaba and Santa Virginia Nuclei. This key prioritizes the morphological features that are easily observed in the field as well as on herbarium specimens. Therefore, the intention was to develop a key containing the maximum set of possible macroscopic features and to avoid the practice of cutting herbarium specimens.

The key does not present families or genera. We avoided presenting our results in the traditional way, because we believe that the users of this key could be enthusiasts in the study of lycophytes and ferns and they are familiarized with the common morphological features of the different groups. Unlike keys that separate different groups, the present paper pays attention to the morphological structures that are similar between species, even if they are phylogenetically distant.

Results and Discussion

We found 135 species distributed in 53 genera and 19 families of ferns and lycophytes for the two areas (Table 1). The most representative families were Polypodiaceae, with 28 species, and Dryopteridaceae, with 19 species. The genera with more species were *Asplenium* (12 species), followed by *Blechnum* and *Elaphoglossum* (eight species each).

Table 1. Species of ferns and lycophytes found in the Biota Gradiente Funcional area (EA= endemic of the Atlantic Forest, exclusively; EB= Endemic of Brazil, not exclusively of the Atlantic Rain Forest). RF = Restinga Forest; LF = Lowlands Rain Forest; SF = Submontane Rain Forest; MF = Montane Rain Forest. T = terrestrial; R = rupicolous; E = epiphyte; H = hemiepiphyte; S = scandent; Sb = subarborescent A = arborescent.

Family	Species	Forest type	Life form
Anemiaceae	^{EA}*Anemia mandioccana* Raddi	RF, LF	FT, R, E
Anemiaceae	*Anemia phyllitidis* (L.) Sw.var. *phyllitidis*	LF	T, R
Aspleniaceae	*Asplenium auriculatum* (Hook. f.) C.V. Morton & Lellinger	LF	E
Aspleniaceae	*Asplenium claussenii* Hieron.	LF, SF	E
Aspleniaceae	^{EA} *Asplenium kunzeanum* Hieron.	MF	T
Aspleniaceae	*Asplenium mucronatum* C. Presl	LF, SF, MF	E
Aspleniaceae	^{EA} *Asplenium mullerianum* Rosenst.	SF	E
Aspleniaceae	*Asplenium oligophyllum* Kaulf.	SF, MF	T
Aspleniaceae	^{EA} *Asplenium pseudonitidum* Raddi	LF, SF, MF	T
Aspleniaceae	*Asplenium pteropus* Mett.	LF, SF, MF	E
Aspleniaceae	*Asplenium raddianum* Gaudich.	MF	E
Aspleniaceae	*Asplenium radicans* (Raddi) Lellinger	MF	E
Aspleniaceae	*Asplenium scandicinum* Kaulf.	MF	E
Aspleniaceae	*Asplenium serratum* L.	RF	E
Aspleniaceae	*Hymenasplenium triquetrum* (N. Murak. & R.C. Moran) L. Regalado & C. Prada	LF, SF	T, R
Athyriaceae	*Diplazium cristatum* (Desr.) Alston	LF, SF	T
Athyriaceae	*Diplazium riedelianum* (Bong. ex Kuhn) Kuhn ex C. Chr.	SF	T
Blechnaceae	*Blechnum brasiliense* Desv.	LF	Sb
Blechnaceae	*Blechnum acutum* (Desv.) Mett.	LF, SF, MF	H
Blechnaceae	*Blechnum cordatum* (Desv.) Hieron.	MF	T
Blechnaceae	*Blechnum gracile* Kaulf.	LF	T, R
Blechnaceae	*Blechnum schomburgkii* (Klotzsch) C. Chr.	MF	S
Blechnaceae	*Blechnum lanceola* Sw.	LF	T, R
Blechnaceae	*Blechnum occidentale* L.	LF	T
Blechnaceae	*Blechnum polypodioides* Raddi	LF	T
Blechnaceae	*Salpichlaena volubilis* (Kaulf.) J. Sm.	SF	S
Cyatheaceae	*Alsophila setosa* (Kaulf.) Domin	MF	A
Cyatheaceae	^{EB}*Alsophila sternbergii* (Sternb.) D.S. Conant	LF, SF, MF	A
Cyatheaceae	*Cyathea atrovirens* (Langsd. & Fisch.) Domin	RF, LF, MF	A
Cyatheaceae	*Cyathea delgadii* Sternb.	LF, MF	A
Cyatheaceae	^{EA} *Cyathea dichromatolepis* (Fée) Domin	MF	A
Cyatheaceae	^{EA} *Cyathea glaziovii* (Fée) Domin	SF	A
Cyatheaceae	^{EA} *Cyathea hirsuta* C. Presl	MF	A

Table 1. Continued...

Family	Species	Forest type	Life form
Cyatheaceae	^{EA} *Cyathea leucofolis* Domin.	LF	A
Cyatheaceae	^{EA}*Cyathea phalerata* Mart.	LF, SF, MF	A
Dicksoniaceae	*Lophosoria quadripinnata* (J.F. Gmel.) C. Chr.	MF	Sb
Dryopteridaceae	*Bolbitis serratifolia* (Mart. ex Kaulf.) Schott	LF, SF	R
Dryopteridaceae	^{EA} *Ctenitis deflexa* (Kaulf.) Copel.	RF, LF, SF, MF	T
Dryopteridaceae	*Ctenitis submarginalis* (Langsd. & Fisch.) Ching	MF	T
Dryopteridaceae	*Didymochlaena truncatula* (Sw.) J. Sm.	SF, MF	T
Dryopteridaceae	^{EA} *Elaphoglossum chrysolepis* (Fée) Alston	SF, LF	E
Dryopteridaceae	^{EA} *Elaphoglossum lingua* (C. Presl) Brack.	RF, LF, MF	E
Dryopteridaceae	^{EA} *Elaphoglossum macahense* (Fée) Rosenst.	RF	E
Dryopteridaceae	*Elaphoglossum decoratum* (Kunze) T. Moore	LF, SF, MF	E
Dryopteridaceae	*Elaphoglossum horridulum* (Kaulf.) J. Sm.	LF	E
Dryopteridaceae	*Elaphoglossum luridum* (Fée) Christ	LF	E
Dryopteridaceae	*Elaphoglossum macrophyllum* (Mett. ex Kuhn) Christ	RF, MF	E
Dryopteridaceae	*Elaphoglossum minutum* (Pohl ex Fée) T. Moore	MF	E
Dryopteridaceae	*Lastreopsis amplissima* (C. Presl) Tindale	LF, MF	T
Dryopteridaceae	*Mickelia scandens* (Raddi) R.C. Moran et al.	LF, SF, MF	E, H, R
Dryopteridaceae	*Olfersia cervina* (L.) Kunze	LF, SF	T, R
Dryopteridaceae	^{EA} *Polybotrya semipinnata* Fée	SF	H
Dryopteridaceae	^{EA} *Polybotrya cylindrica* Kaulf.	RF, LF, SF, MF	H
Dryopteridaceae	^{EA} *Stigmatopteris caudata* (Jacq.) Maxon	SF	T
Dryopteridaceae	^{EA} *Stigmatopteris heterocarpa* (Fée) Rosenst.	LF, SF	T
Gleicheniaceae	*Gleichenella pectinata* (Willd.) Ching	LF	T
Gleicheniaceae	*Sticherus bifidus* (Willd.) Ching	MF	T
Gleicheniaceae	^{EB}*Sticherus nigropaleaceus* (Sturm) J. Prado & Lellinger	LF, SF	T
Hemidictyaceae	*Hemidictyum marginatum* (L.) C. Presl	LF	T
Hymenophyllaceae	*Abrodictyum rigidum* (Sw.) Ebihara & Dubuisson	LF, SF, MF	T, R
Hymenophyllaceae	*Didymoglossum hymenoides* (Hedw.) Desv.	RF	E
Hymenophyllaceae	*Didymoglossum krausii* (Hook. & Grev.) C. Presl	LF, MF	E
Hymenophyllaceae	*Didymoglossum reptans* (Sw.) C. Presl	LF, SF	E
Hymenophyllaceae	*Hymenophyllum asplenioides* (Sw.) Sw.	MF	E
Hymenophyllaceae	*Hymenophyllum caudiculatum* Mart.	MF	E
Hymenophyllaceae	*Hymenophyllum hirsutum* (L.) Sw.	RF, MF	E
Hymenophyllaceae	*Hymenophyllum polyanthos* (Sw.) Sw.	RF, SF, MF	E
Hymenophyllaceae	*Hymenophyllum rufum* Fée	MF	E
Hymenophyllaceae	*Polyphlebium angustatum* (Carmich.) Ebihara & Dubuisson	MF	E
Hymenophyllaceae	*Polyphlebium pyxidiferum* (L.) Ebihara & Dubuisson	MF	E
Hymenophyllaceae	*Trichomanes cristatum* Kaulf.	RF	E
Hymenophyllaceae	*Trichomanes polypodioides* L.	MF	E
Hymenophyllaceae	*Vandenboschia radicans* (Sw.) Copel.	LF, SF, MF	E
Lindsaeaceae	*Lindsaea divaricata* Klotzsch	SF, MF	T
Lindsaeaceae	*Lindsaea lancea* var.*lancea* (L.) Bedd.	RF, LF, MF	T
Lindsaeaceae	^{EB}*Lindsaea quadrangularis* Raddi subsp. *quadrangularis*	RF, SF, MF	T
Lindsaeaceae	^{EA} *Lindsaea virescens* Sw. var. *virescens*	MF	T
Lomariopsidaceae	^{EA} *Lomariopsis marginata* (Schrad.) Kuhn	LF, SF	H
Lomariopsidaceae	^{EB}*Nephrolepis biserrata* (Sw.) Schott	RF, LF	E
Lomariopsidaceae	*Nephrolepis cordifolia* (L.) C. Presl	LF	E
Lomariopsidaceae	*Nephrolepis rivularis* (Vahl) Mett. ex Krug	LF, SF	E
Lygodiaceae	*Lygodium volubile* Sw.	LF, SF	S
Marattiaceae	^{EA} *Danaea geniculata* Raddi	LF, SF, MF	T
Polypodiaceae	*Campyloneurum angustifolium* (Sw.) Fée	MF	E
Polypodiaceae	^{EA} *Campyloneurum decurrens* C. Presl	LF, SF	E, R
Polypodiaceae	^{EA} *Campyloneurum lapathifolium* (Poir.) Ching	MF	E
Polypodiaceae	*Campyloneurum minus* Fée	LF, SF	E
Polypodiaceae	*Campyloneurum nitidum* (Kaulf.) C. Presl	RF, LF, SF, MF	E, R
Polypodiaceae	*Campyloneurum rigidum* J. Sm.	RF, MF	E
Polypodiaceae	^{EA} *Cochlidium punctatum* (Raddi) L.E. Bishop	MF	E
Polypodiaceae	*Cochlidium serrulatum* (Sw.) L.E. Bishop	RF, MF	E

Table 1. Continued...

Family	Species	Forest type	Life form
Polypodiaceae	*Melpomene pilosissima* (M. Martens & Galeotti) A.R. Sm. & R.C. Moran	MF	E
Polypodiaceae	*Microgramma geminata* (Schrad.) R.M. Tryon & A.F. Tryon	RF, LF	E
Polypodiaceae	*Microgramma percussa* (Cav.) de la Sota	SF	E
Polypodiaceae	^{EB}*Microgramma tecta* (Kaulf.) Alston var. tecta	LF, SF, MF	E
Polypodiaceae	*Microgramma vacciniifolia* (Langsd. & Fisch.) Copel.	RF	E
Polypodiaceae	^{EA} *Moranopteris achilleifolia* (Kaulf.) R.Y. Hirai & J. Prado	MF	E
Polypodiaceae	*Niphidium crassifolium* (L.) Lellinger	MF	E
Polypodiaceae	*Pecluma chnoophora* (Kunze) Salino & Costa Assis	LF	E
Polypodiaceae	^{EA} *Pecluma paradiseae* (Langsd. & Fisch.) M.G. Price	MF	E
Polypodiaceae	^{EA} *Pecluma recurvata* (Kaulf.) M.G. Price	MF	E
Polypodiaceae	^{EA} *Pecluma sicca* (Lindm.) M.G. Price	MF	E
Polypodiaceae	*Pleopeltis astrolepis* (Liebm.) E. Fourn.	MF	E
Polypodiaceae	*Pleopeltis furcata* (L.) A.R.Sm.	SF	E
Polypodiaceae	*Pleopeltis hirsutissima* (Raddi) de la Sota	LF	E
Polypodiaceae	^{EA} *Pleopeltis pleopeltifolia* (Raddi) Alston	SF	E
Polypodiaceae	*Serpocaulon catharinae* (Langsd. & Fisch.) A.R. Sm.	MF	E
Polypodiaceae	*Serpocaulon fraxinifolium* (Jacq.) A.R. Sm.	LF, SF, MF	E
Polypodiaceae	^{EA} *Serpocaulon laetum* (C. Presl) Schwartsb. & A.R. Sm.	MF	E
Polypodiaceae	^{EA} *Serpocaulon latipes* (Langsd. & L. Fisch.) A.R. Sm.	LF, MF	E
Polypodiaceae	^{EA} *Serpocaulon menisciifolium* (Langsd. & Fisch.) A.R. Sm.	MF	E
Polypodiaceae	^{EA} *Terpsichore chrysleri* (Proctor ex Copel.) A.R. Sm.	MF	E
Pteridaceae	*Acrostichum danaeifolium* Langsd. & Fisch.	LF	T
Pteridaceae	*Adiantum windischii* J. Prado	LF	T
Pteridaceae	*Anetium citrifolium* (L.) Splitg.	SF	E
Pteridaceae	*Doryopteris concolor* (Langsd. & Fisch.) Kuhn	LF	T
Pteridaceae	*Pityrogramma calomelanos* (L.) Link	LF	T
Pteridaceae	*Pteris decurrens* C. Presl	LF, SF, MF	T
Pteridaceae	*Pteris splendens* Kaulf.	MF	T
Pteridaceae	*Pteris deflexa* Link	MF	T
Pteridaceae	*Radiovittaria stipitata* (Kunze) E.H.Crane	RF, MF	E
Saccolomataceae	*Saccoloma brasiliense* (C. Presl) Mett.	LF, SF	T
Selaginellaceae	*Selaginella flexuosa* Spring	LF	R, T
Selaginellaceae	^{EA} *Selaginella macrostachya* (Spring) Spring	MF	T, R
Selaginellaceae	*Selaginella muscosa* Spring	LF	T
Selaginellaceae	*Selaginella sulcata* (Desv. ex Poir.) Spring ex Mart.	LF, SF	T
Tectariaceae	*Tectaria incisa* Cav.	LF, SF	T
Thelypteridaceae	*Macrothelypteris torresiana* (Gaudich.) Ching	LF	T
Thelypteridaceae	*Thelypteris angustifolia* (Willd.) Proctor	LF	T
Thelypteridaceae	^{EA} *Thelypteris eriosora* (Fée) Ponce	MF	T
Thelypteridaceae	*Thelypteris interrupta* (Willd.) K. Iwats.	LF	T
Thelypteridaceae	*Thelypteris longifolia* (Desv.) R.M. Tryon	RF	T
Thelypteridaceae	^{EA} *Thelypteris metteniana* Ching	LF	T
Thelypteridaceae	*Thelypteris opposita* (Vahl) Ching	LF	T
Thelypteridaceae	*Thelypteris salzmannii* (Fée) C.V. Morton	LF	T

Among the guilds of life forms, the epiphytes were predominant, with 62 species overall (Figure 2). According to Madison (1977), the high diversity of epiphytes in neotropical forests is favored by an abundance of favorable habitats, especially in montane regions. In these regions, these groups of plants represent about 50% of the total flora (Kelly *et al*., 1994), due, primordially, to the forest structure and water availability (Grubb & Withimore, 1966).

The high degree of endemism for south and southeastern Brazil (Tryon & Tryon, 1982; Prado & Silvestre, 2010) can be exemplified in this work, which presents about 30.37% (41 spp.) of the taxa considered endemic from Brazil. About 85% (35 spp.) of these are endemic to the Atlantic Rain Forest (Figure 3).

Two invasive exotic species, *Macrothelypteris torresiana* (Gaudich.) Ching and *Nephrolepis cordifolia* (L.) C. Presl, were found in the study area. These species are common in various other sites of the Atlantic Forest (Zenni & Ziller, 2011).

In total, five species are considered endangered in the vulnerable category, according to “Lista oficial de espécies ameaçadas de extinção no Estado de São Paulo” (Resolução SMA nº 48/2004): *Anetium citrifolium* (L.) Splitg., *Asplenium muellerianum* Rosenst., *Cyathea glaziovii* (Fée) Domin, *Elaphoglossum macahense* (Fée) Rosenst., and *Thelypteris angustifolia* (Willd.) Proctor. This factor stresses the importance of the Picinguaba and Santa Virgínia Nuclei for the conservation of biodiversity in the State of São Paulo.

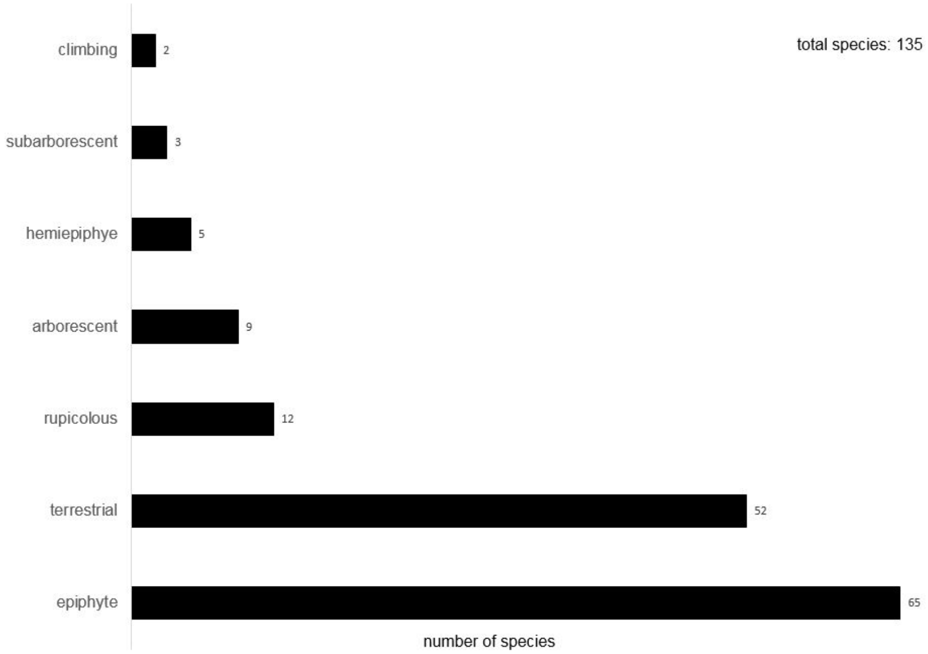

Figure 2. Species number per different life forms in the Picinguaba and Santa Virginia Nuclei.

Figure 3. Species number found in PESM area, separated by geographic distribution class.

This forest is lush and diverse, with humidity and relief suitable for the development of ferns and lycophytes. Thus, the present paper contributes to the knowledge of these groups and highlights the importance of the permanent preservation of these areas.

The key presented ahead is the first one for a broad area covered by the Atlantic Rain Forest in Brazil. It constitutes an important tool for the identification of ferns and lycophytes from the northeastern portion of the state of São Paulo.

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Identification key for lycophytes and ferns species found in Biota Gradient Functional areas (Picinguaba and Santa Virgínia Nuclei)

1. Arborescent plants (tree ferns)

2. Petiole base with black, tapered and rigid spines; thickly coated with filamentous setae scales

3. Aphlebias present; petiole base persistent on the stem .... *Alsophila setosa*

3. Aphlebias absent; petiole base deciduous leaving a scar on the stem .... *Alsophila sternbergii*

2. Petiole base with spines with the same coloration of this, conical, acute apex or absents; lanceolate scale scattered or concentrated in proximal portion, setae present or absent

4. Petiole scales whitish or bicolor (i.e., whitish at margins and brown at center)

5. Petiole base deciduous leaving a scar on the stem, scales with black setae .... *Cyathea hirsuta*

5. Petiole base persistent on the stem, scales without setae

6. Petiole scales concolor (whitish) ....*Cyathea leucofolis*

6. Petiole scales bicolor (whitish and brown) .... *Cyathea dichromatolepis*

4. Petiole scales brown

7. Petiole base deciduous leaving a scar on the stem, indusium globose …….. *Cyathea delgadii*

7. Petiole base persistent on the stem, indusium absent

8. Secondary veins predominantly forked; costae and costules only with inflated scales …….. *Cyathea phalerata*

8. Secondary veins predominantly simple; costae and costules with plan and inflated scales (bullate scales)

9. Petiole with spines at base; sori with paraphyses longer than the sporangia …….. *Cyathea atrovirens*

9. Petiole without spines (with small round projections); sori with paraphyses shorter than the sporangia …….. *Cyathea glaziovii*

1. Herbaceous plants (climbers, epiphytes, hemiepiphytes, terrestrial, rupicolous, or subarborescent)

10. Leaves with a single vein (microphylls) and with a minute ligule; stems with rhizophores

11. Stems articulate; lateral and axillary microphylls with base auriculate.………..…………………….....……..........……....... *Selaginella sulcata*

11. Stems not articulate, lateral and axillary microphylls not auriculate at base

12. Microphylls with ciliate margins .... *Selaginella macrostachya*

12. Microphylls without ciliate margins

13. Lateral microphylls oval; dorsal microphylls asymmetric …….. *Selaginella muscosa*

13. Lateral microphylls oblong or oblong-elliptic; dorsal microphylls symmetric …….. *Selaginella flexuosa*

10. Leaves with more than one vein (megaphylls), without ligule; rhizome or stem with adventitious roots, without rhizophores

14. Lamina undivided (or only fertile leave undivided in *Cochlidium serrulatum*), without segments (not pinnate)

15. Sori round, oblong or ovate; venation anastomosing with free veins included in the areoles

16. Stem scales not clathrate

17. Lamina without scales .... *Microgramma geminata*

17. Lamina with scales

18. Scales present only on the adaxial surface .... *Microgramma vacciniifolia*

18. Scales present on both surfaces

19. Sterile leaf linear-lanceolate .... *Microgramma percussa*

19. Sterile leaf ovate .... *Microgramma tecta*

16. Stem scales clathrate

20. Sori oblong or ovate, longer than wide .... *Pleopeltis astrolepis*

20. Sori round
    21. One row of sori between two lateral veins .... *Niphidium crassifolium*
    21. Two rows of sori between two lateral veins
        22. Lateral veins abaxially prominent
            23. Stem scales brown, ovate, sub-globose .... *Campyloneurum nitidum*
            23. Stem scales slightly bicolor (brown and light-brown), lanceolate ….. *Campyloneurum minus*
        22. Lateral veins abaxially not prominent
            24. Rhizome with peltate scales; lamina margins revolute ……………………….......... *Campyloneurum angustifolium*
            24. Rhizome with scales basifix, cordate; lamina margins flat
                25. Lamina linear, rigid and bright.. *Campyloneurum rigidum*
                25. Lamina lanceolate, flexible, opaque .... *Campyloneurum lapathifolium*

15. Sori not round, oblong or oval; veins free or if anastomosing without free veins included in the areoles
    26. Sori acrostichoid
        27. Lamina elliptic, oblong or ovate
            28. Apex of the lamina round .... *Elaphoglossum lingua*
            28. Apex of the lamina acuminate or acute
                29. Stem scales yellow or light brown, ovate .... *Elaphoglossum minutum*
                29. Stem scales black, fimbriate, with irregular process and cilia .... *Elaphoglossum luridum*
        27. Lamina lanceolate
            30. Lamina without scales on laminar tissue (present only on the petiole, costae, and margins) .... *Elaphoglossum decoratum*
            30. Lamina with scales on laminar tissue (including petiole and costae) or lamina glabrous
                31. Lamina glabrous or with scales, the scales not similar to those of the petiole
                    32. Veins free near the margins of the lamina .... *Elaphoglossum macahense*
                    32. Veins anastomosing near the margins of the lamina ….. *Elaphoglossum macrophyllum*
                31. Lamina with scales, the scales similar to those of the petiole
                    33. Scales of the lamina linear-lanceolate .... *Elaphoglossum horridulum*
                    33. Scales of the lamina oblong-lanceolate or lanceolate ……………........................... *Elaphoglossum chrysolepis*
    26. Sori not acrostichoid (sporangia forming lines parallel to the veins, costae, and margins or immersed, or on the surface forming coenosorus)
        34. Venation free
            35. Lamina shorter than 5 cm long; sporangia forming coenosorus; spores with chlorophyll
                36. Hydathodes inconspicuous on the adaxial surface of the lamina; sori restricted to the distal pat of the lamina …......... ....…......... *Cochlidium serrulatum*
                36. Hydathodes conspicuous on the adaxial surface of the lamina; sori not restricted to the distal pat of the lamina ……… ....….. *Cochlidium punctatum*
            35. Lamina bigger than 5 cm long; sporangia linear; spores without chlorophyll
                37. Lamina > 4 cm wide; sori parallel to the lateral veins ……………..............................………… *Asplenium serratum*
                37. Lamina < 3 cm wide; sori parallel to the costa ………….. *Blechnum lanceola*
        34. Venation anastomosing, without free veins included in the areoles
            38. Lamina with only one row of areoles between the margin and costa .... *Radiovittaria stipitata*
            38. Lamina with several rows of areoles between the margin and costa .... *Anetium citrifolium*

14. Lamina divided (pinnate, 2-pinnate or more divided, pinnatifid, pinnatisect, or dichotomous)

39. Lamina with 1 or 2 cell layers in thickness, translucid

40. Indusium bivalve, receptacle not extended beyond the margins of the involucre

41. Lamina glabrous

42. Lamina 1-pinnate-pinnatisect, petiole not winged .... *Hymenophyllum asplenioides*

42. Lamina 2 or 3-pinnate-pinnatissect, petiole winged

43. Terminal segments long (caudate), plants > 10 cm long .... *Hymenophyllum caudiculatum*

43. Terminal segments shorts (not caudate), plants < 10 cm long .... *Hymenophyllum polyanthos*

41. Lamina with hairs

44. Rachis fully winged; fronds with stellate hairs on the petiole, rachis, veins, and margins of the lamina (except on the laminar tissue between veins and margins) .... *Hymenophyllum hirsutum*

44. Rachis irregular winged; fronds with stellate hairs on the entire blade (including the laminar tissue) .... *Hymenophyllum rufum*

40. Indusium tubular and bilabiate, receptacle long beyond involucre margins

45. Plants terrestrial; rhizome erect or short-creeping; fronds fasciculate

46. Lamina deltoid and 3 or 4-pinate-pinnatisect, rachis without wings .... *Abrodictyum rigidum*

46. Lamina lanceolate and 1-pinate-pinatissect, rachis with narrow wings .... *Trichomanes cristatum*

45. Plants epiphytes; rhizome long-creeping; fronds not fasciculate

47. False veins present in the laminar tissue

48. Indusium included in the lamina; false veins parallel to the margin of the lamina .... *Didymoglossum krausii*

48. Indusium exserted; false veins not parallel to the margin of the lamina

49. Plants up to 5 cm long; margins of the lamina with furcate and stellate hairs, restricted to sinus .... *Didymoglossum reptans*

49. Plants up to 2 cm long; margins of the lamina with only furcate hairs ....*Didymoglossum hymenoides*

47. False veins absent in the laminar tissue

50. Venation catadromous .... *Trichomanes polypodioides*

50. Venation anadromous

51. Petiole not winged .... *Polyphlebium angustatum*

51. Petiole winged

52. Stem and petiole with brown hairs .... *Vandenboschia radicans*

52. Stem and petiole with black hairs .... *Polyphlebium pyxidiferum*

39. Lamina with more than 2 cell layers in thickness, not translucid

53. Petiole base persistent in the stem, forming phyllopodium

54. Lamina dichotomously divided

55. Sori rounded or oblong .... *Pleopeltis pleopeltifolia*

55. Sori linear .... *Pleopeltis furcata*

54. Lamina pinnate, 2-pinnate or more divided

56. Petiole cylindrical, not sulcate

57. Veins sim........ *Pecluma sicca*

57. Veins forked

58. Proximal segments reduced (auriculate) .... *Pecluma paradiseae*

58. Proximal segments not reduced .... *Pecluma recurvata*

56. Petiole sulcate

59. Venation free

60. Scales abundant on the laminar tissue .... *Pleopeltis hirsutissima*

60. Scales absent on the laminar tissue .... *Pecluma chnoophor*a

59. Venation anastomosing

61. Lamina pinnatisect

62. Stem dark-brown to black, pruinose .... *Serpocaulon catharinae*

62. Stem light brown to yellow, without waxy deposits

63. Lamina without hairs, scales presents in the costae ….. *Serpocaulon latipes*

63. Lamina with hyaline hairs ….. *Serpocaulon laetum*

61. Lamina 1-pinnate

64. Medial pinnae not adnate .... *Serpocaulon fraxinifolium*

64. Medial pinnae with the acroscopic side slightly adnate ……………………...... *Serpocaulon meniscifolium*

53. Phyllopodium absent

65. Sori linear

66. Sori marginal or submarginal

67. Sori submarginal, protected by an abaxial indusium

68. Pinnules 2 or 3 times forked .... *Lindsaea virescens* var. *virescens*

68. Pinnules not forked (pinnate or more divided)

69. Rachis and secondary rachis quadrangular .... *Lindsaea quadrangularis* subsp. *quadrangularis*

69. Rachis and secondary rachis not quadrangular

70. Rachis and secondary rachis paleaceous, winged paleaceous; pinnules semilunate ……………………
....………………. *Lindsaea lancea* var. *lancea*

70. Rachis and secondary rachis reddish brown, winged paleaceous contracting with rachis color; pinnules not semilunate .... *Lindsaea divaricata*

67. Sori marginal, protected by an adaxial indusium formed by the revolute margin of the lamina

71. Lamina not fully pinnate ……………...………………………………......………..…. *Doryopteris concolor*

71. Lamina pinnate

72. Lamina 1-pinnate .... *Pteris splendens*

72. Lamina 2-3-pinnate

73. Venation free .... *Pteris deflexa*

73. Venation anastomosing .... *Pteris decurrens*

66. Sori not marginal and not submarginal

74. Sori parallel and adjacent to the costa

75. Plants with indeterminate growth, climbing ….. *Salpichlaena volubilis*

75. Plants with determinate growth, not climbing

76. Fertile and sterile fronds monomorphic

77. Proximal pinnae gradually reduced toward the lamina base

78. Plants herbaceous; stem stoloniferous; petiole with lanceolate and brownish scales …………………
………………...……*Blechnum polypodioides*

78. Plants sub-arborescent; stem not stoloniferous; petiole with linear to linear-lanceolate and blackish scales .... *Blechnum brasiliense*

77. Proximal pinnae not reduced or only slightly reduced toward the lamina base

79. Fronds entire .... *Blechnum lanceola*

79. Fronds pinnate

80. Proximal pinnae petiolulate .... *Blechnum gracile*

80. Proximal pinnae sessile or adnate .... *Blechnum occidentale*

76. Fertile and sterile fronds dimorphic

81. Petiole base with concolor scales .... *Blechnum cordatum*

81. Petiole base with bicolor scales

82. Stem erect, subarborescent with scales, the scales blackish or brown in the center and golden near the margin .... *Blechnum schomburgkii*

82. Stem scandent with scales, the scales blackish or brown in the center and light brown near the margin .... *Blechnum acutum*

74. Sori not parallel to the costa

83. Sori in both sides of the secondary vein, at least in the proximal veins

84. Lateral pinnae entire .... *Diplazium riedelianum*

84. Lateral pinnae divided .... *Diplazium cristatum*

83. Sori only in one side of the secondary veins

85. Venation anastomosing near the lamina margin .... *Hemidictyum marginatum*

85. Venation free

86. Lamina 2-4-pinnate at base

87. Rachis with proliferous buds .... *Asplenium radicans*

87. Rachis without proliferous buds

88. Plants epiphyte; fronds pendulous; stem with linear scale; green lamina .... *Asplenium scandicinum*

88. Plants terrestrial; fronds erects; stem with lanceolate scale; bluish-green lamina .... *Asplenium pseudonitidum*

86. Lamina 1-pinnate at base

89. Stem long-creeping with coloration conspicuously green .... *Hymenasplenium triquetrum*

89. Stem erect or decumbent with coloration little evident

90. Lamina margin entire to weakly crenate .... *Asplenium oligophyllum*

90. Lamina margin weakly or deeply incised (serrate)

91. Apex of the segments mucronate

92. Petiole green and glabrous .... *Asplenium mucronatum*

92. Petiole greyish with linear-lanceolate scales .... *Asplenium mullerianum*

91. Apex of the segments not mucronate

93. Pinnae acroscopically with an auricle overlapping the rachis .... *Asplenium auriculatum*

93. Pinnae acroscopically without auricle or, if it is present, not overlapping the rachis

94. Proximal pinnae gradually reduced (1/2 the length of medial or smaller)

95. Fronds erect; petiole long about 1/3 of the lamina length .... *Asplenium claussenii*

95. Fronds pendulous; petiole short about 1/10 of the lamina length .... *Asplenium pteropus*

94. Proximal pinnae not gradually reduced or only slightly reduced

96. Apex of the lamina without proliferous buds .... *Asplenium raddianum*

96. Apex of the lamina with proliferous buds .... *Asplenium kunzeanum*

65. Sori not linear

97. Sori acrostichoid

98. Venation anastomosing

99. Fronds 2-4 m long; spores trilete …………….. *Acrostichum danaeifolium*

99. Fronds smaller than 2 m long; spores monolete

100. Pinnae articulate to the rachis .... *Mickelia scandens*

100. Pinnae not articulate to the rachis

101. Sterile pinna with basiscopic side excavate; veins joined by a submarginal vein (inconspicuous in dry material) …... *Olfersia cervina*

101. Sterile pinna with basiscopic and acroscopic sides conform; veins conspicuously areolate …........ .... *Bolbitis serratifolia*

98. Venation free

102. Lamina 1-pinnate; pinnae entire articulate with the rachis .... *Lomariopsis marginata*

102. Lamina 1-3-pinnate-pinnatisect; pinnae pinnate or more divided not articulate to the rachis

103. Stem scales with entire margins and recurved base; proximal pinnae 3-pinnate-pinnatisect .... *Polybotrya cylindrica*

103. Stem scales with eroded margins to slightly denticulate and base not recurved; proximal pinnae pinnate-pinnatisect .... *Polybotrya semipinnata*

97. Sori not acrostichoid

104. Sporangia gathered in synangium or in spikes

105. Plants terrestrial; rhizome fleshy and protected by amilaceous stipules; sporangia in synangium .... *Danaea geniculata*

105. Plants climbing; rhizome long-creeping without stipules; sporangia in spikes .... *Lygodium volubile*

104. Sporangia not gathered in synangium or spikes

106. Pair of fertile pinnae modified in spike; sporangia pyriform with apical annulus

107. Terminal pinna conform; equilateral pinna base; anastomosing veins …................... *Anemia phyllitidis*

107. Terminal pinna pinnatifid; pinna base not equilateral; free veins …...................... *Anemia mandioccana*

106. Pair of fertile pinnae not modified in spike; sporangium globose with oblique, lateral or vertical annulus

108. Sporangium with oblique annulus

109. Fronds 3-4-pinnate-pinnatifid; rhizome erect and stout with golden hairs, 4-10 mm long; plants subarborescent ……... *Lophosoria quadripinnata*

109. Fronds dichotomously divided (pinnae furcate); rhizome creeping with scales or hairs (up to 4 mm long); plants herbaceous

110. Buds protected by hairs; veins 2-4-furcate .... *Gleichenella pectinata*

110. Buds protected by scales; veins one time furcate

111. Axes scales patent; segments > 1.5 cm long …………….….... *Sticherus nigropaleaceus*

111. Axes scales appressed; segments <1.5 cm long ……….............… *Sticherus bifidus*

108. Sporangium pedicelate with annulus vertical interrupted by the pedicel

112. Spores with chlorophyll

113. Petiole and lamina glabrous, lacking brown setae .... *Cochlidium serrulatum*

113. Petiole and lamina conspicuous with brown setae and hyaline hairs

114. Stem scales clathrate .... *Melpomene pilosissima*

114. Stem scales not clathrate

115. Segments veins pinnate .... *Terpsichore chrysleri*

115. Segments veins simple or only one in the acroscopic branch .... *Moranopteris achilleifolia*

112. Spores without chlorophyll

116. Sporangia sparse on the abaxial lamina surface protected by whitish wax ....… *Pytyrogramma calomelanos*

116. Sporangium gathered in defined sori and the lamina lacking white wax

117. Lamina 2-pinnate; sori oblong

118. Fronds large (1-2 m long); sori abaxial …............................. *Didymochlaena truncatula*

118. Fronds small (not exceed 1 m long); sori marginal .... *Adiantum windischii*

117. Lamina 1-pinnate, sori round, not elongate

119. Pinnae articulate to the rachis

120. Indusium reniform; lamina glabrous abaxially ......…....*phrolepis cordifolia*

120. Indusium orbicular; lamina with scales and/or hairs abaxially, the scales fimbriate, the hairs catenate

121. Costa adaxially with hairs catenate ……………..… *Nephrolepis biserrata*

121. Costa adaxially without hairs or with sparse scales .... *Nephrolepis rivularis*

119. Pinnae not articulate to the rachis

122. Costa not sulcate adaxially

123. Veins anastomosing .... *Tectaria incisa*

123. Veins free

124. Petiole with two vascular bundles at base; lamina pubescent, the hairs acicular and septate ……........................... *Macrothelypteris torresiana*

124. Petiole with more than vascular bundles at base; lamina pubescent, the hairs catenate or clavate

125. Rachis adaxially with two prominent edges; clavate hairs on the adaxial surface of the axis ....…......... *Lastreopsis amplissima*

125. Rachis adaxially lacking prominent edges, catenate hairs on the adaxial axis

126. Rachis and costae lacking scales …………..... *Ctenitis deflexa*

126. Rachis and costae with clathrate scales ……................... .... *Ctenitis submarginalis*

122. Costa sulcate adaxially

127. Veins clavate at apex, ending before the lamina margin; lamina with internal glands punctuated and translucent

128. Lamina 1-pinnate-pinatissect ....……… *Stigmatopteris caudata*

128. Lamina 1-pinnate, entire pinnae with crenate margin .... *Stigmatopteris heterocarpa*

127. Veins not clavate at apex, ending at margin of the lamina; lamina without internal glands

129. Lamina 3 or 4 pinnate; indusium double (adaxially formed by the green laminar tissue and abaxially scarious and slender); spores trilete ……………………………………………*Saccoloma brasiliense*

129. Lamina 2-pinnate; indusium single or absent; spores monolete

130. Lamina 1-pinnate; venation anastomosing, meniscioid

  131. Pedicel of the sporangium with setiform hairs .... *Thelypteris longifolia*

  131. Pedicel of the sporangium without setiform hairs

    132. Lamina glabrous abaxially; capsule of the sporangium with setiform hairs .... *Thelypteris angustifolia*

    132. Lamina pubescent abaxially; capsule of the sporangium glabrous ………………..……….. *Thelypteris salzmannii*

130. Lamina 1-pinnate-pinnatifid or 1-pinnate-pinnatisect; venation free or only the proximal veins of the adjacent segments anastomosing (not meniscioid)

  133. Proximal pinna greater than or with the same size of the medial ones, or reduced, with proximal veins of the adjacent segments joining in the sinus or below the sinus (subg. *Cyclosorus*) .... *Thelypteris interrupta*

  133. Proximal pinnae smaller than the medial ones, gradually or abruptly reduced, with proximal veins of the adjacent segments joining to the margin above the sinus (subg. *Amauropelta*)

    134. Glandular hairs absent on the laminar tissue and/or veins, costa and margins .... *Thelypteris eriosora*

    134. Glandular hairs present on the laminar tissue and/or veins, costa, and margins

      135. Costa of the segments lacking scales abaxially; aerophores absent .... *Thelypteris opposita*

      135. Costae of the segments with inconspicuous fimbriate scales; aerophores present on the base of the pinnae abaxially .... ……………………..... *Thelypteris metteniana*

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Inventory

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Abstract: The fishes herein included were collected in four small streams of the upper rio Tapajós basin. Through fieldwork carried out in 2011, 2013 and 2014 during the low water season 1.728 specimens belonging to 22 species distributed in 11 families, and five orders were captured. Characidae was the most representative family both in number of species and specimens captured. The most abundant species were *Hyphessobrycon melanostichos*, *H. hexastichos*, and *H. notidanos*. Five species are recognized as new, and four as endemic to the upper rio Tapajós basin. This study represents the first fish inventory for the region and will provide valuable information for the conservation of the poorly known diversity of fishes of the Chapada dos Parecis, in the headwaters of the upper rio Tapajós basin.

Keywords: *South America, Neotropical fish, Amazon, endemism.*

Ictiofauna do alto rio Juruena na Chapada dos Parecis, Mato Grosso, Brasil

Resumo: Os peixes registrados aqui foram coletados em quatro igarapés da bacia do alto rio Tapajós. Expedições realizadas em 2011, 2013 e 2014 durante a estação de seca resultaram na coleta de 1.728 indivíduos pertencendo à 22 espécies distribuídas em 11 famílias e cinco ordens. Characidae foi a família com o maior número de espécies e espécimes capturados. As espécies com maior abundância foram *Hyphessobrycon melanostichos, H. hexastichos* e *H. notidanos*. Cinco espécies são reconhecidas como novas e quatro como endêmicas da bacia do alto rio Tapajós. Este trabalho representa o primeiro inventário sobre os peixes da região e fornecerá informações valiosas para a conservação da diversidade pouco conhecida de peixes da Chapada dos Parecis, nas cabeceiras da bacia do alto rio Tapajós.

Palavras-chave: *América do Sul, peixe Neotropical, Amazônia, endemismo.*

Introduction

The Neotropical region, that includes the South and part of Central America, harbours the most diverse freshwater fish fauna in the world including 5.400 registered species (Reis 2013), with estimates of a final number between 8.000 – 9.000 species (Schaefer 1998, Reis et al. 2016). Most of this ichthyofaunal diversity is located in the Amazon basin (Amazon, Orinoco and Guiana basins), in which 2.354 (Albert et al. 2011) or 2.411 (Reis et al. 2016) valid fish species are included. Most of the major tributaries of the Amazon river basin, still lack an inventory of their fish species, including the rio Tapajós.

Located in the Brazilian Shield the 1.784 km long, rio Tapajós is one of the largest tributaries of rio Amazonas (Costa 2007). Its upper portion was until recently virtually unknown by ichthyologist (Britski & Lima 2008). However, on the last decades, the collecting activity largely increased in the area, 97 of the 109 species presently known from the rio Tapajós basin having been described in the past 30 years. Currently, approximately 300 fishes are registered from the rio Tapajós basin (Ferreira et al. 1998, Camargo et al. 2005, Silva-Oliveira et al. 2016), but collecting efforts have mostly concentrated on the lower and middle portions of the basin, so that a catalogue of fishes of the upper rio Tapajós basin is still lacking. This contribution represents the first attempt to survey the fish species of the upper rio Tapajós basin and will certainly provide valuable information for future studies especially on conservation of the poorly known diversity of fishes of the rio Tapajós basin.

Material and Methods

Study Area

The rio Tapajós is formed by the confluence of the Teles Pires and Juruena rivers. The rio Juruena is about 1.240 Km long and is formed by several tributaries draining from the Chapada dos Parecis, an important watershed between three river systems (Madeira, Paraguai and Tapajós river basins) with moderate altitude (750 m), located at the western border of the Brazilian Shield. The rivers in Chapada dos Parecis, tributaries of the rio Juruena (*i.e.* Mutum, 12 de Outubro, Primavera, Camararezinho, Sacre, Formiga, Juína, Sangue), where samples were obtained for this study, are generally rectilinear, embedded and deep, characterized by turbulent waters and presence of many waterfalls. The studied area is about 500 to 510 meters a.s.l., and is located between Comodoro and Vilhena towns, near BR 364 (Figure 1) on the Chapada dos Parecis and are considered headwater streams entering the upper rio Juruena, rio Tapajós basin.

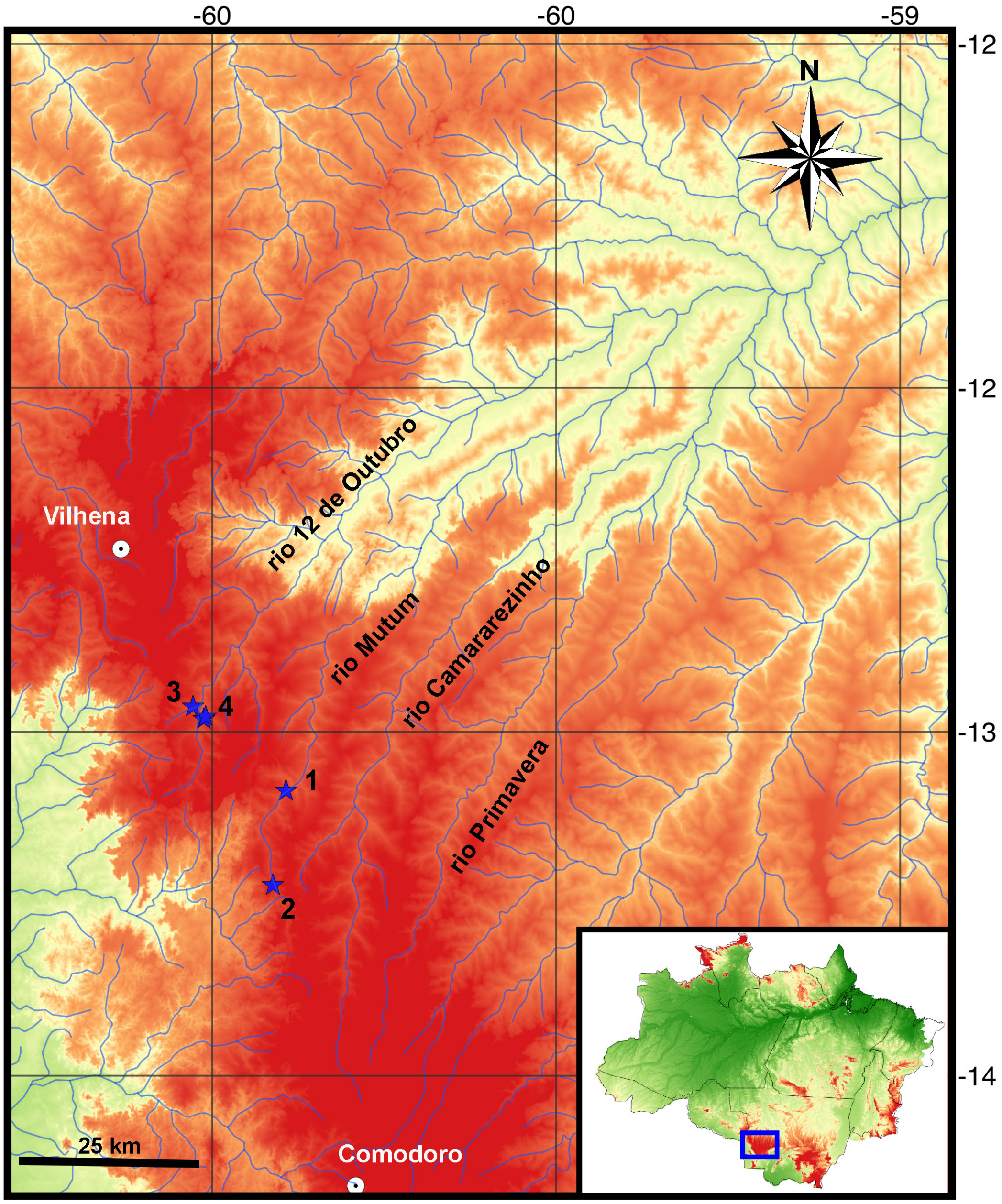

Figure 1. Map of the study area showing the four stations sampled (indicated by number) from the upper rio Juruena, rio Tapajós basin, Mato Grosso, Brazil.

Station 1 (13°05'08"S, 59°53'32"W) - igarapé Mutum located near BR 364, 3-6 m wide and 0.5-2.5 m deep, preserved riparian vegetation, swift current, and sand, pebbles and dead leaves on the bottom (Fig. 2a).

Station 2 (13°13'23"S, 59°54'42"W) - Headwater of igarapé Mutum in flooded portions of the stream due to damming caused by road, 6-8 m wide and 0.5-1.5 m deep, lentic environment, mud and decomposed organic matter on the bottom.

Station 3 (12°58'41"S, 60°00'34"W) - igarapé 12 de Outubro located near BR 364, 2-4 m wide and 0.5-2 m deep, few preserved riparian vegetation, swift current, and sand and dead leaves on the bottom (Fig. 2b).

Station 4 (12°57'50"S, 60°01'40"W) - Tributary of 12 de Outubro located near BR 364, 1-2 m wide and 0.5-1.7 m deep, preserved riparian vegetation, swift current, subaquatic vegetation and sand on the bottom (Fig. 2c).

Sampling

Samples were taken in November 2011, July and August 2013, September and November 2014 in four stations. Sampling took one hour long, and four were undertaken during the day and one during the nocturnal period. The following gears were used: trapezoid hand-nets with area of 1 m^2 and internode distance of 0.1 cm, seine-nets 3-5 m wide, 1.5-2.5 m deep and internode distance of 1 cm and casting-nets 2.5 m deep, 22 m of circumference and internode distance of 1.5 cm. Photographs were taken in three stations that were was georeferenced with a GPS device. Abiotic data such as depth, water transparency and soil were observed *in situ*. No sazonal differences were detected in the abiotic data. Collection permit was granted by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (registration number IBAMA 83/2012, May 2012-September 2013).

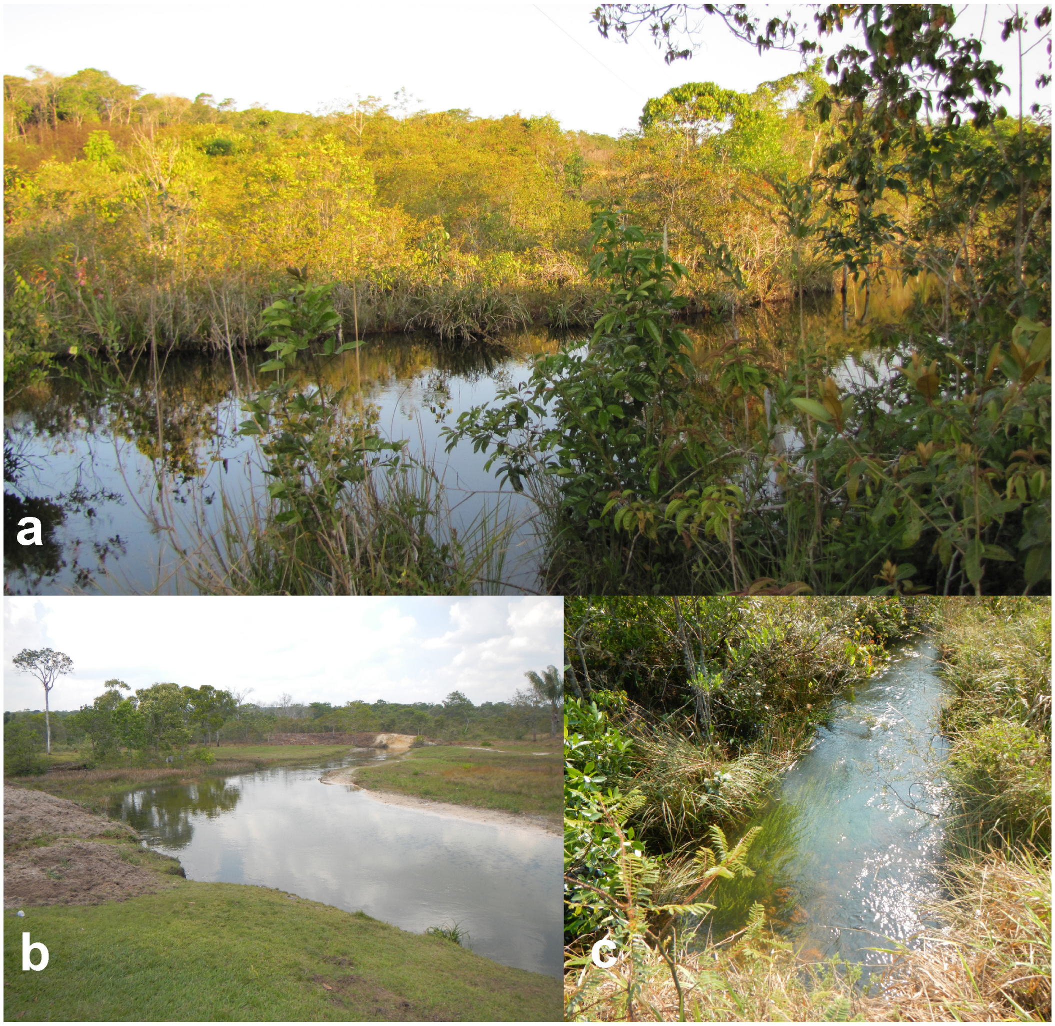

Figure 2. Habitats of three stations sampled from the upper rio Juruena, rio Tapajós basin, Mato Grosso, Brazil. (a) igarapé Mutum; (b) headwaters of igarapé Mutum; (c) igarapé 12 de Outubro; (d) tributary of 12 de Outubro.

The sampled fishes were anesthetized with clove-oil (1ml/liter), put in plastic bags, fixed in 10% formalin for 48 hours and transferred to 70% ethanol. The material was then counted and identified to the lowest possible level using revisionary studies by Bertaco & Malabarba (2007), Bertaco & Carvalho (2005 a, b), Carvalho & Bertaco (2006), Costa (2001), Queiroz et al. (2013), Reis et al. (2005), and comparisons with identified material deposited in the fish collections whenever needed. The classification adopted follows Reis et al. (2003), Wiley & Jonson (2010), and Van Der Laan et al. (2014), with genera listed in alphabetical order within each family. Voucher specimens were deposited in the fish collections of the Museu de Zoologia da Universidade de São Paulo (MZUSP) and the Universidade Federal de Rondônia, Ictiologia (UFRO-I). Species and specimens were counted for each registered species with data organized in Table 1 and Figures 3 and 4.

Results

The species recorded from the upper rio Tapajós basin are listed in Table 1 and the corresponding photos are provided in Figures 3 and 4. A total of 1.728 specimens representing 22 species distributed in 11 families, and five orders were collected in four stations in both the igarapé Mutum and the igarapé 12 de Outubro. Characiformes (55%, 12 species) was the predominant group, followed by Siluriformes (28%, 6 species), Gymnotiformes (9%, 2 species), Labriformes (4%, 1 species) and Cyprinidontiformes (4%, 1 species) in number of recorded species (Figure 5).

The most representative families considering number of species collected were Characidae (seven species), and Heptapteridae (five species). In terms of captured specimens Characiformes prevailed again (1.498 specimens collected = 86%), followed by Siluriformes (129 specimens collected = 7%), Gymnotiformes and Labriformes (49 specimens each = 3%) and Cyprinodontiformes (3 specimens = 1%) (Figure 6). Characidae includes the three most abundant species recorded from the upper rio Tapajós basin: *Hyphessobrycon melanostichos* Carvalho & Bertaco, 2005, *Hyphessobrycon hexastichos* Bertaco & Carvalho, 2005, and *Hasemania nambiquara* Bertaco & Malabarba, 2007, with 610, 305 and 205 captured specimens respectively, representing 65% of the total captured specimens. On the other hand one single specimen of *Hoplerythrinus unitaeniatus* and *Pimelodella* sp. were recorded. *Moenkhausia* sp. and *Melanorivulus modestus* (Costa, 2001) also presented low abundance, with two and three captured specimens, respectively.

A total of 1.104 specimens belonging to 20 species were recorded from the igarapé Mutum (Stations 1 and 2). The fish fauna is composed by Characiformes (12 species, 913 specimens), Siluriformes (6 species,

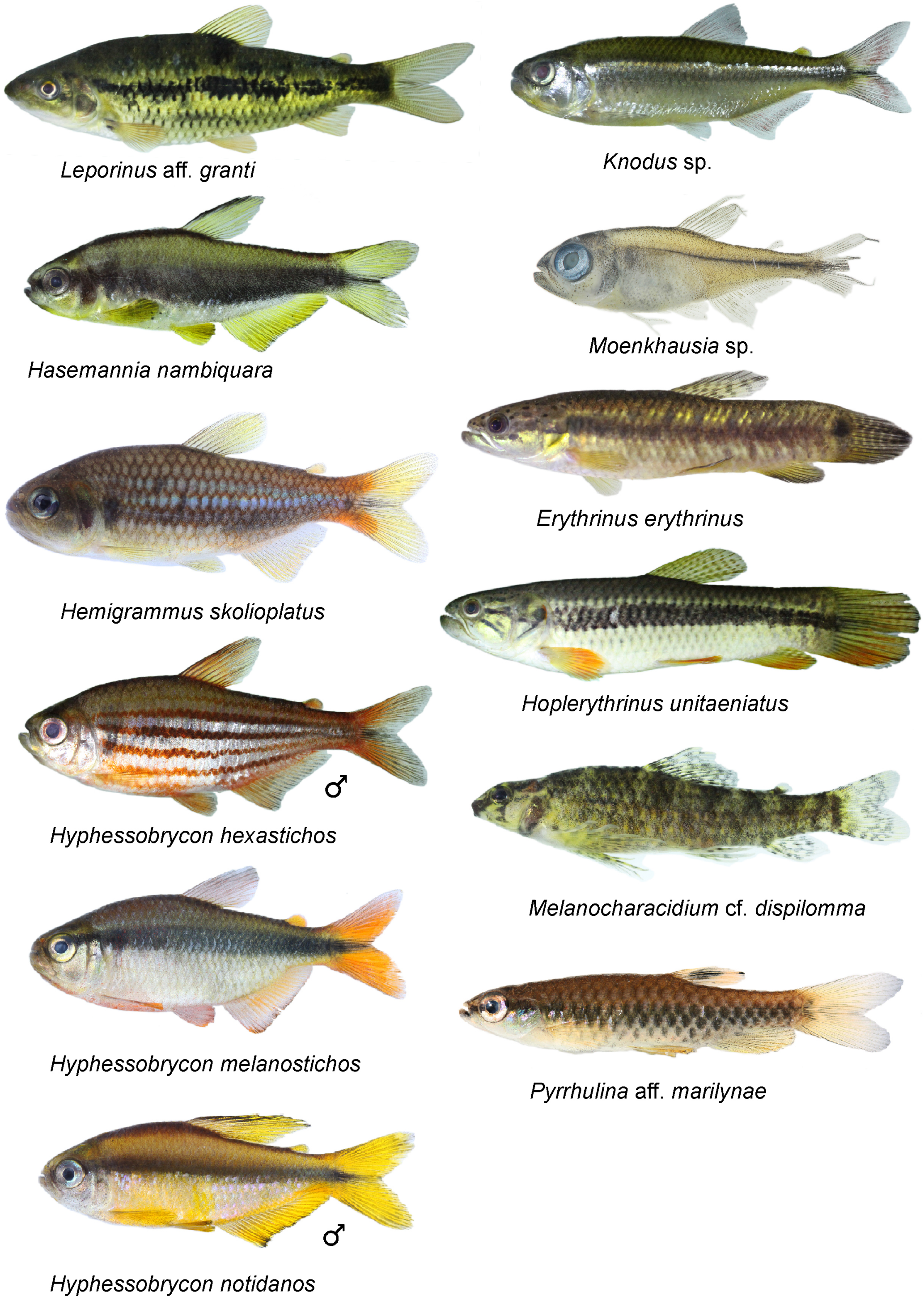

Figure 3. Characiformes registered from the upper rio Juruena, rio Tapajós basin, Mato Grosso, Brazil.

118 specimens), Gymnotiformes (1 species, 40 specimens) and Labriformes (1 species, 33 specimens). No Cyprinodontiformes species was captured in the igarapé Mutum. The most representative families in number of species and specimens were Characidae (seven species), and Heptapteridae (five species). Characidae includes the three most abundant species registered in the igarapé Mutum, *Hyphessobrycon hexastichos, Hasemania nambiquara*, and *Hyphessobrycon melanostichos*, with 358, 205 and 189 captured specimens respectively.

Twenty species (90%) with 1.068 captured specimens (62%) were registered in the Station 1. A low number of species and specimens were registered in all the other three stations. The Station 2, the headwater of igarapé Mutum, was represented by eight species (38%) and 36 captured specimens (2%), the lowest values of captured species and specimens herein recorded. Stations 3 and 4 are located in the igarapé 12 de Outubro basin. A total of 624 specimens belonging to 11 species were collected. The fish fauna is composed by Characiformes (6 species, 585 specimens), Siluriformes

Table 1. List of species registered in four stations from the upper rio Juruena, rio Tapajós basin, Mato Grosso, Brazil.

Ordem	Family	Species	Sampling Stations				N	Vouchers
			1	2	3	4		
Characiformes	Characidae	*Hasemania nambiquara*	198	7	0	0	205	UFRO-I 12346, 12392, 22736
		Hemigrammus skolioplatus	1	0	0	11	12	MZUSP 115497
		Hyphessobrycon hexastichos	356	2	0	0	358	UFRO-I 12297, 12318, 12681
		Hyphessobrycon melanostichos	180	9	404	17	610	UFRO-I 12281, 12657, 22884
		Hyphessobrycon notidianos	5	0	2	97	104	MZUSP 115505, 115501
		Knodus sp.	11	9	9	1	30	UFRO-I 12305, 22844, 22905
		Moenkhausia sp.	2	0	0	0	2	UFRO-I 22881
	Erythrinidae	*Erythrinus erythrinus*	1	1	1	4	7	UFRO-I 22738, 22846
		Hoplerythrinus unitaeniatus	1	0	0	0	1	UFRO-I 22846
	Anostomidae	*Leporinus* aff. *granti*	11	0	0	0	11	UFRO-I 12300, 22717
	Crenuchidae	*Melanocharacidium* cf. *dispilomma*	113	0	0	0	113	UFRO-I 12656, 22734,
	Lebiasinidae	*Pyrrhulina* aff. *marilynae*	1	5	37	2	45	UFRO-I 22718
Siluriformes	Callichthyidae	*Megalechis thoracata*	11	2	3	2	18	UFRO-I 12684, 22732, 22847
	Heptapteridae	*Cetopsorhamdia* sp.1	81	0	0	0	81	UFRO-I 12343, 12682, 22733
		Cetopsorhamdia sp.2	11	0	0	0	11	UFRO-I 22716
		Cetopsorhamdia sp.3	4	0	0	6	10	MZUSP 115498, 115478
		Pimelodella sp.	1	0	0	0	1	UFRO-I 22885
		Phenacorhamdia sp.	8	0	0	0	8	UFRO-I 22887
Labriformes	Cichlidae	*Aequidens* cf. *rondoni*	32	1	4	12	49	UFRO-I 12277, 12673, 22843
Gymnotiformes	Hypopomidae	*Brachyhypopomus* sp.n.	0	0	0	9	9	MZUSP 115496
	Sternopygidae	*Eigenmannia* sp.n.	40	0	0	0	40	UFRO-I 12275, 12683, 22737
Cyprinodontiformes	Cynolebiidae	*Melanorivulus modestus*	0	0	3	0	3	MZUSP 115507
Total number of specimens			**1068**	**36**	**463**	**161**	**1728**	
Total number of species			**20**	**8**	**8**	**10**	**22**	

N = number of registered specimens.

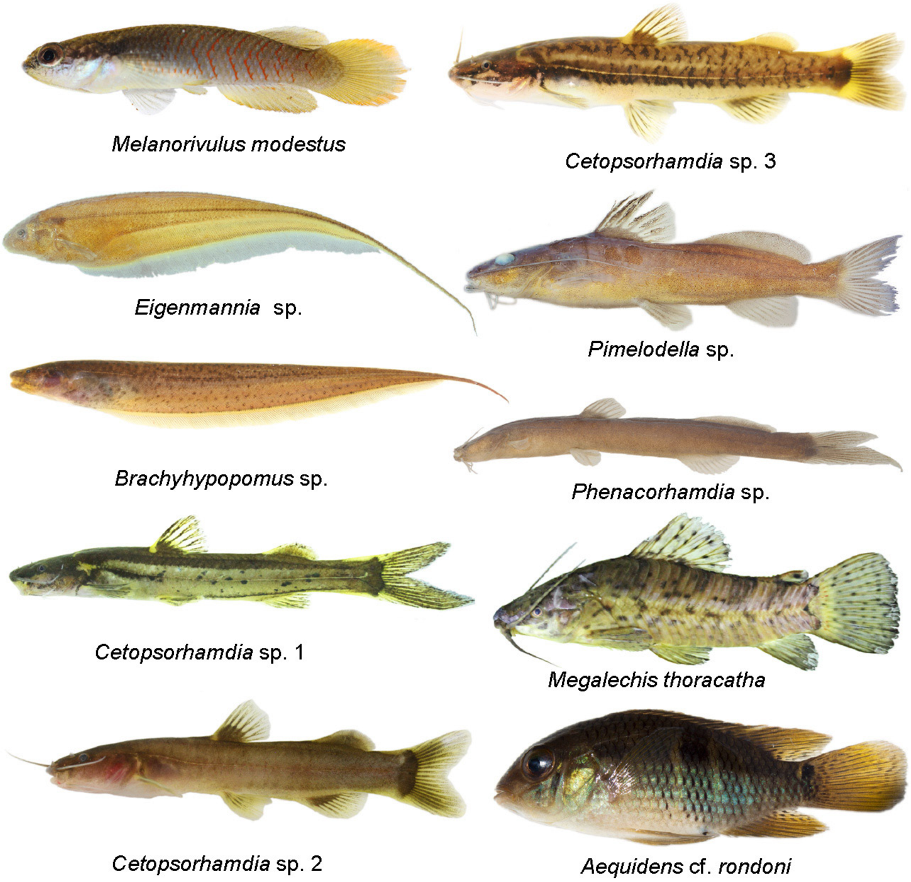

Figure 4. Cyprinodontiformes, Gymnotiformes Siluriformes, and Labriformes registered from the upper rio Juruena, rio Tapajós basin, Mato Grosso, Brazil.

(2 species, 11 specimens), Gymnotiformes (1 species, 9 specimens), Labriformes (1 species, 16 specimens) and Cyprinodontiformes (1 species, 3 specimens). The most representative family in number of species and specimens was Characidae, with four recorded species, including the two most abundant species registered in the igarapé 12 de Outubro basin: *Hyphessobrycon melanostichos* and *H. notidanos*, with 421 and 99 captured specimens respectively.

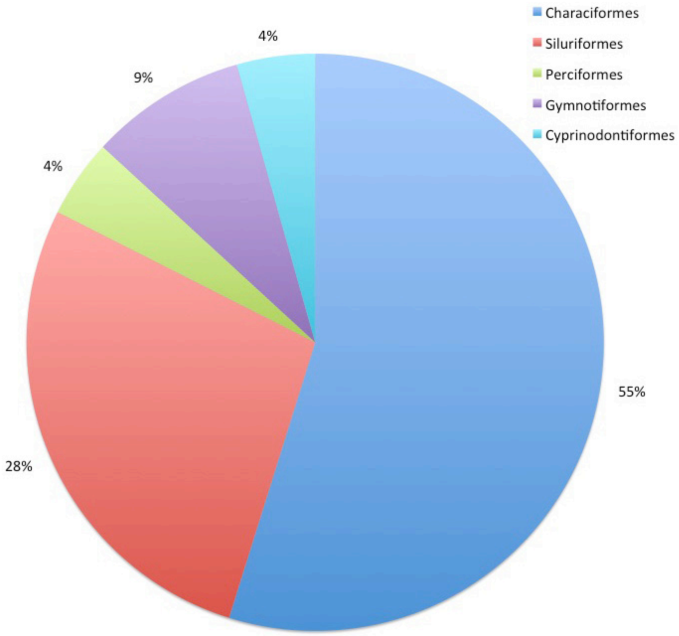

Figure 5. Relative diversity of species among the five orders registered from the upper rio Tapajós basin.

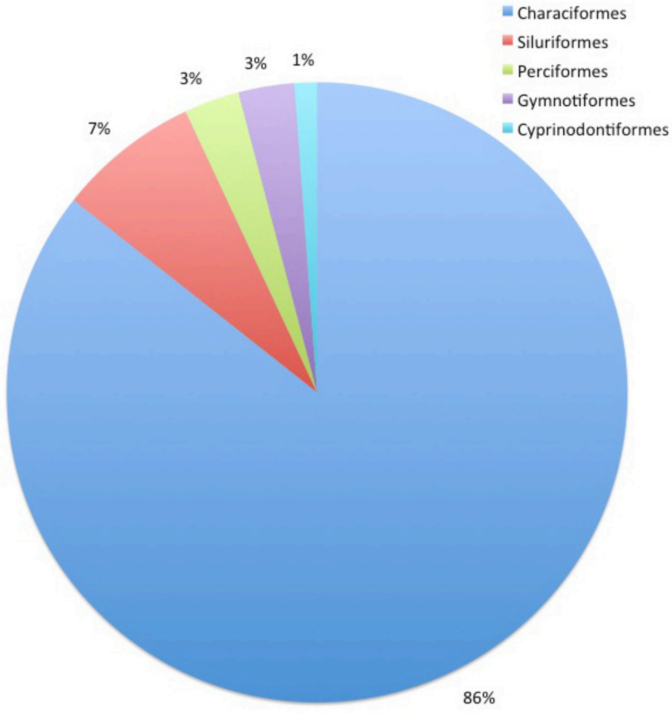

Figure 6. Relative abundance of number of species and number of individuals registered in each sample station in the four stations sampled, upper rio Tapajós basin.

Nine captured species (43%) were identified as "sp.", including two Characiformes, five (all) Heptapteridae and two (all) Gymnotiformes. Three of the Heptapteridae species, and the two Gymnotiformes species were herein recognized as undescribed species, however more undescribed species herein registered could be recognized in the future with additional research. Moreover, *Cetopsorhamdia* sp.1, *Cetopsorhamdia* sp.2 (Heptapteridae), *Brachyhypopomus* sp.n. and *Eigenmannia* sp.n. (Gymnotiformes) are currently under taxonomic revisions and preliminary examination indicates that they could represent new species endemic for the rio Juruena (Bockmann pers. communication for Heptapteridae and Ohara. personal observation for Gymnotiformes). Other four species (19%) were tentatively identified indicating that more taxonomic studies on the neotropical ichthyofauna are needed.

No threatened species were found, however four endemic species to the upper rio Tapajós basin were recorded. *Melanorivulus modestus*, and *H. nambiquara* are only known from the igarapé Mutum and *Hyphessobrycon notidanos* is only known from the igarapé 12 de Outubro. Even though *Hemigrammus skolioplatus* is known from both the igarapé Mutum and the igarapé 12 de Outubro, it occurs only in a small restricted area.

Discussion

Available literature records about the ichthyofauna of the rio Tapajós basin are primarily concerned with the description of new species (Bertaco & Malabarba 2007, Bertaco & Carvalho 2005a, b, Bertaco & Garutti 2007, Birindelli et al. 2008, Birindelli & Britski 2013, Birindelli et al. 2013, Britski & Garavello 1980, 1993, 2005, 2007, Britski & Lima 2008, Caires & Figueiredo 2011, Caires 2013, Calegari et al. 2013, Carvalho & Bertaco 2006, Castro 1993, Carvalho & Datovo 2012, Campos-da-Paz 2002, Costa 1991, 1994, 2007, Dagosta & Pastana 2014, Dagosta & Netto-Ferreira 2015, Dagosta et al. 2016, Eigenmann 1908, 1917, de Oliveira et al. 2010, 2016, Dutra et al. 2012, Espíndola et al. 2014, Fink 1979, Feitosa et al. 2011, Ferreira & Netto-Ferreira 2010, Fichberg et al. 2014, Fink 1979, Fisch-Muller et al. 2005a, b, Géry 1980, Hollanda-Carvalho & Weber 2005, Isbrücker & Nijessen 1989, Kullander 1988, Kullander 1990, Kullander & Ferreira 2006, Langeani 1999, Lima et al. 2007, 2009, 2014, Lima & Flausino 2016, Loeb 2012, Lucena 2003, Lujan et al. 2010, Lundberg & Mago-Leccia 1986, Marinho & Langeani 2010, Marinho & Lima 2009, Marinho et al. 2016a, b, Mendonça et al. 2016, Menezes 1987, 2006, Miranda-Ribeiro 1918, 1920, 1937, Moreira et al. 2002, Netto-Ferreira et al. 2009, Netto-Ferreira & Marinho 2013, Netto-Ferreira, Marinho & Vari 2011, Netto-Ferreira et al. 2014, Nijssen & Isbrücker 1976, 1987, Nijssen 1972, Oyakawa & Mattox 2009, Oliveira & Marinho 2016, Pastana & Dagosta 2014, Pereira & Castro 2014, Roberts 2013, Römer et al. 2010, Sabaj-Pérez & Birindelli 2013, Sarmento-Soares et al. 2013, Silva et al. 2014, Silva et al. 2015, Sousa et al. 2010, Scharcansky & Lucena 2007, Teixeira et al. 2014, 2016, Toledo-Piza et al. 1999, Varella et al. 2012, Vari 1989, Vari & Calegari 2014, Vari 1992, Vari et al. 2005, 2012, Vari & Goulding 1985, Weitzman et al. 2005, Weitzman 1978, Zanata 1997, Zanata et al. 2010, Zawadzki et al. 2015). However, a recent unpublished survey of the fishes from the lower and middle rio Teles Pires basin, recorded 355 species (Ohara & Lima pers. obs.). According to the authors, based on the available literature and the analyses of fish specimens deposited in museums at least 620 species may occur in the rio Tapajós basin, 12% of which are probably endemic.

A comparison of the species herein recorded and the fish assemblage from the lower portion of the rio Tapajós basin was performed based on the available literature (Ferreira et al. 1998, Camargo et al. 2005, Silva-Oliveira et al. 2016) and no common species between two portions was observed. The headwater streams seem to harbor a unique species assemblage due to observed differences in abiotic factors such as temperature, light, hydrologic regime, water chemistry, substrate type, food resources and species pool influenced by small-scale differences in local conditions (Meyer et al. 2007).

A high number of species and specimens were captured in the igarapé Mutum, with the highest values obtained for the survey undertaken in Station 1, and the lowest values in Station 2. On the other hand, a low number of species and specimens were captured in the igarapé 12 de Outubro. Differences on environmental heterogeneity and presence of riparian vegetation were herein registered, however, the number of species and specimens captured should not be compared within this survey due to the non-standardization of the sampling effort in the field trips.

Four endemic species to the upper rio Tapajós basin were herein registered, including *Hasemania nambiquara, Hemigrammus skolioplatus* Bertaco & Carvalho, 2005, *Hyphessobrycon notidanos* and *Melanorivulus modestus*. Although, *Hyphessobrycon hexastichos* and *H. melanostichos* have distribution range apparently restricted to the Chapada dos Parecis, they also were collected in the upper rio Guaporé (13º14’43”S 59º54’26”W), rio Madeira basin and in the igarapé Piracolina (12º49’58”S 60º06’34”W), upper rio Machado, rio Madeira basin (cf. Ohara & Lima 2015, Ohara & Marinho 2016, Ohara et al. 2016), respectively. So *Hyphessobrycon hexastichos* and *H. melanostichos* are not herein considered as endemic species for the upper rio Tapajós. According to Ohara & Lima (2015) a large number of fish species from the upper rio Juruena are found exclusively in the headwater rivers of the Chapada dos Parecis, which suggests that the area has apparently an endemic ichthyofauna that differs from rest of the rio Tapajós basin, including the rio Teles Pires.

Additionally, as stated by Meyer et al. (2007) fish fauna from headwater streams can make a significant contribution to regional fish diversity. The presence of a high number of endemic fish and at least five new species in a small portion of the upper rio Juruena indicates it as a hotspot area for fish diversity, and as such as having potential priority for conservation measures (Carvalho & Bertaco 2006, Britski & Lima 2008, Ohara & Lima 2015).

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Author Contributions

Substantial contribution in the concept and design of the study: WMO

Contribution to data collection: WMO

Contribution to data analysis and interpretation: ML

Contribution to manuscript preparation: WMO; ML

Contribution to critical revision, adding intelectual content: WMO; ML

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Biodiversity of benthic macroinvertebrates on hard substrates in the Currais Marine Protected Area, in southern Brazil

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Abstract: This study describes the biodiversity of benthic invertebrates on hard substrates in the Currais Marine Protected Area (Currais MPA), in the state of Paraná. The benthic community was sampled during 2012 to 2015, in winter and summer, at two islands and four groups of artificial reefs (ARs). Samples were collected along shallow (2-4 m) and deep (6-8 m) transects at the islands and ~18 m transects at the ARs. We also searched the literature to review all published records of benthic invertebrates on hard substrates in the Currais MPA. We recorded 176 taxa in the phyla Annelida (class Polychaeta), Arthropoda (class Maxillopoda, order Sessilia), Bryozoa, Cnidaria, Chordata (class Ascidiacea), Echinodermata, Mollusca and Porifera, in 13 classes, 40 orders and 75 families. With these 102 new records, our list comprises 58% of all recorded species. Of these, 58 taxa were first records for the state of Paraná. This remarkable number of new records highlights that biodiversity studies are lacking in Paraná. Fifteen non-indigenous species and one endangered species, the sea star *Coscinasterias tenuispina* (Lamarck, 1816), are included. This is an important transitional area to monitor expansion or constriction of the latitudinal distributions of species, in the context of climate change, that may influence the geographical distribution of species (both native and invasive). This study is the first inventory of marine hard substrate habitats of the Currais MPA with a surprisingly diverse community.

Keywords: *benthic invertebrates, exotic species, inventory, marine conservation, Paraná coast.*

Biodiversidade da comunidade bêntica de ambientes rochosos na Área Marinha Protegida de Currais, sul do Brasil.

Resumo: Este estudo descreve a biodiversidade da comunidade de invertebrados bênticos de ambientes rochosos da Área Marinha Protegida de Currais (AMP Currais), localizada no estado do Paraná. A comunidade bêntica foi amostrada entre 2012 e 2015, durante períodos de inverno e verão, em duas ilhas e quatro grupos de recifes artificiais (RAs). As amostras foram obtidas em transecções rasas (2-4 m) e mais profundas (6-8 m) nas ilhas e a ~18 m nos RAs. Também foi realizada uma pesquisa bibliográfica para examinar todos os registros de invertebrados bênticos publicados para a área da AMP Currais. Foram encontrados 176 táxons pertencentes aos filos Annelida (classe Polychaeta), Arthropoda (classe Maxillopoda, ordem Sessilia), Bryozoa, Cnidaria, Chordata (classe Ascidiacea), Echinodermata, Mollusca e Porifera, distribuídos em 13 classes, 40 ordens e 75 famílias. Há 102 novos registros para a área, representando 58% de todas as espécies registradas. Destes, 58 táxons não haviam sido registrados anteriormente no estado do Paraná. Este notável número de novos registros revela a falta de estudos sobre a biodiversidade no litoral do Paraná. Quinze espécies exóticas foram encontradas, e uma espécie em extinção, a estrela-do-mar *Coscinasterias tenuispina*. Esta é uma importante área de transição para acompanhar a expansão ou constrição da distribuição latitudinal das espécies, considerando as alterações climáticas que poderão influenciar na distribuição geográfica das espécies (tanto nativas quanto invasoras). O presente estudo constitui o primeiro inventário dos habitats de substrato rochoso da AMP Currais e revela grande biodiversidade.

Palavras-chave: *invertebrados bênticos, espécies exóticas, inventário, conservação marinha, litoral do Paraná.*

Introduction

The National Marine Park of Currais Islands is a new Marine Protected Area (MPA, hereafter Currais MPA) that was created in 2013 (Brazilian federal law number 12.829, Brasil 2013). It is the first MPA in the category National Marine Park in the state of Paraná and the third in Brazil (the other two are Abrolhos and Fernando de Noronha, both in northeastern Brazil). Currais MPA is in an area of large economical and ecological importance, because of a major commercial port with international traffic of container ships and oil tankers and because of the extensive system of estuaries with mangroves. The creation of the Currais MPA was based on its importance for seabird breeding (Krul 2004, Carniel & Krul 2010). Previous studies of the marine environment tended to focus on the ichthyofauna (Félix & Harckradt 2008, Félix-Hackradt & Hackradt 2008, Harckradt & Félix-Harckradt 2009, Daros et al. 2012). Only one study examined the soft bottom infauna (Lorenzi & Borzone 2009), three examined benthic invertebrates on hard substrates, one of ascidians (Rocha & Faria 2005) and two experimental studies on temporal colonization of artificial substrates near the islands (Brandini & Silva 2011, Bumbeer & Rocha 2012). Since the creation of the MPA, there has been only one study of marine biota, which examined the algal community (Pellizzari et al. 2014). On a larger scale, invertebrates of hard substrates are very poorly studied along the entire coast of Paraná, and is a major gap in the understanding of species distributions in Brazil.

Hard substrates such as those typically present around coastal islands, rocky shores and calcareous bottoms are uncommon in coastal Paraná. Thus, Currais MPA is ecologically relevant for its hard substrate for communities adapted to reef-like habitats, and because it is less impacted as nearer the mainland. Also, Currais islands was at one time (prior to creation of the MPA) an important area for both recreational and artisanal fisheries and also the main site for recreational scuba diving in Paraná. The Currais MPA is also under the influence of continental drainage from the Paranaguá Estuarine Complex, with anthropogenic impact that potentially threatens local biodiversity, such as contamination by urban and industrial development (Noernberg et al. 2008, Possatto et al. 2014) and bioinvasions (Bumbeer & Rocha 2016). Indeed, the presence of a large port with its ship traffic probably favors the spread of non-indigenous species (NIS) to the open coastal environment, including Currais MPA (Bumbeer & Rocha 2016).

Understanding the benthic communities on hard substrates is critical because this environment has been heavily disturbed by human activities, potentially leading to decline in biodiversity and to irreversible loss of biological information. Despite this importance, three years after its establishment, no management plan has been developed for MPA Currais. During the same time interval, development on the mainland has been growing rapidly, including the construction of a new port for containers that will increase by 55% the port capacity in the state and is scheduled to start activities in 2018 (http://portopontal.com.br). Therefore, in this scenario it is clear that establishing baselines of community composition and distribution on all types of habitats is very important within MPA Currais, including benthic communities, in order to monitor and understand future changes. Here we provide the first inventory of the benthic macroinvertebrate species on hard substrates of the Marine Protected Area of Currais, including the sessile community and sedentary vagile organisms (i.e., Gastropoda, Polychaeta and Echinodermata).

Material and Methods

The National Marine Park of Currais Islands is located 6.2 miles from the coast, between two estuaries, Guaratuba Bay and the Paranaguá Estuarine Complex (Figure 1). With a total area of 1400 ha, the MPA includes three islands (Grapirá, Três Picos and Filhote) and four groups of artificial reefs (ARs) (concrete blocks placed on the seabed to provide new environments for encrusting communities). The depth along the archipelago varies from 1.5 to 16 m, with natural hard substrates usually up 10 m. The inclination of the rocky shores is moderate, between 45° and 60° (Daros et al. 2012). The artificial reefs were placed in 1997 on the sandy bottom at a depth around 18 m.

The benthic community was sampled at two islands, Grapirá and Três Picos, and four ARs. Sites of different depth and wave exposure were sampled to include a wider variety of environmental conditions. At each island, two sites were chosen, one exposed to the open sea and another sheltered from the main wave train by the island. Each of the four sites

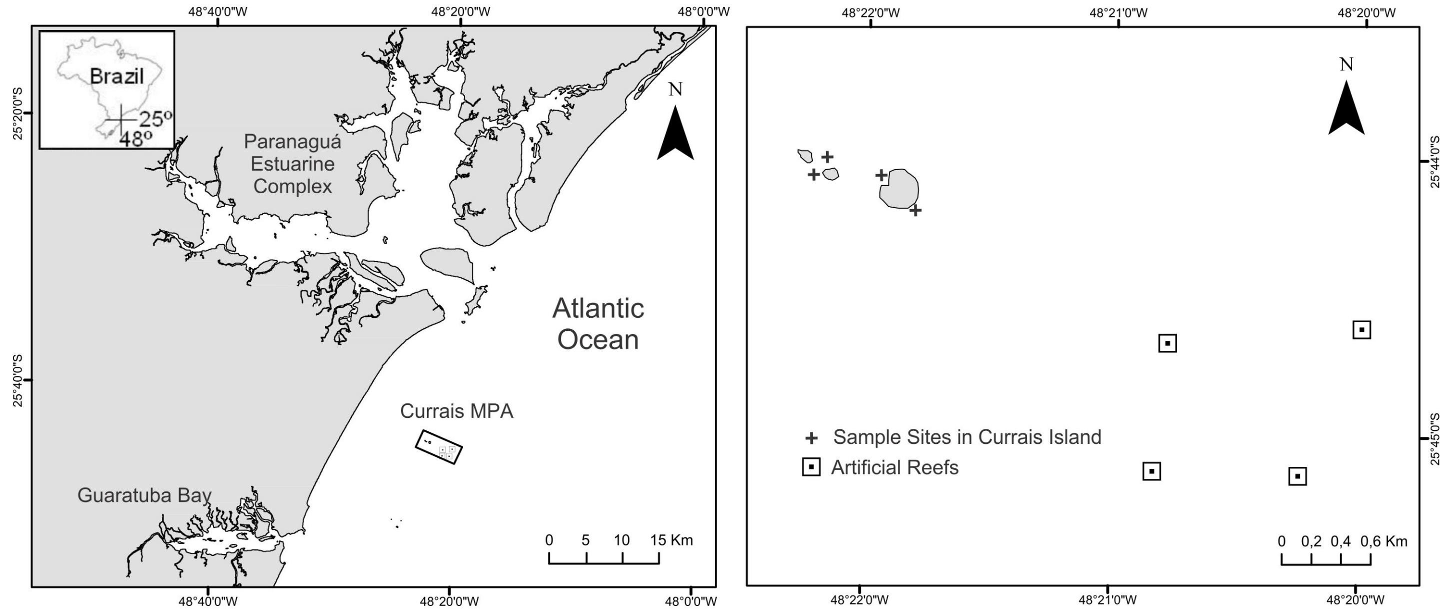

Figure 1. The Marine Protected Area of Currais Islands and the sampling sites. Left: the location and area of the MPA in the Paraná coast. Right: detail of the sampling sites inside the MPA.

were surveyed in shallow (around 2 - 4 m) and deep (6 - 8 m) transects, while artificial reef sites were surveyed in two transects at ~18 m (Table 1).

Sites were sampled during 37 SCUBA dives, between July 2012 and January 2015 (Table 1), during summer and winter to include possible seasonal variation in abundance of species. During dives, we actively searched for all relevant species within the area of the transect (20 m long vs. 2 m wide), photographed and individuals and colonies were manually collected for identification. Horizontal, vertical and negative surfaces were sampled, as well as crevices and under rocks. Upon collection, samples were treated with a menthol solution in seawater for relaxation of the fauna and were subsequently fixed in 4% formalin for taxonomical study by specialists. The Mollusca were deposited in the Zoology Museum of University of São Paulo (MZUSP), Porifera in the National Museum of University of Rio de Janeiro (MN-UFRJ), Cnidaria and Tunicata in the collection of the Zoology Department of the Federal University of Paraná (DZUP).

Table 1. Number of transects and collecting dates (in day/month/year format) per sampling site.

Sampling Sites	Coordinates	Date	# of Transects
Currais Islands			
Grapirá Exposed	25º 44’ 06”S, 48º 21’ 59”W	24/07/2012	2
		18/12/2012	2
		06/06/2013	2
		17/12/2013	2
		26/06/2014	2
		08/01/2015	2
Grapirá Protected	25º 44’ 04”S, 48º 21’ 50”W	24/07/2012	2
		18/12/2012	2
		06/06/2013	2
		17/12/2013	2
		26/06/2014	2
		08/01/2015	2
Três Picos Exposed	25º 44’ 06”S, 48º 22’ 16”W	24/07/2012	2
		18/12/2012	2
		06/06/2013	1
		17/12/2013	2
		26/06/2014	2
		08/01/2015	2
Três Picos Protected	25º 44’ 01”S, 48º 22’ 13”W	24/07/2012	2
		18/12/2012	2
		06/06/2013	2
		17/12/2013	2
		26/06/2014	2
		08/01/2015	2
Artificial Reefs			
AR1	25º 44’ 04”S, 48º 20’ 46”W	13/12/2012	2
		13/02/2013	2
		17/12/2013	2
		07/01/2015	2
AR2	25º 44’ 36”S, 48º 20’ 46”W	13/06/2013	2
		17/12/2013	2
AR3	25º 45’ 08”S, 48º 20’ 14”W	13/02/2013	2
		13/06/2013	2
		17/12/2013	2
		31/07/2014	2
		07/01/2015	2
AR4	25º 45’ 08”S, 48º 20’ 50”W	13/12/2012	2
		13/06/2013	2

A search of the literature was also conducted to review all published records of benthic invertebrates on hard substrates in the area of the Currais MPA. The species recorded on both field survey and previous studies were indicated if found in natural substrata of islands, ARs or recruitment plates. The status of bioinvasion and endangered species were also indicated according to literature and Brazilian official lists (Lopes 2009, MMA 445/14).

Results

We found 132 taxa in this survey, with 99 found on the hard substrates of the islands and 122 on artificial substrata (86 in AR and 57 in recruitment plates). Only 45 were common to both natural and artificial substrates (Table 2). Of the 132 taxa sampled, 76 were found in both winter and summer, 22 only in summer and 34 only in winter (Table 2). Currently, a total of 176 taxa, comprising the phyla Porifera, Cnidaria, Bryozoa, Mollusca, Annelida (class Polychaeta), Arthropoda (class Maxillopoda, order Sessilia), Echinodermata and Chordata (class Ascidiacea), including 13 classes, 40 orders and 75 families, have been recorded in Currais MPA (Figures 2-5, Table 2). The most common groups were Mollusca (21 bivalves and 21 gastropods), Cnidaria (13 anthozoans and 22 hydrozoans), Ascidiacea (25 taxa), Porifera (23 taxa), Polychaeta (22 taxa), Bryozoa (14 taxa), Sessilia and Echinodermata with eight taxa each.

New records (n = 102) for the MPA area include 58% of all recorded species. Of these, 58 were not previously recorded for Paraná. Except Arthropoda, new records were found for all phyla, mainly Porifera (n = 20). Additionally, some species have not yet been described. Examples in Polychaeta are a Lumbrineridae (genus *Lumbricalus*) found at both islands and ARs and a bluish Nereididae, found only in the ARs. In the Ascidiacea, a new didemnid has a peculiar zebra-striped pattern (*Didemnum* sp.1), and which was previously found in the area and the neighbors states of São Paulo and Santa Catarina (R.M. Rocha, unpublished data) and a transparent *Eudistoma* in small colonies that were usually attached to red coralligenous algae.

Fifteen non-indigenous species were recorded, including three new records for Currais MPA: *Ophiothela mirabilis* Verrill, 1867, *Didemnum perlucidum* Monniot F., 1983 and *Myoforceps aristatus* (Dillwyn, 1817) (also known as *Lithophaga aristata* and *Leisolenus aristatus*). Also, one endangered sea star *Coscinasterias tenuispina* (Lamarck, 1816) is considered vulnerable by the most recent statement of the Environmental Ministry (MMA 445/14).

Discussion

In this first comprehensive list of the benthic invertebrates on hard substrates of the Currais MPA, many species first records for the state of Paraná. Previous reports of the biodiversity of Currais MPA were superficial and so as a consequence, our field survey increases by 58% the number of species found there. Some of these new records had been found in the neighbor states of São Paulo and Santa Catarina, and so were not surprising.

Most bryozoans have taxonomic issues to be solved before being able to identify species. The unidentified ascidians are new species in the process of being described in our lab. *Diplosoma* sp., however, will require further sampling in order to identify the species. Some polychaetes are new species, while features to identify some others are lacking. Many sponges are difficult to identify without extensive study of internal anatomy, for which more samples are needed. Thus, 32 taxa remain unidentifiable, which further emphasizes the importance of continued studies in this region.

The differences between taxa found at the islands on natural substrates and those found on artificial substrates were not very surprising. Artificial reefs of concrete to attempt mimicking the natural substrate still have different shapes and textures and they were simply laid on the seabed at

Table 2. List of macroinvertebrate taxa from the sublitoral hard habitats of the Currais Marine Protected Area. Introduced species are indicated in bold type

Phylum/Class	Order	Family	Species	Season[1]	Habitat[2]			References [3]	Voucher number [4]
					Islands	ARs	RP		
PORIFERA									
Calcarea	Clathrinida	Clathrinidae	*Clathrina conifera* Klautau & Borojevic, 2001	S/W	x				UFRJPOR 8717
Demospongiae	Chondrosida	Chondrillidae	*Chondrilla* cf. *nucula* Schmidt, 1862	S/W	x	x			MNRJ 20751
	Clionaida	Clionaidae	*Cliona celata* Grant, 1826	S/W		x			MNRJ 20575
	Hadromerida	Polymastiidae	*Polymastia janeirensis* (Boury-Esnault, 1973)	S/W	x				
	Hadromerida	Suberitidae	*Protosuberites* sp.	S/W	x				MNRJ 20571
			Pseudosuberites sp.	S/W	x				MNRJ 20745
			Terpios manglaris Rützler & Smith, 1993	S/W	x				MNRJ 20752
	Halichondrida	Axinellidae	*Axinella corrugata* (George & Wilson, 1919)	S/W	x				MNRJ 20757
			Dragmacidon reticulatum (Ridley & Dendy, 1886)	S/W	x				MNRJ 20574
		Halichondriidae	*Axinyssa* sp.	S	x				MNRJ 20749
			Halichondria sp.	S/W	x				MNRJ 20740
		Scopalinidae	*Scopalina ruetzleri* (Wiedenmayer, 1977)	S/W	x				MNRJ 20741, 20742
	Haplosclerida	Callyspongiidae	*Callyspongia (Callyspongia)* sp.	S/W	x				
		Chalinidae	*Haliclona (Haliclona)* sp.	S	x	x			MNRJ 20569
		Niphatidae	*Amphimedon* sp.	S	x				MNRJ 20754, 20755
		Petrosiidae	*Petrosiidae*	S	x				MNRJ 20747
	Poecilosclerida	Microcionidae	*Clathria* sp.	S/W	x				MNRJ 20746
		Mycalidae	*Mycale (Carmia) microsigmatosa* Arndt, 1927 *	S/W		x	x	1	
			Mycale (Zygomycale) angulosa (Duchassaing & Michelotti, 1864) *	S/W	x	x			MNRJ 20570, 20736
			Mycale magnirhaphidifera van Soest, 1984 *	-		x	x	1	
		Tedaniidae	*Tedania ignis* (Duchassaing & Michelotti, 1864)	S/W	x	x			MNRJ 20572
	Verongida	Aplysinidae	*Aplysina caissara* Pinheiro & Hajdu, 2001	W	x				MNRJ 20758
Homoscleromorpha	Homosclerophorida	Plakinidae	*Plakinastrella* sp.	S/W	x	x			MNRJ 20743
CNIDARIA									
Anthozoa	Actiniaria	Actiniidae	*Actinostella flosculifera* (Le Sueur, 1817)	S/W	x				
			Bunodosoma caissarum Corrêa in Belém, 1987	S/W	x				
			Bunodosoma cangicum Belém & Preslercravo, 1973	S/W	x	x			
	Alcyonacea	Clavulariidae	***Carijoa riisei* (Duchassaing & Michelotti, 1860)** *	S/W	x	x	x	1,2	
			***Stragulum bicolor* Ofwegen & Haddad, 2001** *	-			x	2	
		Gorgoniidae	*Leptogorgia punicea* (Milne Edwards & Haime, 1857)	S/W	x	x			DZUP-Cn 0900
	Ceriantharia	Cerianthidae	*Ceriantheomorphe brasiliensis* Carlgren, 1931	S/W		x			
	Scleractinia	Astrocoeniidae	*Madracis decactis* (Lyman, 1859) *	-		x	x	1	
		Caryophylliidae	*Phyllangia americana* Milne Edwards & Haime, 1849 *	S		x	x	1	DZUP-Cn 0903
		Rhizangiidae	*Astrangia rathbuni* Vaughan, 1906 *	S/W	x	x	x	1	DZUP-Cn 0901
	Zoantharia	Parazoanthidae	*Parazoanthus swiftii* (Duchassaing & Michelotti, 1860)	S/W	x				
		Sphenopidae	*Palythoa caribaeorum* (Duchassaing & Michelotti, 1860) *	S/W	x		x	1	
			Palythoa variabilis (Duerden, 1898)	S/W	x				
Hydrozoa	Anthoathecata	Bougainvilliidae	*Bimeria vestita* Wright, 1859 *	-			x	2	
			Bougainvillia muscus (Allman, 1863) *	-			x	2	

[1] The season assigned are related only to this field survey: S = summer, W = winter , S/W = summer and winter.

[2] Islands = natural rocky shores, ARs = artificial reefs ,RP = recruitment plates.

[3] 1= Brandini & Silva 2011, 2= Bumbeer & Rocha 2012, 3= Rocha & Farias 2005.

[4] MNRJ = Museu Nacional Rio de Janeiro, MZSP= Museu de Zoologia, Universidade de São Paulo, DZUP= Departamento de Zoologia, Universidade Federal do Paraná, ZUEC= Museu de Zoologia da UNICAMP

* previous records for Currais MPA. NIS in bold type

Table 2. Continued...

Phylum/Class	Order	Family	Species	Season[1]	Habitat[2]			References [3]	Voucher number [4]
					Islands	ARs	RP		
			Bougainvillia rugosa Clarke, 1882 *	-			x	1	
			Garveia franciscana **(Torrey, 1902)** *	-			x	2	
		Eudendriidae	*Eudendrium carneum* Clarke, 1882	S		x			DZUP-Cn 0216
		Oceaniidae	*Corydendrium parasiticum* (Linnaeus, 1767) *	-			x	2	
			Turritopsis nutricula McCrady, 1857 *	-			x	2	
		Pennariidae	*Pennaria disticha* Goldfuss, 1820 *	-			x	1, 2	
	Leptothecata	Aglaopheniidae	*Aglaophenia latecarinata* Allman, 1877	S		x			DZUP-Cn 0217
			Gymnangium allmani (Marktanner-Turneretscher, 1890)						DZUP-Cn 0212
			Macrorhynchia philippina Kirchenpauer, 1872	S/W	x	x			DZUP-Cn 0201
		Campanulariidae	*Clytia gracilis* (Sars, 1850) *	-			x	1	
			Obelia bidentata Clark, 1875 *	S/W	x	x	x	2	
			Obelia dichotoma (Linnaeus, 1758) *	S/W	x	x	x	2	
		Cirrholoveniidae	*Cirrholovenia tetranema* Kramp, 1959 *	-			x	2	
		Kirchenpaueriidae	*Kirchenpaueria halecioides* (Alder, 1859)	S		x			DZUP-Cn 0209
		Plumariidae	*Dentitheca* sp. *	-			x	1	
		Sertulariidae	*Dynamena dalmasi* (Versluys, 1899) *	-			x	2	
			Idiellana pristis (Lamouroux, 1816)	S/W		x			DZUP-Cn 0207
			Sertularia marginata (Kirchenpauer, 1864)	S/W	x	x			DZUP-Cn 0213
			Sertularia turbinata (Lamouroux, 1816)	S/W	x	x			
		Tubulariidae	*Ectopleura dumortierii* (Van Beneden, 1844) *	-			x	2	
BRYOZOA									
Gymnolaemata	Cheilostomatida	Aeteidae	*Aetea* sp. *	S/W		x	x	2	
		Bugulidae	*Crisularia bowiei* (Vieira, Winston & Fehlauer-Ale, 2012)	W		x			
		Candidae	*Licornia* sp.	S/W	x	x			
		Catenicellidae	*Catenicella uberrima* (Harmer, 1957)	S/W	x	x			
		Epistomiidae	*Synnotum* sp. *	S/W		x	x	2	
		Hippopodinidae	*Hippoporina indica* Madhavan Pillai, 1978	W		x			
		Membraniporidae	*Biflustra arborescens* (Canu & Bassler, 1928) *	-			x	2	
		Membraniporidae	*Biflustra denticulata* (Busk, 1856) *	-			x	2	
		Phidoloporidae	*Rhynchozoon* sp.	S/W		x			
		Quadricellariidae	*Nellia* sp.	W		x			
		Savignyellidae	*Savignyella lafontii* (Audouin, 1826)	W		x			
		Schizoporellidae	*Schizoporella* sp. *	-			x	1	
	Ctenostomatida	Vesiculariidae	*Amathia* sp.	S		x			
Stenolaemata	Cyclostomatida	Crisiidae	*Crisia* sp.	S/W	x	x			
MOLLUSCA									
Bivalvia	Arcida	Arcidae	*Arca imbricata* Bruguière, 1789 *	W		x	x	1	MZSP118701
			Barbatia candida (Helbling, 1779)	S/W	x	x			MZSP115113
			Bathyarca pectunculoides (Scacchi, 1835) *	-			x	2	

[1] The season assigned are related only to this field survey: S = summer, W = winter , S/W = summer and winter.

[2] Islands = natural rocky shores, ARs = artificial reefs ,RP = recruitment plates.

[3] 1= Brandini & Silva 2011, 2= Bumbeer & Rocha 2012, 3= Rocha & Farias 2005.

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* previous records for Currais MPA. NIS in bold type

Table 2. Continued...

Phylum/Class	Order	Family	Species	Season[1]	Habitat[2]			References [3]	Voucher number [4]
					Islands	ARs	RP		
			Lunarca ovalis (Bruguière, 1789) *	S/W	x	x	x	2	MZSP115153
	Carditida	Carditidae	*Carditamera* sp.*	-			x	1	
	Imparidentia (Superorder)	Chamidae	*Arcinella brasiliana* (Nicol, 1953) *	-			x	2	
			Chama sp.*	-			x	1	
	Myoida	Myidae	*Sphenia fragilis* (H. Adams & A. Adams, 1854) *	S/W	x	x	x		
	Mytilida	Mytilidae	*Brachidontes rodriguezii* (d'Orbigny, 1842)	W		x			MZSP115160
			Leiosolenus bisulcatus (d'Orbigny, 1853)	W		x			
			Modiolus carvalhoi Klappenbach, 1966 *	S/W	x	x	x	1	MZSP115112, 115115
			Musculus viator (d'Orbigny, 1842) *	W	x		x	2	
			***Myoforceps aristatus* (Dillwyn, 1817)**	S/W	x	x			MZSP115111
			Mytella bicolor (Bruguière, 1792) *	-			x	2	
	Ostreida	Ostreidae	*Ostrea puelchana* d'Orbigny, 1842 *	S/W		x	x	1	MZSP121807, 118707
		Pinnnidae	*Atrina seminuda* (Lamarck, 1819) *	-			x	2	
		Pteriidae	*Pteria colymbus* (Röding, 1798) *	S/W	x	x	x	2	MZSP118700
	Pectinida	Pectinidae	*Paraleptopecten bavayi* (Dautzenberg, 1900) *	S	x	x	x	2	
			Nodipecten nodosus (Linnaeus, 1758) *	-			x	1	
	Veneroida	Semelidae	*Semele proficua* (Pulteney, 1799)	W	x				MZSP115126
			Spondylus americanus Hermann, 1781 *	-			x	1	
Gastropoda	Caenogastropoda	Cerithiidae	*Bittiolum varium* (Pfeiffer, 1840)	S/W	x	x			MZSP115119
			Cerithium atratum (Born, 1778)	S/W	x				MZSP115156, 115157
	Littorinimorpha	Calyptraeidae	*Crepidula* sp.*	-			x	1	
		Naticidae	*Polinices hepaticus* (Röding, 1798)	S		x			MZSP115104
		Ranellidae	*Monoplex parthenopeus* (Salis Marschlins, 1793)	W		x			
	Neogastropoda	Columbellidae	*Anachis lyrata* (G. B. Sowerby I, 1832) *	-			x	2	
			Astyris lunata (Say, 1826) *	-			x	2	
			Costoanachis sertulariarum (d'Orbigny, 1839)	S/W	x	x			
			Costoanachis sparsa (Reeve, 1859)	S/W	x				MZSP115155
		Mangeliidae	*Cryoturris adamsii* (E. A. Smith, 1884)	W		x			MZSP115105
			Ithycythara cf. *hyperlepta* Haas, 1953	W		x			MZSP115108
		Muricidae	*Coralliophila aberrans* (C. B. Adams, 1850)	W		x			MZSP115110
			Stramonita brasiliensis Claremont & D. G. Reid, 2011	S/W		x			MZSP115159, 118712
			Morula nodulosa (C. B. Adams, 1845)	S/W	x				MZSP115117
			Trachypollia turricula (Maltzan, 1884)	W		x			MZSP115109
		Nassariidae	*Nassarius albus* (Say, 1826)	W		x			MZSP115103
		Olividae	*Americoliva circinata* (Marrat, 1871)	W		x			MZSP115104
			Olivella defiorei Klappenbach, 1964	W		x			MZSP115107

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[2] Islands = natural rocky shores, ARs = artificial reefs ,RP = recruitment plates.

[3] 1= Brandini & Silva 2011, 2= Bumbeer & Rocha 2012, 3= Rocha & Farias 2005.

[4] MNRJ = Museu Nacional Rio de Janeiro, MZSP= Museu de Zoologia, Universidade de São Paulo, DZUP= Departamento de Zoologia, Universidade Federal do Paraná, ZUEC= Museu de Zoologia da UNICAMP

* previous records for Currais MPA. NIS in bold type

Table 2. Continued...

Phylum/Class	Order	Family	Species	Season[1]	Habitat[2]			References [3]	Voucher number [4]
					Islands	ARs	RP		
		Terebridae	*Hastula hastata* (Gmelin, 1791)	S		x			MZSP115106
	Trochidae	Calliostomatidae	*Calliostoma moscatellii* Quinn, 1992	W		x			MZSP118702
	Vetigastropoda	Fissurellidae	*Diodora patagonica* (d'Orbigny, 1839)	W		x			MZSP115101
ANNELIDA									
Polychaeta	Eunicida	Eunicidae	*Nicidion cariboea* (Grube, 1856)	S/W	x	x			ZUEC-18928, 18952, 18957
			Eunice vittata (Delle Chiaje, 1828)	S/W	x	x			ZUEC-18929, 18943
			Lysidice cf. *ninetta* Audouin & H Milne Edwards, 1833	S	x				ZUEC-18931
		Lumbrineridae	*Lumbricalus* sp.	S/W	x				ZUEC-18964, 18973
	Phyllodocida	Nereididae	*Nereis riisei* Grube, 1857	W	x				ZUEC-18974
			Nereis zonata Malmgren, 1867	W	x				ZUEC-18956
			Nereididae sp.	S		x			ZUEC-18979
			Platynereis sp.	W	x				ZUEC-18965, 18966, 18967
		Polynoidae	*Eunoe serrata* Amaral & Nonato, 1985 *	W	x		x	2	ZUEC-18977
			Subadyte pellucida (Ehlers, 1864)	S		x			ZUEC-18959
		Syllidae	*Opisthosyllis* sp.	W	x				ZUEC-18968
			Syllis gracilis	W	x				ZUEC-18970
			Syllis sp.	S/W	x	x			ZUEC-18975
			Trypanosyllis zebra (Grube, 1860)	W	x				ZUEC-18972
	Sabellida	Serpulidae	*Hydroides dirampha* Mörch, 1863	W		x			
		Sabellariidae	*Sabellaria wilsoni* Lana & Gruet, 1989	S/W		x			ZUEC-18969,18980
	Terebellida	Cirratulidae	*Caulleriella* sp.	W	x	x			ZUEC-18945, 18953
		Terebellidae	*Nicolea* sp.	S/W	x	x			ZUEC-18937, 18939,18971
			Pista sp.	S	x				ZUEC-18930
			Streblosoma sp.	W	x	x			ZUEC-18938, 18940, 18944
		Trichobranchidae	*Terebellides* sp.	S		x			ZUEC-18981
		Cirratulidae	*Timarete* sp.	S/W	x	x			ZUEC-18932, 18936
ARTHROPODA									
Maxillopoda	Sessilia	Archaeobalanidae	***Striatobalanus amaryllis* (Darwin, 1854)** *	S/W		x	x	2	
		Balanidae	***Amphibalanus amphitrite* (Darwin, 1854)** *	S/W		x	x	2	
			Amphibalanus eburneus (Gould, 1841) *	-			x	2	
			Amphibalanus improvisus (Darwin, 1854) *	-			x	2	
			***Amphibalanus reticulatus* (Utinomi, 1967)** *	S		x	x	2	

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Table 2. Continued...

Phylum/Class	Order	Family	Species	Season[1]	Habitat[2]			References [3]	Voucher number [4]
					Islands	ARs	RP		
			***Balanus trigonus* Darwin, 1854** *	S		x	x	2	
			Chthamalus bisinuatus (Pilsbry, 1916) *	-			x	2	
			***Megabalanus coccopoma* (Darwin, 1854)** *	-			x	2	
ECHINODERMATA									
Asteroidea	Forcipulatida	Asteriidae	*Coscinasterias tenuispina* (Lamarck, 1816)	S/W	x				
	Spinulosida	Echinasteridae	*Echinaster (Othilia) brasiliensis* Müller & Troschel, 1842	S/W	x				
Crinoidea	Comatulida	Tropiometridae	*Tropiometra carinata* (Lamarck, 1816)	S/W	x				
Echinoidea	Arbacioida	Arbaciidae	*Arbacia lixula* (Linnaeus, 1758)	S/W	x	x			
	Camarodonta	Echinometridae	*Echinometra lucunter* (Linnaeus, 1758)	S/W	x	x			
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria (Halodeima) grisea* Selenka, 1867	S/W	x				
		Stichopodidae	*Isostichopus badionotus* (Selenka, 1867)	S/W	x				
Ophiuroidea	Ophiurida	Ophiotrichidae	***Ophiothela mirabilis* Verrill, 1867**	S/W	x	x			
CHORDATA									
Ascidiacea	Aplousobranchia	Clavelinidae	***Clavelina oblonga* Herdman, 1880** *	S/W	x			3	DZUP-Cla59,60
		Didemnidae	*Didemnum granulatum* Tokioka, 1954 *	S/W	x			3	DZUP-Did464, 465, 466, 467
			***Didemnum perlucidum* Monniot F., 1983**	S	x				DZUP-Did473
			Didemnum rodriguesi Rocha & Monniot F., 1993 *	-	x			3	
			Didemnum speciosum (Herdman, 1886) *	-	x			3	
			Didemnum sp.1*	S/W	x			3	
			Didemnum sp.2	S/W	x				
			Didemnum sp.3	W	x				
			Diplosoma listerianum (Milne Edwards, 1841) *	S/W	x	x		3	
			Diplosoma sp.	-	x			3	
			Lissoclinum sp.*	-	x			3	
			Polysyncraton aff. *amethysteum* Van Name, 1902 *	-	x			3	
			Trididemnum orbiculatum (Van Name, 1902) *	S	x	x		3	DZUP-Tri23
		Polyclinidae	***Aplidium pentatrema* (Monniot F., 1972)** *	-	x			3	
			***Eudistoma carolinense* Van Name, 1945** *	-	x			3	
			Eudistoma sp. *	-	x			3	
	Phlebobranchia	Ascidiidae	***Ascidia tenue* Monniot C., 1983** *	-			x	2	
		Perophoridae	*Perophora regina* Goodbody & Cole, 1987 *	S	x			3	
	Stolidobranchia	Molguliidae	*Molgula salvadori* Monniot C., 1970 *	-	x		x	2, 3	
		Pyuridae	*Microcosmus exasperatus* Heller, 1878 *	S/W	x	x		3	DZUP-Mic90, 93
		Styelidae	*Botrylloides nigrum* Herdman, 1886	W		x			DZUP-Botd50
			Botryllus tuberatus Ritter & Forsyth, 1917 *	-	x			3	
			Polyandrocarpa anguinea (Sluiter, 1898) *	W	x	x		3	DZUP-Podc22
			Symplegma brakenhielmi (Michaelsen, 1904) *	W	x			3	DZUP-Symp52
			Symplegma rubra Monniot C., 1972	S/W	x	x			DZUP-Symp41, 51

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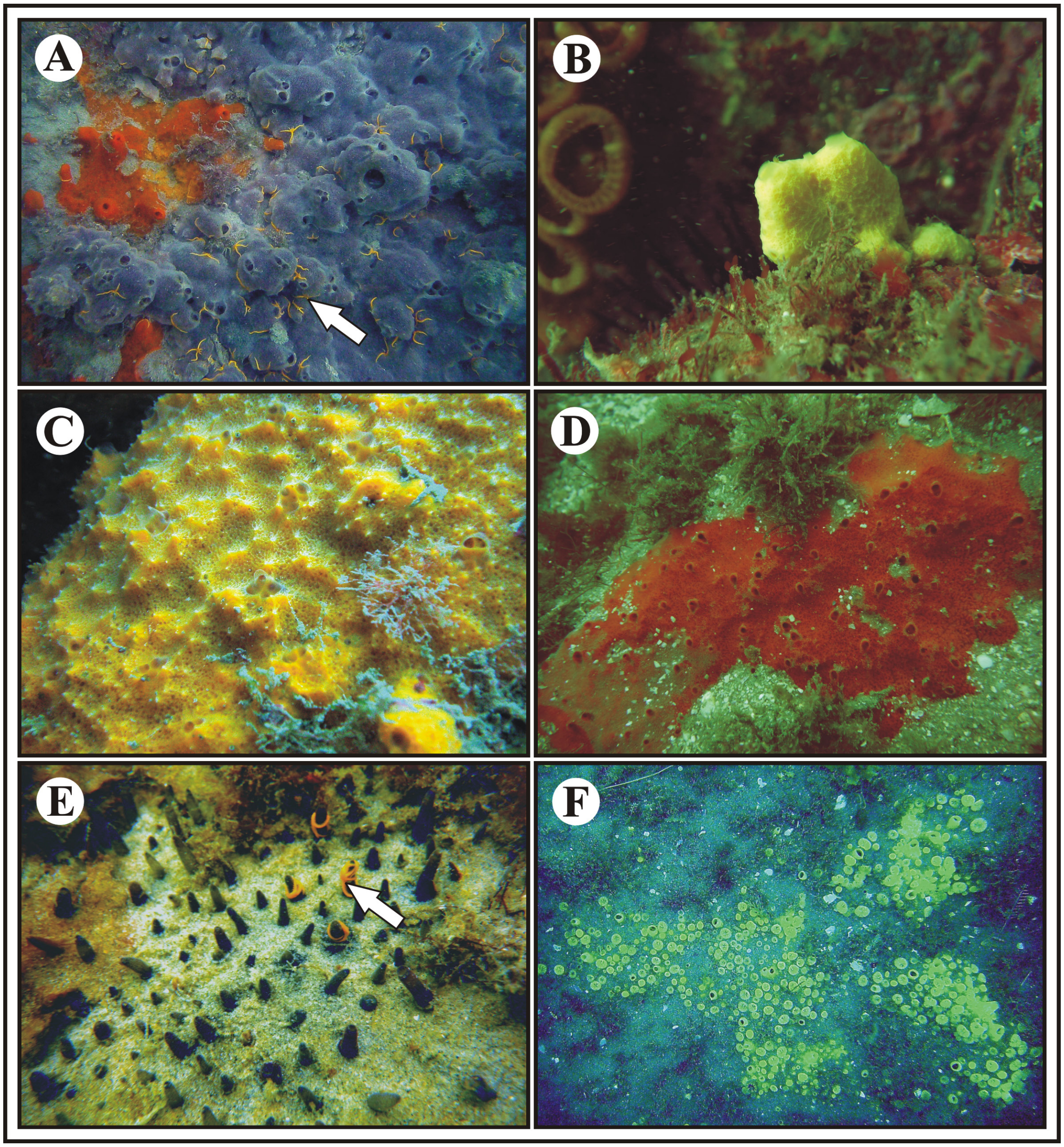

Figure 2. Sponges of Currais MPA: (A) *Mycale (Zygomicale) angulosa* (blue colony) and *Tedania ignis* (orange colony), (B) *Aplysina* cf. *caissara*, (C) *Scopalina ruetzleri*, (D) *Dragmacidon reticulatum*, (E) *Polymastia janeirensis*, (F) *Cliona celata*. The arrows indicate the non-indigenous brittle star *Ophiothela mirabilis*.

18 m depth. The maximum depth that we surveyed in the rocky shores was 8 m and these differences (light, sedimentation) are likely to explain the differences in species composition. Although similar ecological processes act on different surfaces, communities on artificial substrates are known to be very different from those on adjacent natural substrata (Connell & Glasby 1999, Bulleri & Chapman 2004). However, that being said, these two types of substrate still had 45 species in common.

Two prior studies at the Currais MPA used recruitment plates to evaluate colonization of invertebrates (Brandini & Silva 2011, Bumbeer & Rocha 2012), including time in their survey of species. Those studies found mostly pioneer species, that are likely to be due to propagule supply rather than to the already developed community. This process may also explain the little species overlap between those studies and this (Table 2). Additionally, the former study used plates of the same material as the ARs that were fixed close to the bottom (Brandini & Silva 2011), while the latter used polyethylene plates suspended in the water column (Bumbeer & Rocha 2012). Thus, the studies were different with respect to substrate composition, movement and orientation, and these differences are likely to have caused different suit of species reported in each (Glasby & Connell 2001).

The endangered sea-star *Coscinasterias tenuispina* is an important species for conservation in Currais MPA (MMA 445/14). In Brazil, this sea-start has a discontinuous distribution, from Bahia to Santa Catarina, and found in Abrolhos (Bahia), Cagarras (Rio de Janeiro) and Arvoredo (Santa Catarina) MPAs, among others. The sea cucumber *Isostichopus badionotus* (Selenka, 1867) (Figure 4e) was on the Brazilian list of threatened species, but was excluded in the last evaluation (MMA 445/14). This species is classified in the category of least concern by the global IUCN red list, and is abundant in warmer waters of the Caribbean (Toral-Granda et al. 2013).

The remarkable number of new records, and new species, highlights the lack of biodiversity studies in coastal Paraná and many areas of benthic

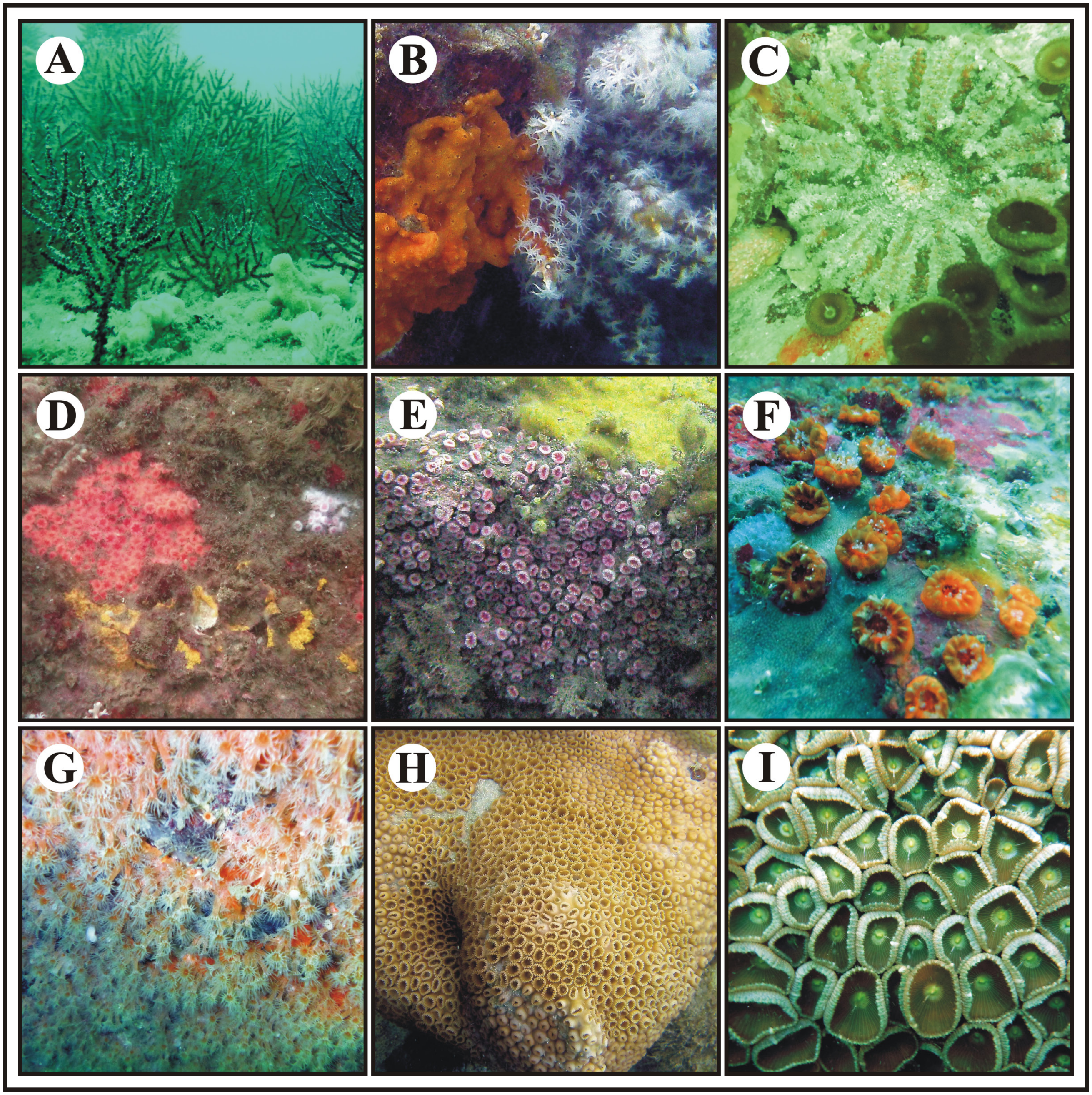

Figure 3. Cnidarians of Currais MPA: (A) *Leptogorgia punicea*, (B) *Carijoa riisei* beside the ascidian *Didemnum granulatum* (orange colony), (C) *Actinostella flosculifera*, (D) *Astrangia rathbuni* beside the ascidian *Symplegma rubra* (yellow colony), (E) *Astrangia rathbuni*, (F) *Phyllangia americana*, (G) *Parazoanthus swiftii*, (H) *Palythoa caribaeorum*, (I) *Palythoa variabilis*.

biodiversity on hard substrates remain to be studied, for example, rocky shores bellow depths of 8 m, inventories of cryptic taxonomic groups and vagile benthos other than gastropods, polychaetes and echinoderms. Taxon oriented inventories by specialists are also mandatory for a comprehensive biodiversity survey. For example, a large algal richness was found in a recent study, which found 101 taxa in the Currais Islands (Pellizzari et al. 2014).

The coast of Paraná is in the area of influence of the southern convergence between the cold Malvinas/Falklands current from the south and the warm Brazilian current from the north (Campos et al. 1996, Fernandes & Brandini 2004), and so the communities are expected to include species from both temperate and tropical waters. Coastal Paraná is also the southern range limit for some species, such as the hydrozoan *Kirchenpaueria halecioides* (Alder, 1859), the polychaete *Nicidion cariboea* (Grube, 1856) and the sponge *Amphimedon* sp.. It is also the northern range limit for the bivalves *Musculus viator* (d'Orbigny, 1842) and *Brachidontes rodriguezi* (d'Orbigny, 1842). Considering the increasing threats to biodiversity, including climate change and ocean warming, that have already caused distributional shifts of species (Sorte et al. 2010), this is an important area to monitor the expansion or constriction of species latitudinal distributions.

Climate change may also modulate the impact and distribution of existing NIS and the establishment of new invasive species (Hellmann et al. 2008). Thus, many NIS found in Currais MPA at low abundances may become invasive, or new species may expand their distribution to Paraná. As has been observed in another MPA located in the southern neighboring state of

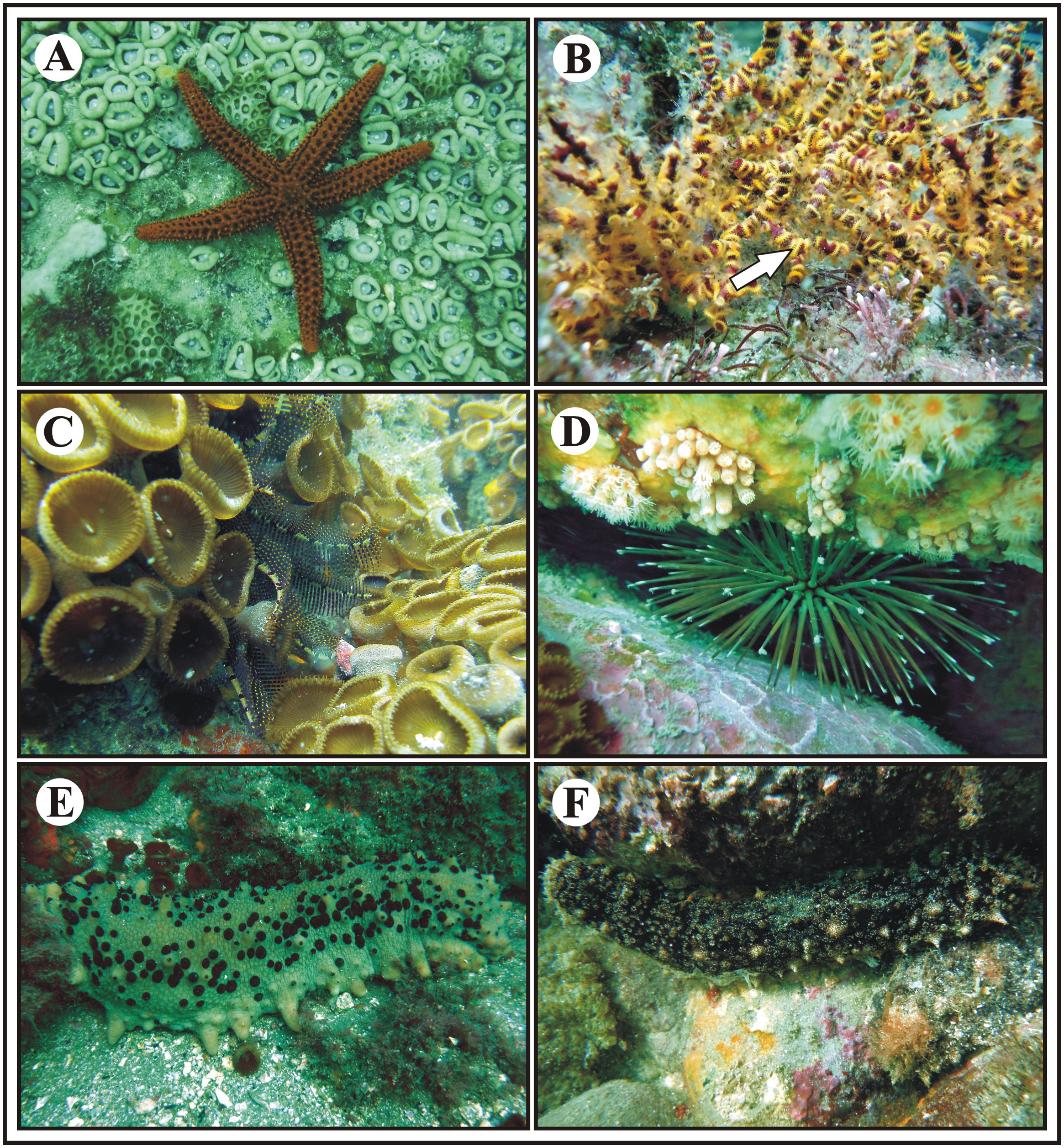

Figura 4. Echinoderms of Currais MPA: (A) Echinaster (Othilia) brasiliensis, (B) Ophiothela mirabilis (arrow) over the gorgonian Leptogorgia punicea, (C) *Tropiometra carinata*, (D) *Arbacia lixula*, (E) *Isostichopus badionotus*, (F) *Holothuria (Halodeima) grisea*.

Santa Catarina (the Biological Reserve of Arvoredo - *see* Metri & Rocha 2008, Bouzon et al. 2012, Cavallari et al. 2012), there are many NIS in the Currais MPA, which endangers the value of this area for biodiversity conservation (Bumbeer & Rocha 2016).

Coastal Paraná is under the influence of many anthropogenic impacts that favor bioinvasions, such as port-related industries and activities, aquaculture, ships and boat traffic that may contribute to the regional spread of species. Currais MPA is also near freight ship traffic routes as they enter and leave the estuary (Bumbeer and Rocha 2012, 2016). As a consequence, the ophiuroid *Ophiothela mirabilis* was first reported in Paraná in 2000 (Hendler et al. 2012) and has now expanded both its range and abundance and occurs abundantly along the entire coast, including Currais MPA (Figures 2 and 4). This species takes advantage of a variety of hosts (Mantellato et al. 2016), yet we still don't know its impact on the native community.

The only invertebrate taxon oriented inventory at Currais MPA (Rocha & Faria 2005) also provides the opportunity to demonstrate additional changes to community composition. Three of the 12 species found previously but not in this study were probably NIS: the ascidians *Aplidium pentatrema* (Monniot F., 1972), *Eudistoma carolinense* Van Name, 1945 and *Diplosoma*

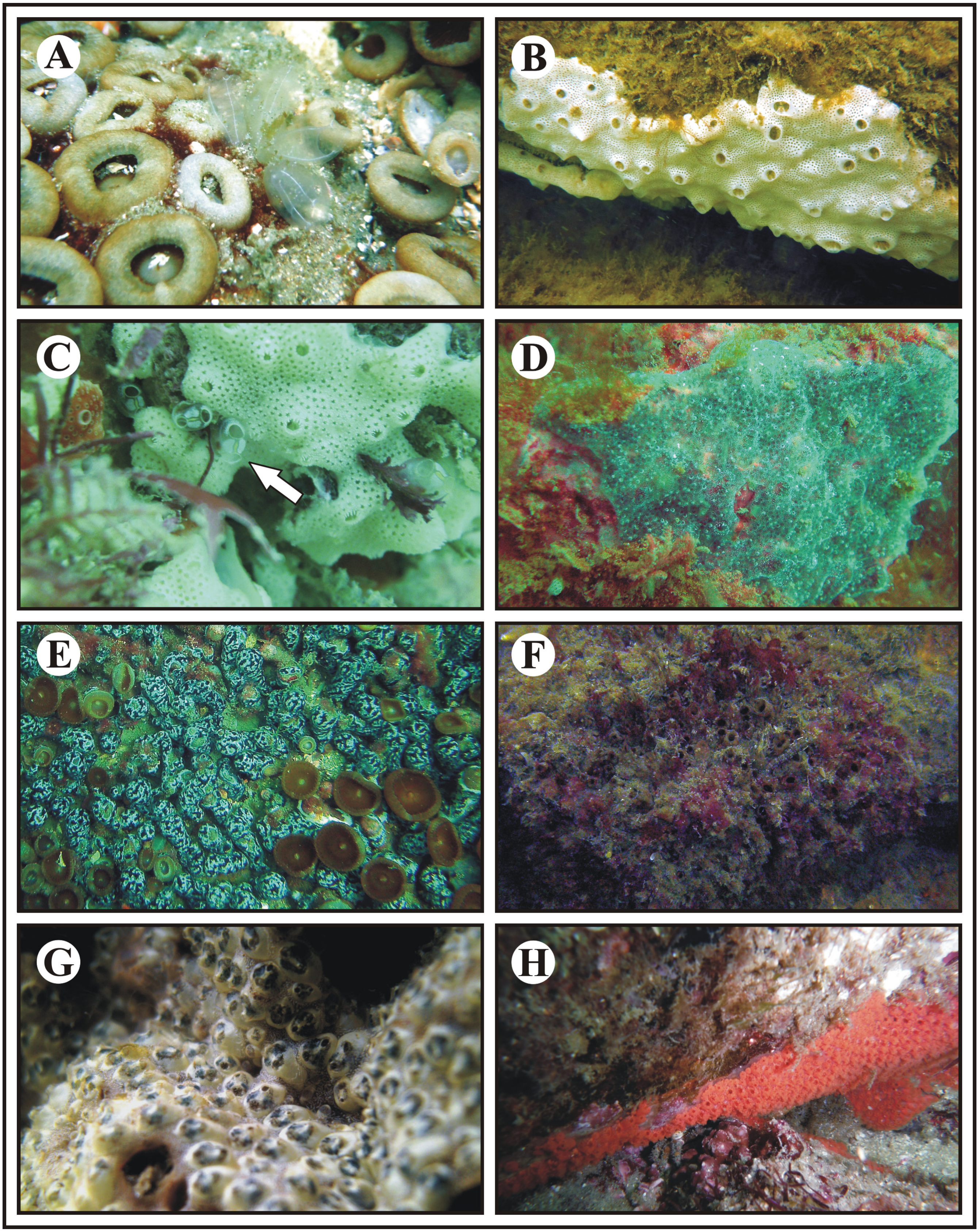

Figure 5. Ascidians of Currais MPA: (A) *Clavelina oblonga*, (B) *Didemnum granulatum,* (C) *Perophora regina* (arrow), *Didemnum granulatum* (white colony), *Didemnum rodriguesi* (orange colony), (D) *Diplosoma listerianum*, (E) *Didemnum* sp.1 over the zoanthid *Palythoa variabilis*, (F) *Polyandrocarpa anguinea*, (G) *Symplegma brakenhielmi*, (H) *Symplegma rubra.*

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sp. (Rocha & Faria 2005). Also, the NIS *Ascidia tenue* Monniot, 1983 was only found on recruitment plates in 2008/2009 (Bumbeer & Rocha 2012). Usually, NIS populations fluctuate widely, so the absence of a few in the present study was not that surprising. We also found some first records for NIS in Currais. The species *Didemnum perlucidum* was first reported in Brazil (in the São Sebastião Channel) in 1995 (Rocha & Monniot 1995) and found here for the first time for Paraná. This ascidian is now widespread worldwide and a recent study revealed low genetic diversity, including a population from southern Brazil with only one COI haplotype (Dias et al. 2016). This suggests that *D. perlucidum* is introduced. *Botrylloides nigrum* Herdman, 1886, another new record for Currais MPA, is considered cryptogenic, but its occurrence on anthropogenic substrates (Rocha & Kremer 2005, Marques et al. 2013) and a new molecular study of global populations (Sheets et al. 2016) suggest that this is also an introduced species in southern Brazil. *Symplegma rubra* Monniot, 1972 was recorded only within the Paranaguá Estuarine Complex before 2005 (Rocha & Kremer 2005), yet now it is common in Currais MPA. As *S. rubra* is quite easily encountered and identified, by the large, brightly colored, colonies (Figure 5h), it is unlikely that, if present, it would have passed unnoticed in the 2002/2003 ascidian inventory (Rocha & Faria 2005). Thus, while probably introduced due to its first records in estuarine areas and recent new occurrences, the lack of genetic information on a global scale leads us to call it cryptogenic.

The new records listed emphasize the importance of continuous monitoring for early detection of new introductions, and suggests that protocols should be established for both early response and control of NIS in the management plan of Currais MPA. Biodiversity inventories should also be encouraged and be carried out by taxonomists. Even a simple list of species can provide a baseline after which changes in the ecosystem can be determined by the disappearance or appearance of species, invasion by NIS, and blooms of opportunistic taxa. Here we provide the first step towards understanding the marine ecosystem of the Currais MPA and towards the development of conservation actions in the southern Brazilian coast.

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Epiphytic diatoms (Diatomeae) from Piraquara II urban reservoir, Paraná state

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Abstract: We conducted a taxonomical study of epiphytic diatoms on the macrophytes *Polygonum hydropiperoides*, *Ludwigia peruviana* and *Alternanthera philoxeroides* collected in the mesotrophic reservoir Piraquara II flooded in 2009, located in the state of Paraná. A total of 135 infrageneric taxa were identified, among them five at generic level and other five are first records to the state. We provided illustration, valve metrics, meristics limits and taxonomic reference for each taxon. Also, life forms and species frequency are given. The most frequent diatoms totalized 15.3% of total identified taxa and sporadic species represented 54.7%. *Achnanthidium minutissimum* (Kützing) Czarnecki and *Brachysira neoexilis* Lange-Bertalot occurred in more than 90% of analyzed samples. Among the very frequent diatoms we found other species included in *Achnantidium, Fragilaria* and *Eunotia*. The solitary *Discotella stelligera* (Cleve & Grunow) Houk & Klee and the short chain *Aulacoseira tenella* (Nygaard) Simonsen are free living species that entangle among diatoms from the biofilm.

Keywords: *Bacillariophyta, freshwater, macrophytes, mesotrophic, periphyton, taxonomy.*

Diatomáceas epifíticas (Diatomeae) no reservatório urbano Piraquara II, estado do Paraná

Resumo: Realizamos um estudo taxonômico das diatomáceas epifíticas nas macrófitas: *Polygonum hydropiperoides, Ludwigia peruviana* e *Alternanthera philoxeroides*, coletadas no reservatório Piraquara II, uma represa urbana mesotrófica inundada em 2009, localizado no estado do Paraná. Um total de 135 táxons infragenéricos foi determinado, entre os quais cinco foram citações pioneiras para o Estado. Ilustrações, limites métricos, merísticos e referências taxonômicas para cada táxon foram providenciadas. Também, dados sobre formas de vida e frequência das espécies foram adicionados. As diatomáceas mais frequentes totalizaram 15,3% dos táxons determinados e as espécies esporádicas representaram 54%. *Achnanthidium minutissimum* (Kützing) Czarnecki and *Brachysira neoexilis* Lange-Bertalot ocorreram em mais de 90% das amostras analisadas. Dentre as diatomáceas muito frequentes encontram-se outras espécies de *Achnanthidium, Fragilaria* e *Eunotia. Discostella stelligera* (Cleve & Grunow) Houk & Klee, uma diatomácea solitária, e *Aulacoseira tenella* (Nygaard) Simonsen, com cadeias curtas, são espécies livres que se emaranham entre as diatomáceas do biofilme.

Palavras-chave: *Bacillariophyta, água doce, macrófitas, perifíton, taxonomia.*

Introduction

Stems of emergent macrophytes are suitable colonizable surfaces to epiphyton communities and are particularly able to transfer a small amount of nutrients to their epiphytes (Cattaneo & Kalff, 1979). As periphytic diatoms are sensitive to eutrophication, it is important to record the species that occured at present for comparision to the future assemblies, helping to understand the relationship between the species and the trophic level of aquatic system. Informations about biodiversity represent a useful tool for ecological and applied studies, but an accurate taxonomy is fundamental. Identification to species level is time consuming and sometimes difficult, but useful and necessary to future ecological studies (Kociolek 2005) in this urban reservoir.

Cetto et al. (2004), Silva et al. (2010), Bertolli et al. (2010) and Faria et al. (2010) provided recent diatom inventories from eutrophic and mesotrophic urbans reservoirs: Iraí, Passaúna and Itaqui. Also, Faria et al. (2013) selected tolerant diatom species from Itaqui reservoir. There are no related studies in the recently flooded Piraquara II urban reservoir. Bittencourt & Gobbi (2006) evaluated phosphorous total maximum daily load in the drainage area of Piraquara II reservoir before flooding. The study demonstrated the reservoir present high potencial to eutrophication due to the intense agricultural use of soil and shallow water. The urban reservoirs have been suffering severe anthropogenic nutrients inputs and consequently eutrophication is accelerated (Calisto et al., 2014) and periphyton may respond by changes in abundance and taxonomic composition (Stoermer & Smol 2004).

We conducted a taxonomical study of epiphytic diatoms in Piraquara II reservoir. For each taxon, we provided illustration, valve metrics and meristics limits, occurence, and literature to species taxonomic determination. The taxa first registered to state of Paraná were also described and commented.

Materials and Methods

Piraquara II reservoir (25º30' S and 49º00' W) is located in a preservation area and was built in 2008 by the dam of Piraquara river, inserted in the Iguaçu watershed, Paraná state, south Brazil (Figure 1). This shallow reservoir with 75 days of water retention time is used for public supply (depth 3.7 m, area 5.64 km^2, drainage area 58 km^2), and is mesotrophic most part of the year (Table 1, SANEPAR, 2013, unpublished data) with Trophic State Index (TSI) around 54 from 55 TSI (SANEPAR, 2010-2014, unpublished data). The main economic activities in the vicinity are the livestock and corn culture (Bittencourt & Gobbi 2006).

Epiphytic diatoms were sampled in June and November 2013 from stems of the emergent macrophytes *Polygnum hydropiperoides* Michaux (Polygonaceae), *Ludwigia peruviana* (L.) H. Hara (Onagraceae) and the amphibious *Alternanthera philoxeroides* (Mart.) Griseb. (Amaranthaceae). The macrophytes were collected according to the local availability in six sampling sites (1-6) along the reservoir (Table 2, Figure 1), three stems (a,b,c) from each core were collected. Diatoms were scrapped off the substrates surfaces with an aluminium spatule, and the samples were cleaned with $KMnO_4$ and HCl (Simonsen 1974 modified by Moreira-Filho & Valente-Moreira 1981). Light microcopy-slides were mounted with Naphrax® and analyzed under Olympus BX40 microscope. Illustrations were captured by DP71 digital equipment. Cleaned samples were prepared and analised at JEOL JSM 6360LV scanning electron microscope (Eletronic Microscopy Center - Federal University of Paraná). Valve terminology followed Barber & Haworth (1981) and Round et al. (1990). Frequencies of occurrence were stablished based on Mateucci & Colma (1982): species as high frequent (F ≥ 70%), frequent (40% ≤ F < 70%), low frequent (10% ≤ F < 40%) and sporadic (F < 10%).

The examined slides and samples were housed at the herbarium of the Universidade Federal do Paraná (UPCB) (Table 2). First recorded taxa to the state of Paraná and those identified to the generic level were described and commented. Diatoms were identified to the lowest taxonomical level according to current taxonomic literature. The references used to identify each taxon even as metrics and meristics limits are listed on Table 3.

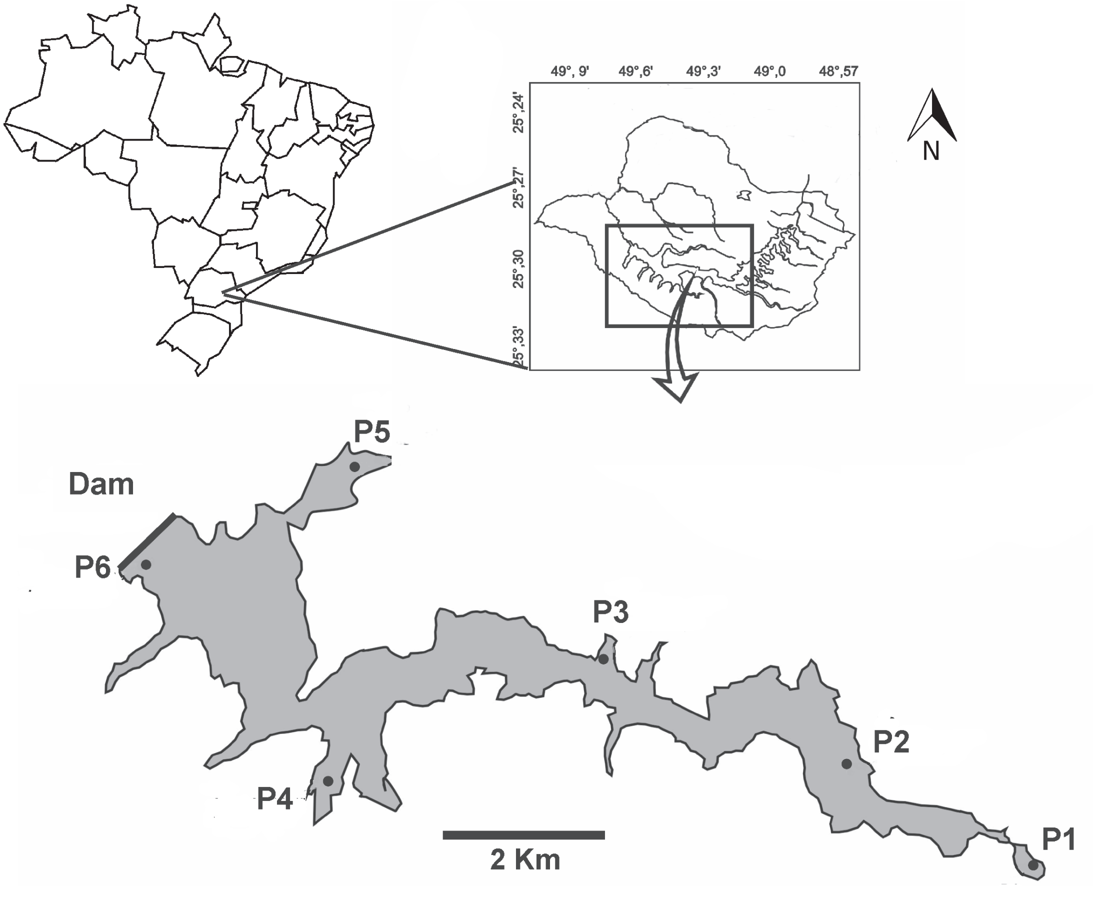


Figure 1. Localization of sampling sites in Piraquara II reservoir. Piraquara municipality, Paraná state, Brazil (modified from Google Earth 2013)

Table 1. Average set of abiotic data in the months of sampling epiphyton

Date	DO (mg/L)	Secchi (m)	pH	COD (mg/L)	TN (mg/L)	TP (mg/L)	TDS (mg/L)	Turbidity (NTU)	IQA
Jun/2013	6.7	2.7	6.8	12.8	1.4	0.025	46.0	3.0	84.5
SD	±0.3	±1.3	±0.3	±8.1	±0.3	±0	±7.0	±0.3	±5.2
Nov/2013	7.24	1.4	6.95	12.66	0.5	0.025	35.0	3.55	84,33
SD	±0.07	±0	±0.25	±5.43	±0	±0	±0	±0.75	±5.31

*DO: dissolved oxygen; COD: Chemical oxygen demand; TN: Total Nitrogen dissolved; TP: Total phosphorus dissolved; TDS: Total dissolved solids; IQA: Index Water Quality; SD: standard deviation.

SANEPAR (2013), unpublished data

Table 2. Piraquara II reservoir informations. Collected species of macrophytes, sampling sites and sample register number at Universidade Federal do Paraná Herbarium (UPCB).

Sampling sites	Coordinates	Sampled macrophytes	UPCB	
1	S 25º30’38.2” W 49º1’38.2”	*Polygnum hydropiperoides*	78032	78044
2	S 25º30’23.2” W 49º2’12.6”	*Ludwigia peruviana*	78033	78045
3	S 25º29’42.9” W 49º3’28.4”	*Althernanthera philoxeroides* *Polygnum hydropiperoides*	78034	78046
4	S 25º30’18.4” W 49º2’44.1”	*Althernanthera philoxeroides* *Polygnum hydropiperoides*	78035	78047
5	S 25º28’47.3” W 49º4’42.1”	*Polygnum hydropiperoides*	78036	78048
6	S 25º29’30.1” W 49º5’38.9”	*Polygnum hydropiperoides*	78037	78049

Table 3. List of diatom taxa identified from Piraquara II reservoir. Morphometric & meristics limits, occurrence in samples & consulted literature. D: diameter (µm); L: length (µm); W: width (µm); SH: semi cell height (µm); S: striae in 10 µm; A: areolae in 10 µm; F: fibulae in 10 µm; AC: aliform chanells in 10 µm.

Species Name (Figure)	Metric (µm) & meristic (in 10 µm) limits	Month of occurrence at sampling sites		Consulted literature
		June	November	
Stephanodiscaceae				
Cyclotella meneghiniana Kützing (Figure 2)	D:9.9-15; S:10-12	4b, 6b		Krammer & Lange-Bertalot (1991a)
Discostella stelligera (Cleve & Grunow) Houk & Klee (Figures 3-4)	D:7.4-13.9; S:8-13	1a, 2abc, 3abc 4abc, 5abc, 6abc	2ab, 3ab, 4ac, 5ab, 6ab	Houk et al. (2010)
Aulacoseiraceae				
Aulacoseira ambigua (Grunow) Simonsen var. *ambigua* f. *ambigua* (Figures 15-16)	SH:7.1-12.2; D:6-7.5; S:8	1ab, 2abc, 3abc, 4abc, 5abc, 6abc	2b, 3ac, 4b, 5b, 6b	Krammer & Lange-Bertalot (1991a)
A. ambigua var. *ambigua* f. *spiralis* (Skuja) Ludwig & Valente-Moreira (Figure 10)	SH:10.9; D:3.9; S:14	3c		Ludwig & Valente-Moreira (1990)
A. brasiliensis Tremarin, Torgan & T. Ludwig (Figure 11)	SH:3.8-6.5; D:8.4-9.8; S:13-14; A:6-8	1b, 2abc, 3ac, 5a, 6a, 6b	1b	Tremarin et al. (2012)
A. granulata var. *angustissima* (O. Müller) Simonsen (Figures 17-18)	SH:11.5-14.8; D:2.7-2.8; S:3; A:14-15	2abc, 3ab, 4ac, 5a, 6abc	4c, 6c	Krammer & Lange-Bertalot (1991a)
A. granulata (Ehrenberg) Simonsen var. *granulata* (Figure 25)	SH:13.7-13.8; D:5.1-5.2; S:5-6; A:16-17	2abc, 3abc, 4abc, 5abc, 6abc	2c,3ab, 4c, 5b, 6abc	Krammer & Lange-Bertalot (1991a)
A. herzogii (Lemmermann) Simonsen var. *herzogii* (Figures 12-14)	SH: 3.7-7.1; D: 3.3-5.9	2bc, 4b, 5b, 6bc		Hickel & Häkansson (1991)
A. tenella (Nygaard) Simonsen (Figures 8-9)	SH:0.7-1.7; D: 5.6-6	1bc, 2bc, 3abc, 4abc, 5abc, 6c	2a, 3abc, 5bc, 6ac	Siver & Kling (1997), Camburn & Charles (2000)
Aulacoseira sp. (Figures 5-7)	SH:1-1.8; D:4.5-4.9	2bc, 3ab, 4ac, 5abc	6c	
Fragilariaceae				
Fragilaria mesolepta Rabenhorst (Figure 19)	L:21.8; W:2.8; S:16		5a	Tuji & Williams (2008b)
F. crotonensis Kitton (Figures 31-34)	L:60.8-76; W:2-2.6; S:17	4c, 6b, 2abc, 3b, 4ab, 5abc, 6abc	1ac	Patrick & Reimer (1966)
F. gracilis Ostrup (Figures 26-28)	L:40.2; W:2.2; S:22	4b	2c, 3a, 4bc, 5c, 6ac	Krammer & Lange-Bertalot (1991a)
F. parva (Grunow) Tuji & Williams (Figures 40-43)	L:26.6-51.6; W:2.5-2.6; S:15-16	1b, 2abc, 3ab, 4ac, 6abc	1b, 2abc, 3b, 4c, 5abc, 6abc	Tuji & Williams (2008c)
F. pectinallis (Müll) Lyngbye (Figures 21-24, 220-222)	L:20.8-28.0; W:3.5-3.1; S:16-18	1a, 2ac, 3abc, 4abc, 5a, 6abc	1c, 2b, 4bc, 5bc, 6abc	Tuji & Williams (2008a) as *F. capitellata* (Grun.) Pet., Wetzel & Ector (2015)
F. tenera (W. Smith) Lange-Bertalot (Figures 35-37)	L:34.6-49.4; W:1.9-3.0; S:20	1abc, 2c, 3abc, 4abc, 5abc, 6abc	1a, 2ab, 3b, 4bc, 5b, 6a	Zelazna-Wieczorek (2011)
F. microvaucheriae Wetzel & Ector (Figures 29-30)	L:10.7-11.4; W:4.1-4.4; S:9-10	2abc, 3b, 4abc, 6b	2abc, 3c, 4bc, 6ab	Tuji & Williams (2006)
Fragilariforma javanica (Hustedt) Wetzel, Morales & Ector (Figure 20)	L:27.9-69.8; W:5.5-6.1; S:19	2c	2b	Wetzel et al. (2013a)
Ulnaria acus (Kützing) Aboal (Figure 38)	L:114.9-140.7; W:3.2-3.4; S:16		1a	Levkov et al. (2007)
U. ulna (Nitzsch) Compère (Figure 39)	L:91.2; W:4.9; S:11	1b, 2b, 3b, 4c, 5a, 6ac	2abc, 6ab	Levkov et al. (2007)
Eunotiaceae				
Actinella leontopithecus-rosalia Costa (Figure 52)	L:25.1; W:3.2; S:18		1c, 5b	Costa (1995), Tremarin et al. (2016)

Table 3. Continued...

Species Name (Figure)	**Metric (µm) & meristic (in 10 µm) limits**	**Month of occurrence at sampling sites**		**Consulted literature**
		June	**November**	
Desmogonium ossiculum Metzeltin & Lange-Bertalot (Figure 73)	L:114.1-186.9; W:8.7; S:14-15	2c, 3a	2a	Metzeltin & Lange Bertalot (2007)
D. transfugum (Metzeltin & Lange-Bertalot) Metzeltin & Lange-Bertalot (Figure 74)	L:139.5-198.7; W:4.4-6.1; S:14-16	1a		Metzeltin & Lange-Bertalot (1998,)
*Eunotia bilunaris (*Ehrenberg) Mills (Figure 48)	L:22-43.7; W:3.1-3.4; S:17	1abc, 2bc, 3a, 4a, 5a, 6bc	1ab, 2ab, 3a, 4ac, 5bc, 6c	Lange-Bertalot & Metzeltin (1996)
E. camelus Ehrenberg (Figures 54-55)	L:23.2-44.2; W:5.4-8.5; S:11-14	1ab, 2a	1bc, 5b	Reichardt (1995), Metzeltin et al. (2005)
Eunotia cf. formicina Lange-Bertalot (Figure 53)	L:46.2-49.8; W:6-6.4; S:13-15	2c		Lange-Bertalot et al. (2011)
E. desmogonioides Metzeltin & Lange-Bertalot (Figure 72)	L:109.3-125.5; W:5.8-6.7; S:15	1a, 3ab, 5ab	2b	Metzeltin & Lange-Bertalot (2002)
E. intermedia (Krasske) Nörpel-Schempp & Lange-Bertalot (Figures 49-50)	L:9.7-17.8; W:2.9-3.1; S:14-15	1ac, 2abc, 3bc, 4ab, 5abc, 6abc	1abc, 2abc, 3abc, 5b, 6bc	Lange-Bertalot et al. (2011)
E. luna var. *trapezica* Hustedt (Figure 59)	L:28.7; W:11; S:12	6b		Frenguelli (1941), Simonsen (1987)
E. meridiana Metzeltin & Lange-Bertalot (Figure 56-58)	L:17.2-26.9; W:4-5; S:12-13	2a, 4b, 6b	1abc, 3ab,4b, 5c, 6bc	Metzeltin & Lange-Bertalot (1998)
E. monodon Ehrenberg (Figure 45)	L:69.2; W:9.5; S:10	4a		Hofmann et al. (2013)
E. minor (Kützing) Grunow (Figure 44)	L: 19.9-31.8; W:4.1-5.1; S: 14-17	3c, 6b	2ab, 3ab, 4bc, 6a	Lange-Bertalot et al. (2011)
E. naegelii Migulla (Figures 46-47)	L:61.1-106.6; W:2.5-2.9; S:16-20	1ab, 3c	3a	Krammer & Lange-Bertalot (1991a)
E. neocompacta Mayama (Figure 51)	L:18.4; W:2.7; S:20		6a	Lange-Bertalot et al. (2011)
E. paratridentula Lange-Bertalot & Kulikovskiy (Figure 61)	L:13.6-15.4; W:3-3.3; S:22	2abc		Kulikovskiy et al. (2010)
E. pseudosudetica Metzeltin, Lange-Bertalot & García-Rodríguez (Figure 63-64)	L:29.1-59.9; W:4.1-5.2; S:12	1abc, 2abc, 3b, 4ab, 5abc, 6abc	1abc, 2abc,3abc,4abc, 5b, 6abc	Metzeltin et al. (2005)
E. pyramidata Hustedt var. *pyramidata* (Figure 60)	L:19.5-33.4; W:5.9-8.8; S:13-15		5b	Frenguelli (1941)
E. rabenhorstii var. *monodon* Cleve & Grunow (Figure 62)	L:17.6; W:6.5; S:13	1a		Patrick & Reimer (1966)
E. yanomami Metzeltin & Lange-Bertalot (Figures 65-67)	L: -89 -152.7; W: 17.2-18.7; S:10-13	6b,c		Metzeltin & Lange-Bertalot (1998)
Cymbellaceae				
Cymbella aspera (Ehrenberg) Cleve (Figure 91)	L:108.4-158.3; W:20.6-25.2; S:9-10; A:10-11	2c, 5bc, 6ac	5a	Patrick & Reimer (1975), Krammer (2002)
Cymbopleura naviculiformis var. *naviculiformis* (Auerswald) Krammer (Figure 71)	L:27.5-31.9; W:7.1-7.9; S:14	2bc, 4c, 5bc, 6abc	5b,6c	Krammer (2003)
Encyonema incurvatum Krammer (Figures 68-70)	L:27.2-32.2; W:7.5-8.1; S:10-11	1a, 2abc, 3a, 4abc, 6ab	5b, 6c	Krammer (1997a)
E. neogracile Krammer (Figure 80)	L:26.4-47.4; W:5.5-7.6; S:12-14	1abc, 2abc, 3bc, 4bc, 5abc, 6abc	1c, 2abc, 3b, 4c, 5b, 6c	Krammer (1997a)
E. silesiacum (Bleisch) Mann (Figures 75-77)	L:20.5-24.7; W:6.5-8.1; S:10-13	2a, 6b	2b	Krammer (1997a)
E. vulgare var. *vulgare* Krammer (Figure 78)	L:31.4; W:8.6; S:10	4c		Krammer (1997a)
Encyonopsis frequentiformis Metzeltin & Krammer (Figure 79)	L:38.4-39.7; W:9.3-9.5; S:15-16		3a, 3b,4b,5b	Metzeltin & Lange-Bertalot (1998)
E. microcephala (Grunow) Krammer (Figures 95-96)	L:17.6-23.1; W:4.0; S:23-24	2abc, 3ab, 4c, 5bc, 6abc	3a, 5b	Krammer (1997b)
Geissleria lateropunctata (Wallace) Potapova & Winter (Figure 89)	L:20.5-21.8; W: 7.1-7.7; S: 18-19	2a, 4c, 5b, 6c.	6b	Kulikovskiy et al. (2014)
G. punctifera (Hustedt) Metzeltin, Lange-Bertalot **&** García-Rodríguez (Figure 88)	L:20.8-25.5; W:6.3-6.6; S:17	2b, 6a		Kulikovskiy et al. (2014), Torgan & Oliveira (2001)
Placoneis elginensis (Gregory) Cox (Figures 81-82)	L:30.2-34.8; W:9.9-10.1; S:13	4a		Hustedt (1961-1966), Hofmann et al. (2013)

Table 3. Continued...

Species Name (Figure)	Metric (µm) & meristic (in 10 µm) limits	Month of occurrence at sampling sites		Consulted literature
		June	November	
Placoneis symmetrica (Hustedt) Lange-Bertalot (Figure 83)	L:31.8; W:9.6; S:12	4b		Cox (2003), Hofmann et al. (2013)
Gomphonemataceae				
Gomphonema guaraniarum Metzeltin & Lange-Bertalot (Figures 84-87)	L:68.6-54.7; W:11.1-11.5; S:10-11	1abc, 2ab, 3ac, 4bc, 5bc, 6abc	1ab, 2ab, 3ac, 4bc, 5bc	Metzeltin & Lange-Bertalot (2007)
G. hawaiiensis Reichardt (Figure 103)	L:35.2; W:7.3; S:16.	6b		Reichardt (2005)
G. lagenula Kützing (Figure 104)	L:15.6-21.1; W:5.4-6.1; S:16	1abc, 2abc, 3abc, 4abc, 5abc, 6ab	1a,c, 3ab, 6c	Krammer & Lange-Bertalot (1991b)
G. graciloides Hustedt (Figures 97-101, 214-216)	L:25.4-47.9; W:7.8-8.5; S:11-14	1c		Reichardt (2015)
G. naviculoides W. Smith (Figures 116-117, 213)	L:29.1-56.3; W:6.6-9.3; S:14-16	1abc, 2ab, 3ac, 4bc, 5bc, 6abc	2b, 3a, 4c, 5b,6bc	Reichardt (2015)
G. parvulum (Kützing) Van Heurck var. *parvulum* (Figure 121-122)	L:13.9-17.6; W:3.9-4.4; S:15	1bc, 2a, 3a, 5a	1bc,3a, 6c	Krammer & Lange-Bertalot (1991b)
G. parvulum f. *saprophilum* Lange-Bertalot & Reichardt (Figure 120)	L:11.8-16.4; W:4.6-6.4; S:17	1abc, 2ab, 3ac, 4bc, 5bc, 6a	1abc, 3ac, 5bc, 6a	Krammer & Lange-Bertalot (1991b)
G. parvulum var. *subcapitata* Grunow (Figure 90)	L:12.7-26.1; W:3.7-4.8; S:12-15	1abc, 2ab	1abc	Van Heurck (1880), Krammer & Lange-Bertalot (1986)
G. pseudoaugur Lange-Bertalot (Figures 92-94)	L:27.5-31.8; W:7.2-8.3; S:15	3a	6c	Krammer & Lange-Bertalot (1986)
G. subtile Ehrenberg (Figure 102)	L:48.2; W:7.83; S:9	4b		Krammer & Lange-Bertalot (1986) Patrick & Reimer (1975)
Gomphonema sp. (Figures 118-119)	L:23.6-33.2; W:3.8-4.1; S:14	1abc, 2c		
Achnanthidiaceae				
Achnanthidium caledonicum (Lange-Bertalot) Lange-Bertalot (Figures 105-107)	L:17.4-24.8; W:2.5-2.7	1abc, 2abc, 3abc, 4ac, 5abc, 6abc	1abc, 2b,3ab, 4bc,5b, 6ab	Wojtal et al. (2011)
A. catenatum (Bily & Marvan) Lange-Bertalot (Figures 110-112)	L: 13.6-18.7; W:2.9	1abc, 2ab, 3abc, 4abc, 5abc, 6abc	1b, 2b, 3a, 5b, 6c	Krammer & Lange-Bertalot (1991b)
A. eutrophilum (Lange-Bertalot) Lange-Bertalot (Figures 125-126)	L:8.3-10.7; W:3-3.1	1ab, 2bc, 3ab, 4ac, 5bc, 6a	1abc, 5a	Hlúbiková et al. (2011)
A. exiguum (Grunow) Czarnecki (Figures 123-124)	L:10.6-13.8; W:4.4-4.9	4c		Krammer & Lange-Bertalot (1991b)
A. macrocephalum (Hustedt) Round & Bukhtiyarova (Figures 114-115, 219)	L:9.1-11.6; W:2.6-2.7	1ab, 2abc, 3abc, 4abc, 5abc, 6abc	1abc, 2b, 3bc, 5b, 6bc	Ponader & Potapova (2007), Taylor et al. (2007)
A. minutissimum (Kützing) Czarnecki (Figure 113)	L:7.9-16.4; W:2.5-3.1	1abc, 2abc, 3abc, 4abc, 5abc, 6bc	1abc, 2b, 3abc, 4abc, 5ab, 6abc	Potapova (2009), Siver & Hamilton (2011)
Lemnicola hungarica (Grunow) Round & Basson (Figure 129)	L:23.1; W:7.1; S:20		1b	Round & Basson (1997)
Planothidium biporomum (Hohn et Hellerman) Lange-Bertalot (Figure 130)	L:21.7; W:6.8; S:13	2b		Wetzel et al. (2013b)
P. heteromorphum (Grunow) Lange-Bertalot (Figures 131-132)	L:34.5; W:13.1; S:10	4b		Metzeltin & Lange-Bertalot (1998)
P. rostratum (Oestrup) Lange-Bertalot (Figures 108-109)	L:12.6; W:5; S:14	3a		Krammer & Lange-Bertalot (1991b), Levkov et al. (2007)
Diadesmidaceae				
Humidophila contenta (Grunow) Lowe *et al.* (Figure 128)	L:7.5; W:2.2	1a, 2a, 2b		Metzeltin & Lange-Bertalot (2007), Lowe et al. (2014)
H. implicata (Moser, Lange-Bertalot & Metzeltin) Lowe *et al.* (Figure 127)	L:10.4; W:2.9	5a		Lowe et al. (2014)
Amphipleuraceae				
Frustulia acidophilissima Wydrzycka & Lange-Bertalot (Figure 156)	L:31.8; W:10.8	2a, 4b	6a	Metzeltin & Lange-Bertalot (2007)
F. crassinervia (Brébisson) Costa (Figures 133-134)	L:32.7-34.2; W:7.9-8.8	1ab, 2abc; 6ab	5b	Metzeltin & Lange-Bertalot (1998)
F. guayanensis Metzeltin & Lange Bertalot (Figure 137)	L:34.5-34.4; W:7.8-7.6	2a, 6c		Metzeltin & Lange-Bertalot (1998)
F. quadrisinuata Lange-Bertalot (Figure 157)	L:58.9; W:14.5	6b		Metzeltin & Lange-Bertalot (1998)
F. undosa Metzeltin & Lange-Beratlot (Figures 135-136)	L:32.7-39.1;W:8.4-9.2	2abc, 6b		Metzeltin & Lange-Bertalot (1998) Metzeltin & Lange-Bertalot (2007)

Table 3. Continued...

Species Name (Figure)	Metric (µm) & meristic (in 10 µm) limits	Month of occurrence at sampling sites		Consulted literature
		June	November	
Brachysiraceae				
Brachysira brebissonii Ross (Figure 140)	L:16.9-24.3;W:4.5-6.9	1abc, 2ac	2b	Lange-Bertalot & Moser (1994)
B. neoexilis Lange-Bertalot (Figure 141)	L:26.3-13.9; W:5.4-4.3	1abc, 2abc, 3bc, 4abc, 5abc, 6abc	1ab, 2abc,3abc, 4c, 5ab, 6ab	Lange-Bertalot & Moser (1994)
Neidiaceae				
Neidium affine (Ehrenberg) Pfitzer (Figure 139)	L: 43.3; W: 10.7; S:24	6a		Patrick & Reimer (1966), Krammer & Lange-Bertalot (1986)
N. iridis (Ehrenberg) Cleve (Figure 138)	L:76.6; W:30.3; S:17; A:9	6a		Krammer & Lange-Bertalot (1986)
Sellaphoraceae				
Sellaphora nigri (De Notaris) Wetzel & Ector (Figures 151-152)	L:8.7; W:3.6	4c		Wetzel et al. (2015)
S. pupula (Kützing) Mereschkowsky (Figures 146-147)	L:21.8-25.7; W:6.6-7.4; S:21-25	4b		Mann et al. (2004)
S. sardiniensis Lange-Bertalot, Cavacini, Tagliaventi & Alfinito (Figures 149-150, 218)	L:9.2-12.8; W:4.2-4.5; S:24	4b		Lange-Bertalot et al. (2003)
S. sassiana (Metzeltin & Lange-Bertalot) Wetzel (Figures 144-145, 217)	L:15; W:4.4; S:24	5ac, 6c		Metzeltin & Lange-Bertalot (1998)
S. saugerresii (Desm.) Wetzel & Mann (Figures 142-143)	L:5.4-18.8; W:3.3-5; S:17-22	2abc, 3ab, 4bc, 5ab, 6abc	3ab, 4a, 6bc	Wetzel et al. (2015)
S. ventraloconfusa (Lange-Bertalot) Metzeltin & Lange-Bertalot (Figure 153)	L:15.5-23.3; W:4.6-5.8; S:22	1ab, 2c, 4a		Krammer & Lange-Bertalot (1986)
Sellaphora sp. (Figure 148)	L:15.9; W:5.6; S:23		2a	
Pinnulariaceae				
Chamaepinnularia brasilianopsis Metzeltin & Lange-Bertalot (Figures 171-172)	L:15; W:3.9; S:23	4b		Metzeltin & Lange-Bertalot (1998)
Chamaepinnularia mediocris (Krasske) Lange-Bertalot (Figures 154-155)	L:11.0; W:3.8; S:21	2ac		Lange-Bertalot & Metzeltin (1996)
Pinnularia acrosphaeria (Brébisson) Smith (Figure 158)	L:79.24; W:13.54; S:10	1a		Krammer (2000)
P. brauniana (Gunow) Mills (Figure 160)	L: 49.75; W: 9.6; S:11	1a		Krammer (1992)
P. butantanum (Krasske) Meltzeltin (Figure 166)	L:87.8; W:12.7; S:15	1a		Metzeltin & Lange-Bertalot (1998)
P. divergentissima var. *minor* Krammer (Figure 168)	L:23.7-27.7; W:4.8-5.1; S:15	6b		Krammer (2000)
P. gibba Ehrenberg (Figures 164-165)	L:57.5-74.2; W:10.7-11.7; S:9	1a		Krammer (2000)
P. latarea Krammer (Figure 159)	L:61.7; W:10.1; S:10	1a		Krammer (2000)
P. latevittata Cleve (Figure 162)	L:216.1; W:33.7; S:5	2a		Reichardt (1995)
P. similiformis Krammer (Figure 167)	L:38.9; W:5; S:13		6b	Krammer (2000)
P. subbrevistriata Krammer (Figure 170)	L:48.4; W:9.2; S: 11		6b	Krammer (2000)
P. subcapitata Gregory (Figure 169)	L:28.9; W:4.8; S:14	4b		Krammer (2000)
P. subgibba var. *undulata* Krammer (Figure 163)	L:84.2; W:8.8: S:12	1a		Krammer (1992)
P. stoermeri Metzeltin & Lange-Bertalot (Figure 161)	L:157.6; W:26.6; S:8	4a		Metzeltin & Lange-Bertalot (2007)
Naviculaceae				
Capartogramma crucicula (Grunow) Ross (Figure 173)	L:32.5; W:9.7; S:23	4b		Patrick & Reimer (1966)
Hippodonta capitata ssp. *iberoamericana* Metzeltin, Lange-Bertalot & García-Rodríguez (Figure 174)	L:20.6; W:4.9; S:10	2b		Metzeltin et al. (2005)
Mayamaea permitis (Hustedt) Bruder & Medlin (Figure 187)	L:9.2; W:3.1	4c	3a	Lange-Bertalot et al. (2003)
Navicula angusta Grunow (Figures 175-176)	L:40.5-45.0; W:6.1-6.4; S:12	2bc, 3a, 4bc, 6abc	3a, 4b, 5ab, 6ab	Krammer & Lange-Bertalot (1986)
N. cryptotenella Lange-Bertalot (Figure 179)	L:23.5-26.2; W:5.3-5.3; S:16	1ab, 2bc, 4c, 5abc, 6ac	5b, 6bc	Lange-Bertalot & Metzeltin (1996)
N. notha Wallace (Figure 178)	L:23.7-26.6; W:4.4-4.7; S:16	3c, 5bc		Rumrich et al. (2000)

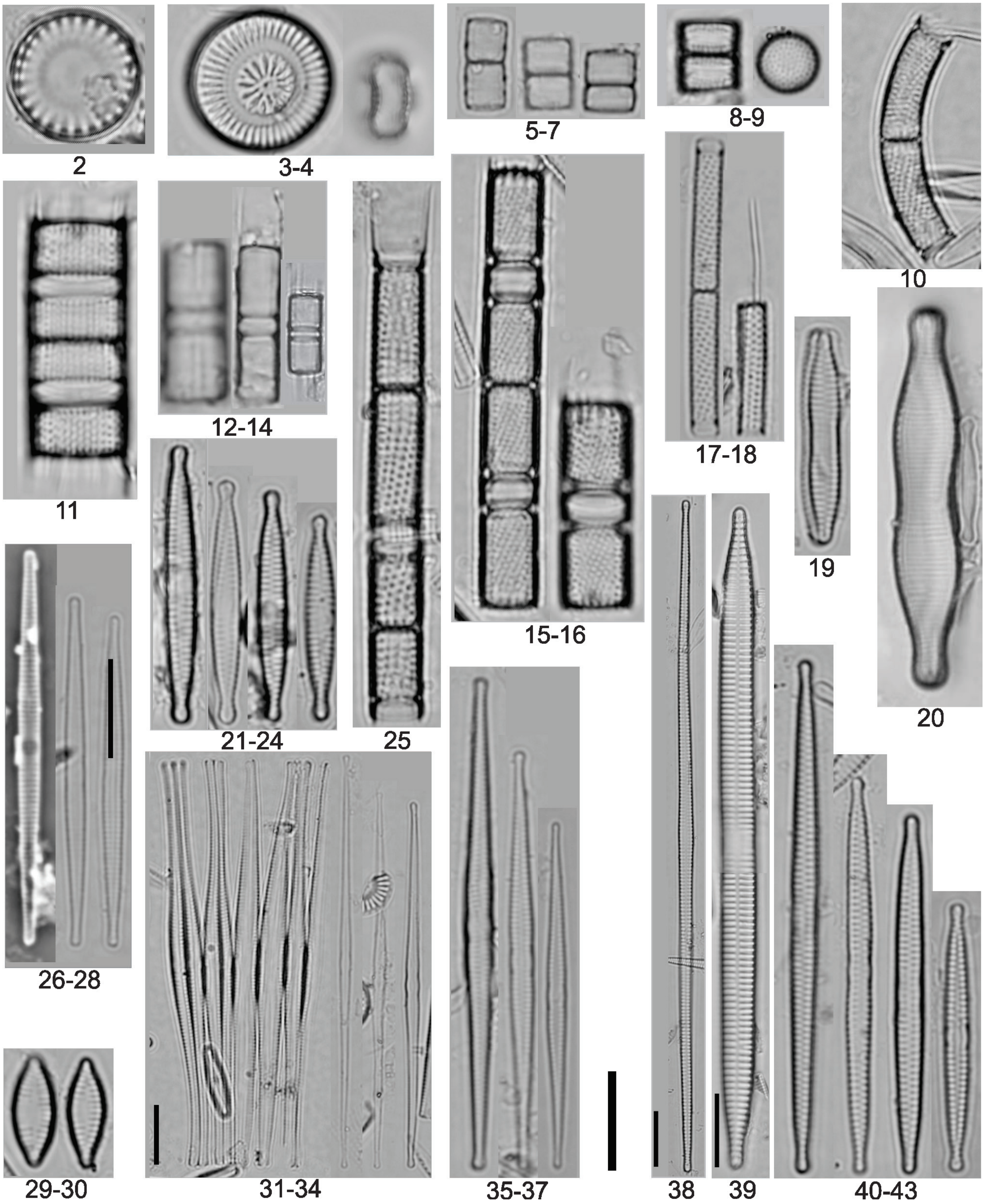
Table 3. Continued...

Species Name (Figure)	Metric (µm) & meristic (in 10 µm) limits	Month of occurrence at sampling sites		Consulted literature
		June	November	
N. tridentula Krasske (Figures 181-182)	L:17.5; W:3.7	5b		Krammer & Lange-Bertalot (1986)
N. veneta Kützing (Figure 180)	L:18.8; W:5.4; S:17	2b		Rumrich et al. (2000)
N. viridulacalcis Lange-Bertalot & Rumrich (Figure 177)	L:44.2-75.6; W:10.5-11.3; S:9	4abc, 5b, 6c	3a, 5a	Rumrich et al. (2000)
N. ventraloconfusa var. *chilensis* (Krasske) Lange-Bertalot (Figures 188-189)	L:15.9-19.2; W:5.2-5.4; S:21	4a, 5b		Krammer & Lange-Bertalot (1986), Lange-Bertalot & Metzeltin (1996)
Nupela torganie Tremarin & Ludwig (Figures 183- 184)	L:10.9-13.7; W: 4.1-5	1ab, 2ab, 3ab, 4ab, 5b, 6c	6c	Tremarin et al. (2015)
Stauroneidaceae				
Craticula riparia (Hustedt) Lange-Bertalot (Figures 192-193)	L:37.6-38.4; W:7.2-8.1; S:22	2ab, 3a, 4b		Krammer & Lange-Bertalot (1986)
C. submolesta (Hustedt) Lange-Bertalot (Figures 185-186)	L:17.0; W:3.8; S:23	4a, 6abc	6c	Krammer & Lange-Bertalot (1986)
Stauroneis anceps Ehrenberg (Figure 200)	L:56.5-59.2; W:9.9-10.7; S:20	5c		Krammer & Lange-Bertalot (1986)
S. gracilis Ehrenberg (Figure 201)	L:88.7; W:15.9; S:19	1b		Reichardt (1995)
Bacillariaceae				
Nitzschia clausii Hantzsch (Figure 203)	L:28.2-41.2; W:4.9-5.3; F:13	3a		Krammer & Lange-Bertalot (1988)
N. gracilis Hantzsch (Figures 196-197)	L:43.1-62.9; W:2.6-3.6; F:14	1bc		Krammer & Lange-Bertalot (1988)
N. intermedia Hantzsch ex Cleve & Grunow (Figures 198-199)	L:42.7-64.7; W:4-4.3; F:11-12	1b, 2b, 3a, 5c, 6c		Krammer & Lange-Bertalot (1988)
N. palea (Kützing) W. Smith var. *palea* (Figures 194-195)	L: 16.1-41.0; W: 2.4-4.7; F: 9-14	1bc, 2abc, 3ab, 4abc, 5bc, 6abc	1b, 3b, 5b, 6c	Rumrich et al. (2000) Levkov et al. (2007)
N. perminuta (Grunow) Peragallo (Figures 190-191)	L:11.2-22.1; W:2.4-2.8; F:10-13	3ab, 4b, 5bc, 6b		Krammer & Lange-Bertalot (1988), Levkov et al. (2007)
N. vermicularis (Kützing) Hantzsch (Figure 202)	L:106.3; W:4.9; F:10	4b		Krammer & Lange-Bertalot (1988), Rumrich et al. (2000)
Rhopalodiaceae				
Rhopalodia gibberula (Ehrenberg) O. Muller (Figure 210)	L:36.1; W:8.6; S:19; A:9	6b		Krammer & Lange-Bertalot (1988)
Surirellaceae				
Stenopterobia curvula (W. Smith) Krammer (Figure 206)	L:127.7-156.4; W:5.2; AC:7	1b		Metzeltin & Lange-Bertalot (1998)
S. delicatissima (Lewis) Brébissoni (Figure 207)	L:60.4-75.6; W:5.3-6.0; AC:7	4b, 6b	6c	Metzeltin & Lange-Bertalot (1998)
Surirella angusta Kutzing (Figure 204)	L:26.1; W:6.8; AC:7	1a		Krammer & Lange-Bertalot (1988)
S. biseriata var. *constricta* Hustedt (Figure 212)	L:190.4; W:17.6; AC:2	1a		Huber-Pestalozii (1942)
S. lineares var. *helvetica* (Ehrenberg) Kützing (Figure 208)	L:49.9; W:14.5; AC:3	4b		Metzeltin & Lange-Bertalot (1998)
S. splendida (Ehrenberg) Kutzing (Figure 211)	L: 113; W: 40.3: AC:2	1a		Krammer & Lange-Bertalot (1988)
S. tenuissima Hustedt (Figure 205)	L:25.3; W:8.5; AC:4	1a		Simonsen (1987), Krammer & Lange-Bertalot (1988)
Surirella sp. (Figure 209)	L:57.2; W:9.5; AC:4	6c		

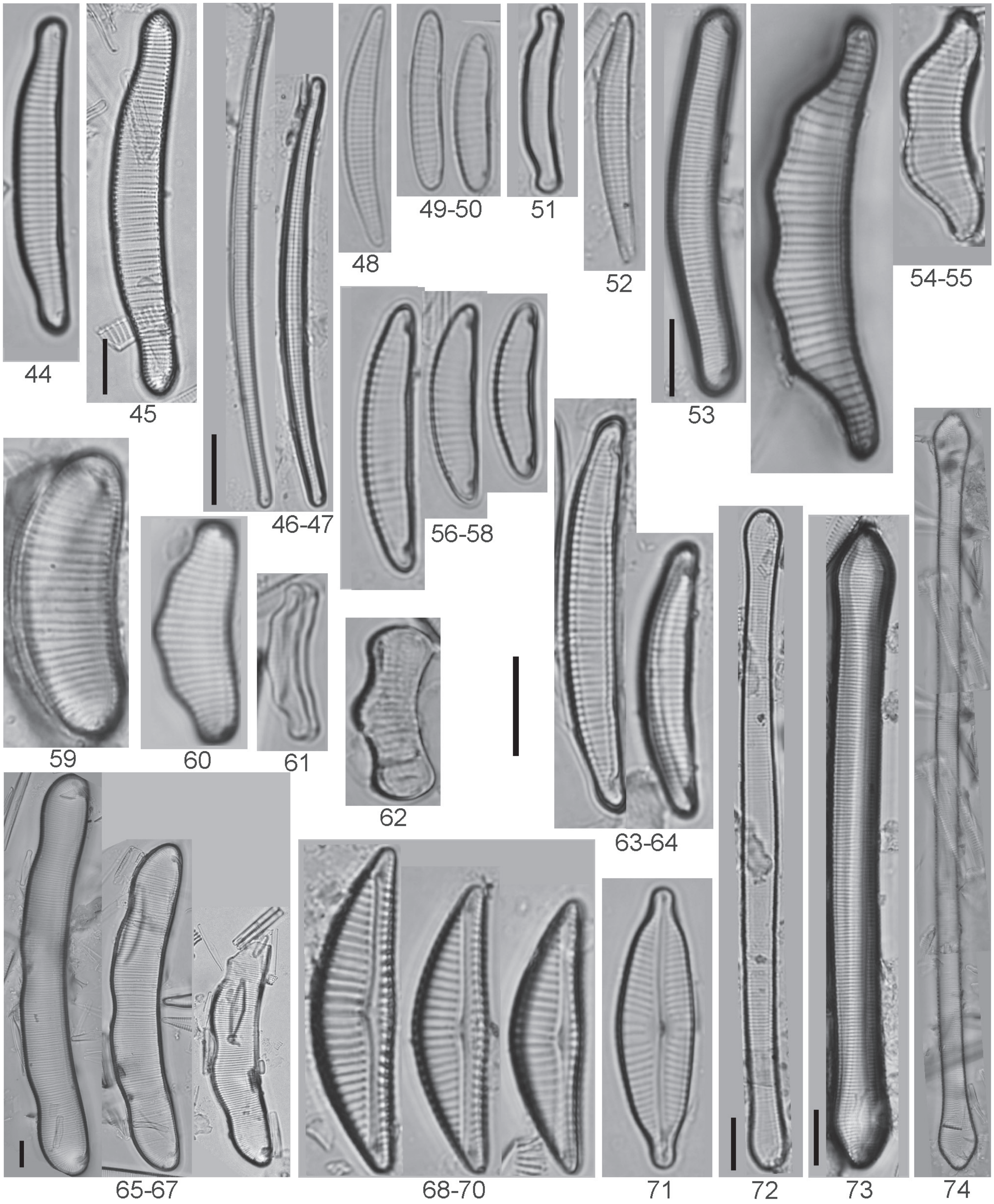
Results and Discussion

A total of 135 infrageneric diatoms taxa were identified (Table 3, Figures 2-222), representing eighteen families (Round et al. 1990, Kulikovskiy et al., 2014). The species richness from Piraquara II reservoir was higher than the diatom floras found in the nearby urban reservoirs Iraí (96 taxa), Passaúna (106 taxa) and Itaqui (124 taxa) (Silva et al. 2010, Bertolli et al. 2010, Faria 2010). In June, (127 taxa) it was found higher richness than in November (66 taxa).

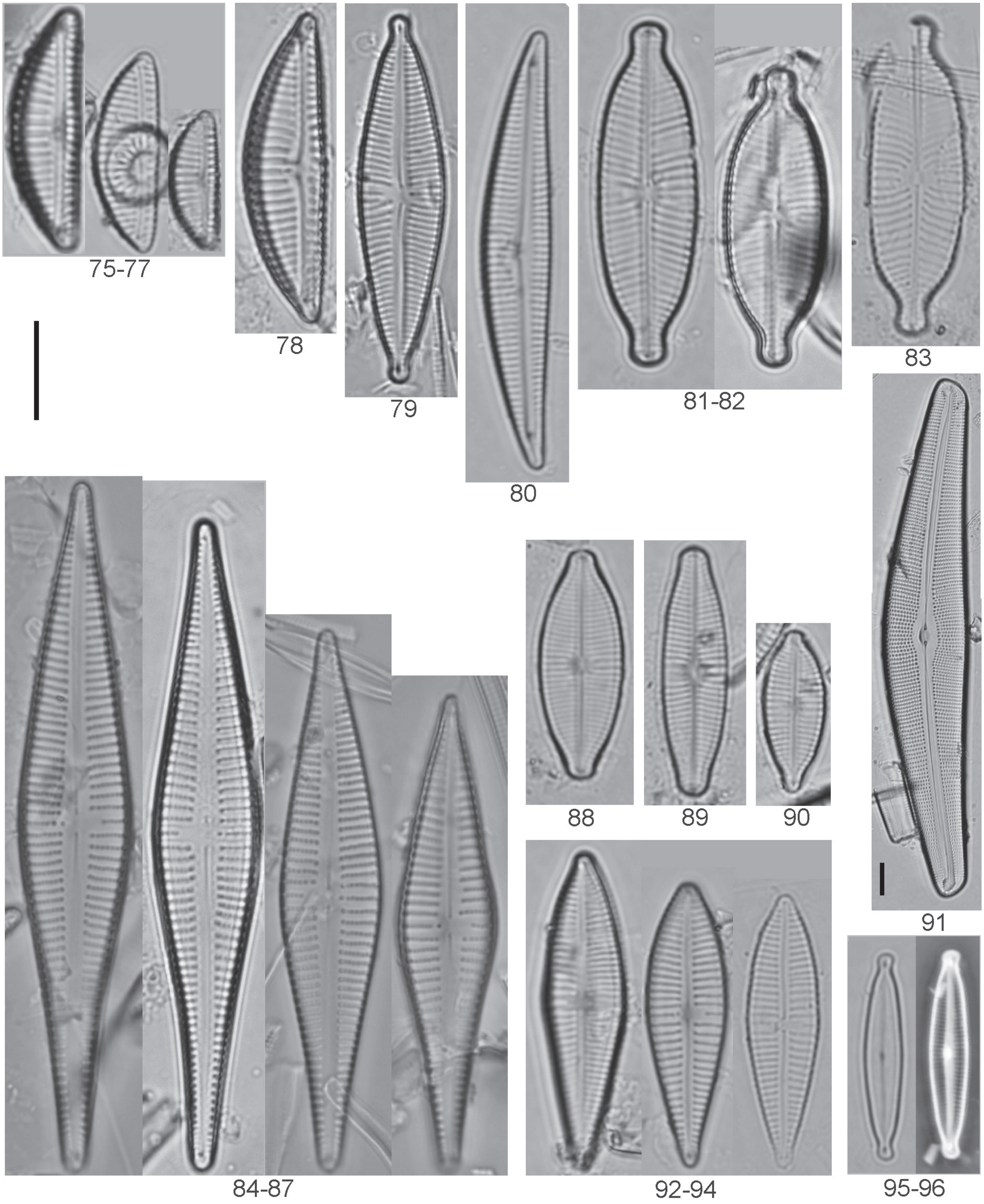
The diatoms occuring highly frequent were (10 taxa): *Achnanthidium caledonicum* (Lange-Bertalot) Lange-Bertalot, *Achnanthidium macrocephalum* (Hustedt) Round & Bukhtiyarova, *Achnanthidium minutissimum* (Kützing) Czarnecki, *Aulacoseira tenella* (Nygaard) Simonsen, *Brackysira neoexilis* Lange-Bertalot, *Discostella stelligera* (Cleve & Grunow) Houk & Klee, *Eunotia pseudosudetica* Metzeltin, Lange-Bertalot & García-Rodríguez, *Eunotia intermedia* (Krasske) Nörpel-Schempp & Lange-Bertalot, *Fragilaria recapitellata* Lange-Bertalot & Metzeltin and *Fragilaria parva* (Grunow) Tuji & Williams. Diatoms registered as frequent were (11 taxa): *Achnanthidium catenatum* (Bily & Marvan) Lange-Bertalot, *Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot, *Aulacoseira ambigua* (Grunow) Simonsen f. *ambigua, Aulacoseira granulata* (Ehrenberg) Simonsen var. *granulata, Eunotia bilunaris* (Ehrenberg) Mills, *Encyonema neogracile* Krammer,



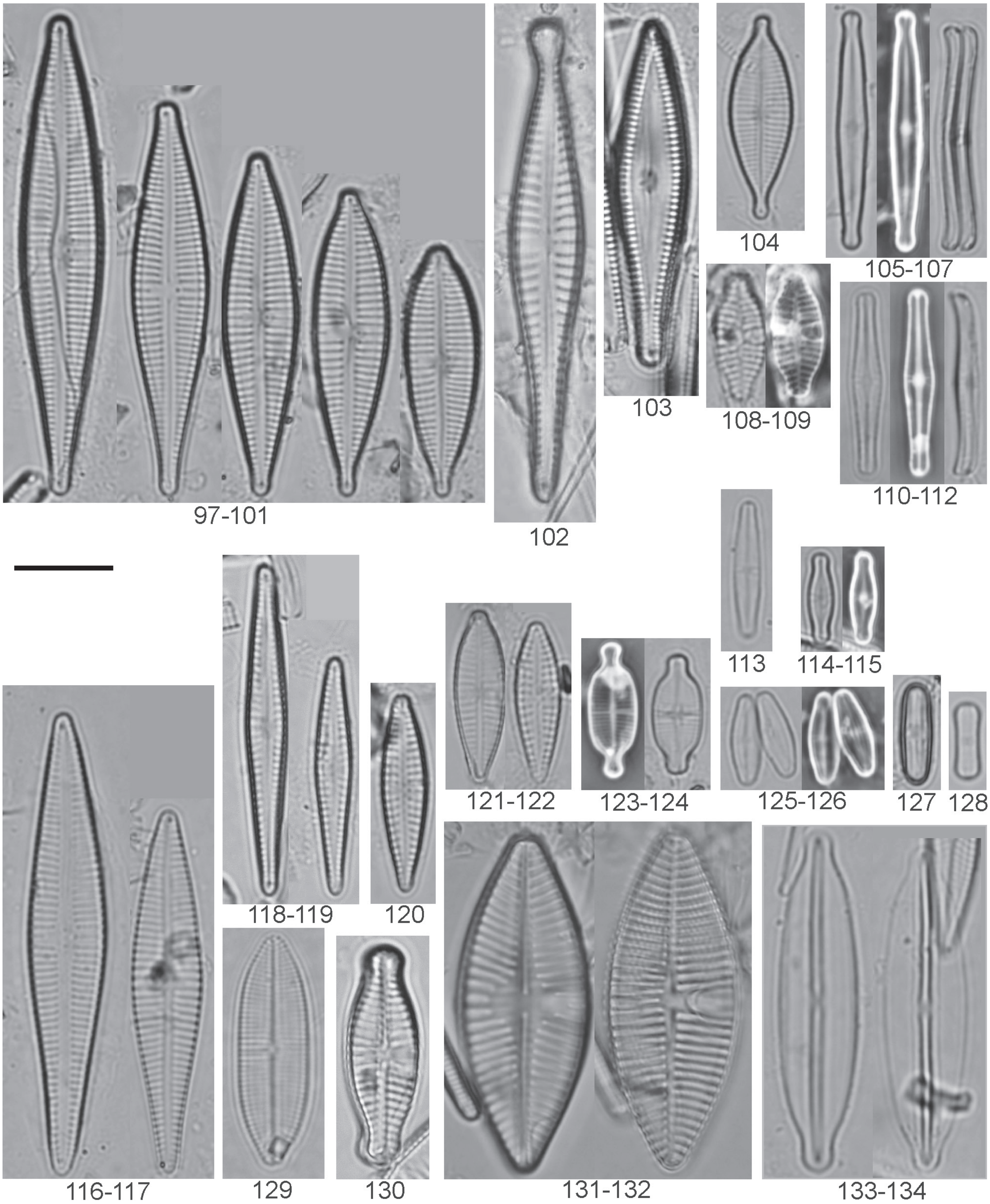
Figures 2-43. Diatoms from Piraquara II reservoir. 2. *Cyclotella meneguiniana.* 3-4. *Discostella stelligera.* 5-7. *Aulacoseira* sp. 8-9. *A. tenella.* 10. *A. ambigua* var. *ambigua* f. *spiralis.* 11. *A. brasiliensis.* 12-14. *A. herzogii* var. *herzogii.* 15-16. *A. ambigua* var. *ambigua* f. *ambigua.* 17-18. *A. granulata* var. *angustissima.* 19. *Fragilaria mesolepta.* 20. *Fragilariforma javanica.* 21-24. *Fragilaria pectinalis.* 25. *Aulacoseira granulata* var. *granulata.* 26-28. *Fragilaria gracilis.* 29-30. *F. microvaucheriae.* 31-34. *F. crotonensis.* 35-37. *F. tenera.* 38. *Ulnaria acus.* 39. *U. ulna.* 40-43. *Fragilaria parva.* Scales: 10 µm.



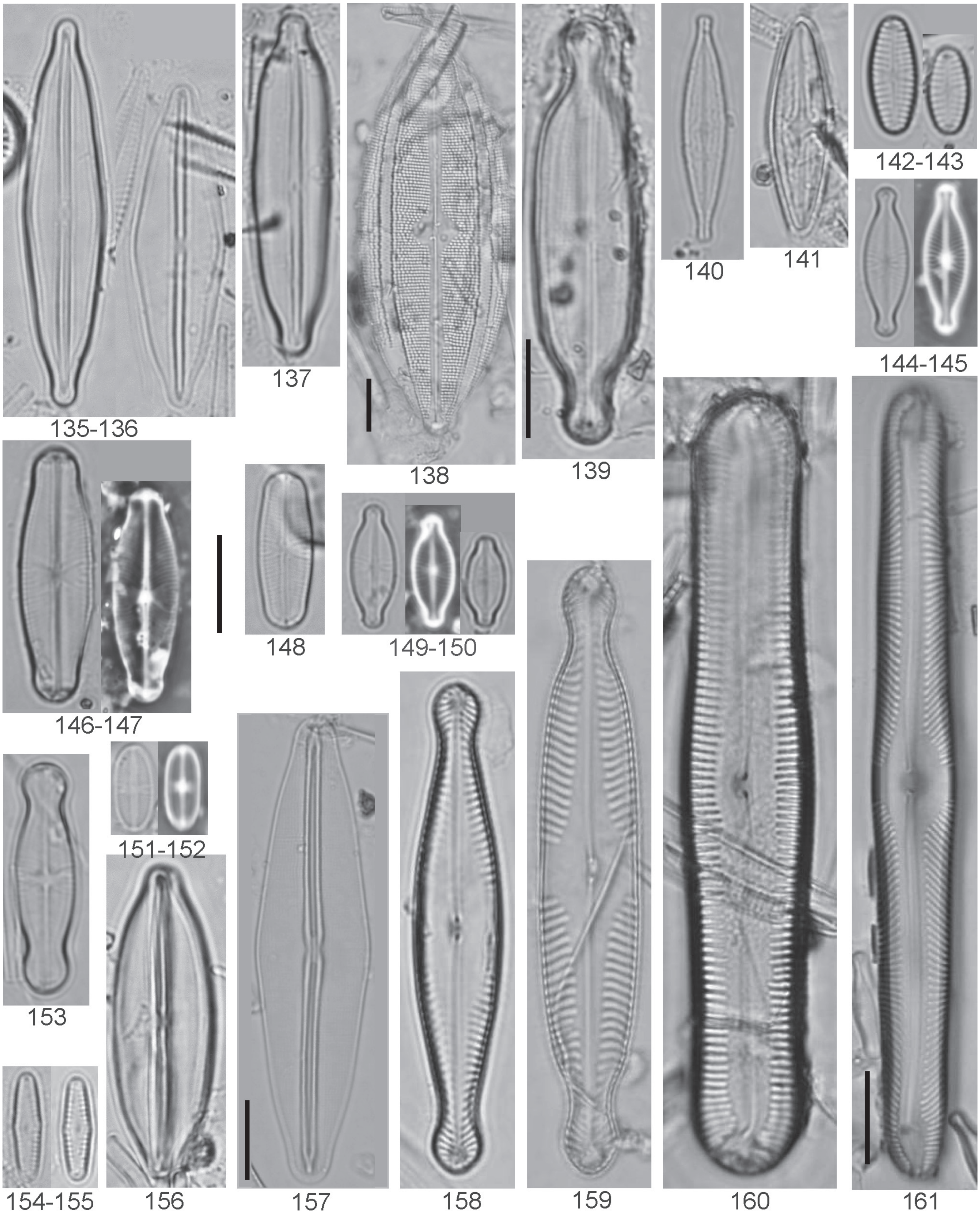
Figures 44-74. Diatoms from Piraquara II reservoir. 44. *Eunotia minor.* 45. *E. monodon.* 46-47. *E. naegelli.* 48. *E. bilunaris.* 49-50. *E. intermedia.* 51. *E. neocompacta.* 52. *Actinella leontopithecus-rosalia.* 53. *Eunotia cf. formicina.* 54-55. *E. camelus.* 56-58. *E. meridiana.* 59. *E. luna* var. *trapezica.* 60. *E. pyramidata* var. *pyramidata.* 61. *E. paratridentula.* 62. *E. rabenhorstii* var. *monodon.* 63-64. *E. pseudosudetica.* 65-67. *E. yanomami.* 68-70. *Encyonema incurvatum.* 71. *Cymbopleura naviculiformis.* 72. *Eunotia desmogonioides.* 73. *D. ossiculum.* 74. *D. transfugum.* Scales: 10 µm.



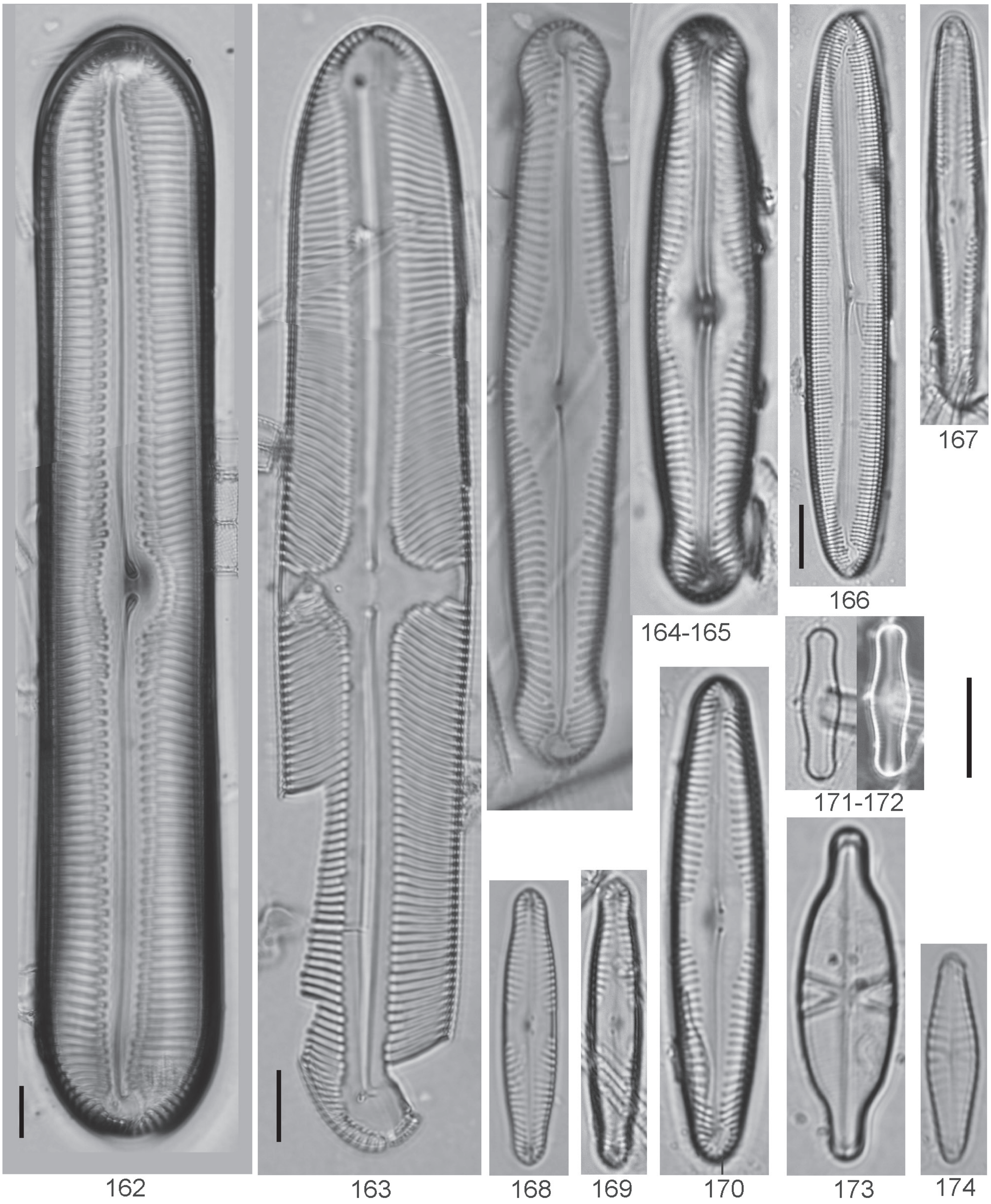
Figures 75-96. Diatoms from Piraquara II reservoir. 75-77. *Encyonema silesiacum*. 78. *E. vulgare* var. *vulgare*. 79. *Encyonopsis frequentiformis*. 80. *Encyonema neogracile*. 81-82. *Placoneis elginensis*. 83. *P. symmetrica*. 84-87. *Gomphonema guaraniarum*. 88. *Geissleria punctifera*. 89. *G.lateropunctata*. 90. *Gomphonema parvulum* var. *subcapitata*. 91. *Cymbella aspera*. 92-94. *Gomphonema pseudoargur*. 95-96. *Encyonopsis microcephala*. Scales: 10 µm.



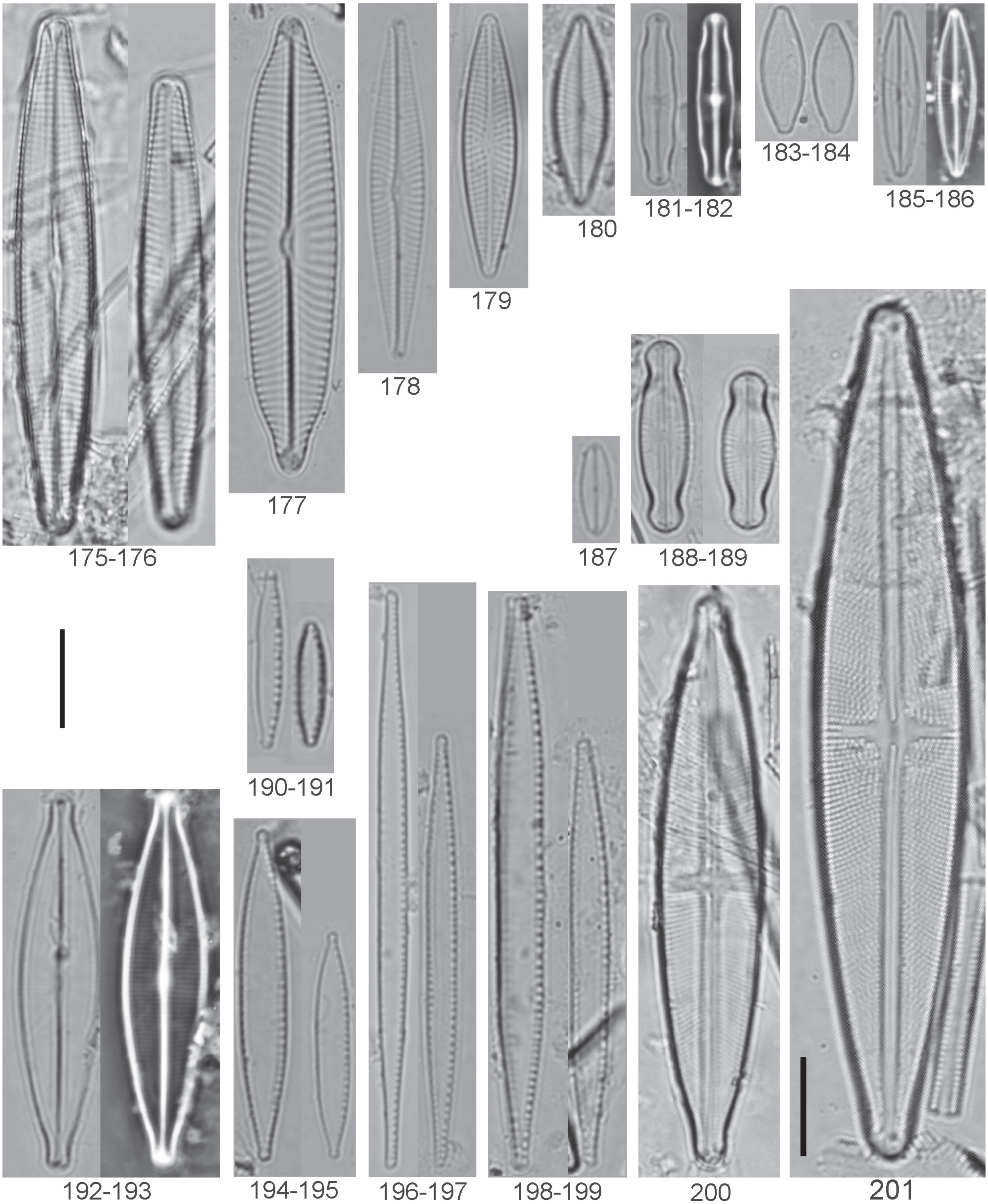
Figures 97-134. Diatoms from Piraquara II reservoir. 97-101. *Gomphonema graciloides.* 102. *G. subtile.* 103. *G. hawaiiensis.* 104. *G. lagenula.* 105-107. *Achnanthidium caledonicum.* 108-109. *Planothidium rostratum.* 110-112. *Achnanthidium catenatum.* 113. *A. minutissimum.* 114-115 *A. macrocephalum.* 116-117. *Gomphonema naviculoides.* 118-119. *Gomphonema* sp. 120. *G. parvulum* f. *saprophilum.* 121-122. *G. parvulum* var. *parvulum* 123-124 *Achnanthidium exiguum.* 125-126 *Achnanthidium eutrophilum.* 127. *Humidophila implicata.* 128. *Humidophila contenta.* 129. *Lemnicola hungarica.* 130. *Planothidium biporomum.* 131-132. *P. heteromorphum.* 133-134. *Frustulia crassinervia.* Scales: 10 µm.



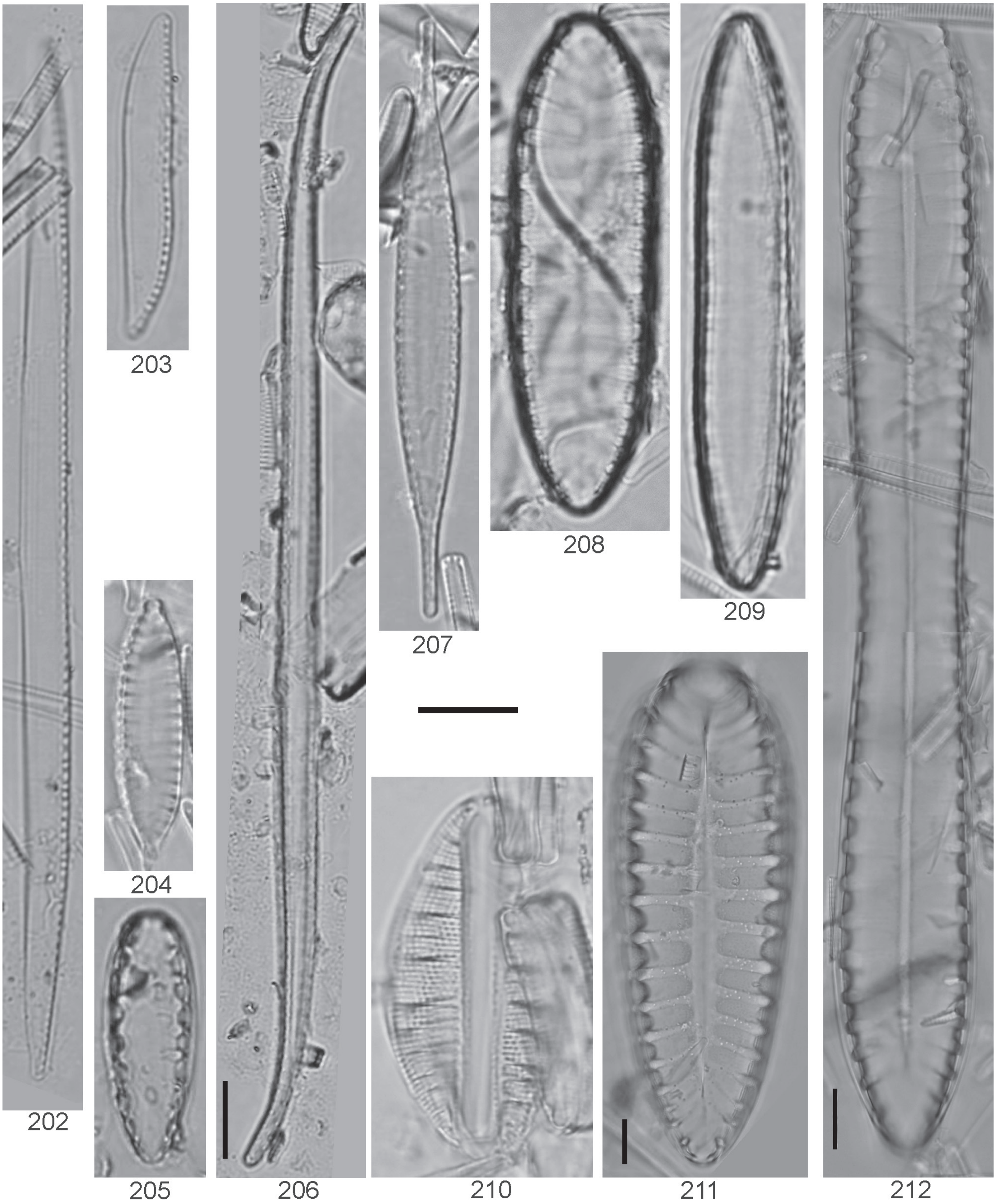
Figures 135-161. Diatoms from Piraquara II reservoir. 135-136. *Frustulia undosa*. 137. *F. guayanensis*. 138. *Neidium iridis*. 139. *N. affine*. 140. *B. brebissoni*. 141. *Brackysira neoexilis*. 142-143 *Sellaphora saugerresii*. 144-145. *S. sassiana*. 146-147. *S. pupula*. 148. *Sellaphora* sp. 149-150. *S. sardiniensis*. 151-152. *S. nigri*. 153. *S. ventraloconfusa*. 154-155. *Chamaepinnularia mediocris*. 156. *Frustulia acidophilissima*. 157. *F. quadrisinuata*. 158. *Pinnularia acrosphaeria*. 159. *P. latarea*. 160. *P. brauniana*. 161. *P. stoermeri*. Scales: 10 µm.



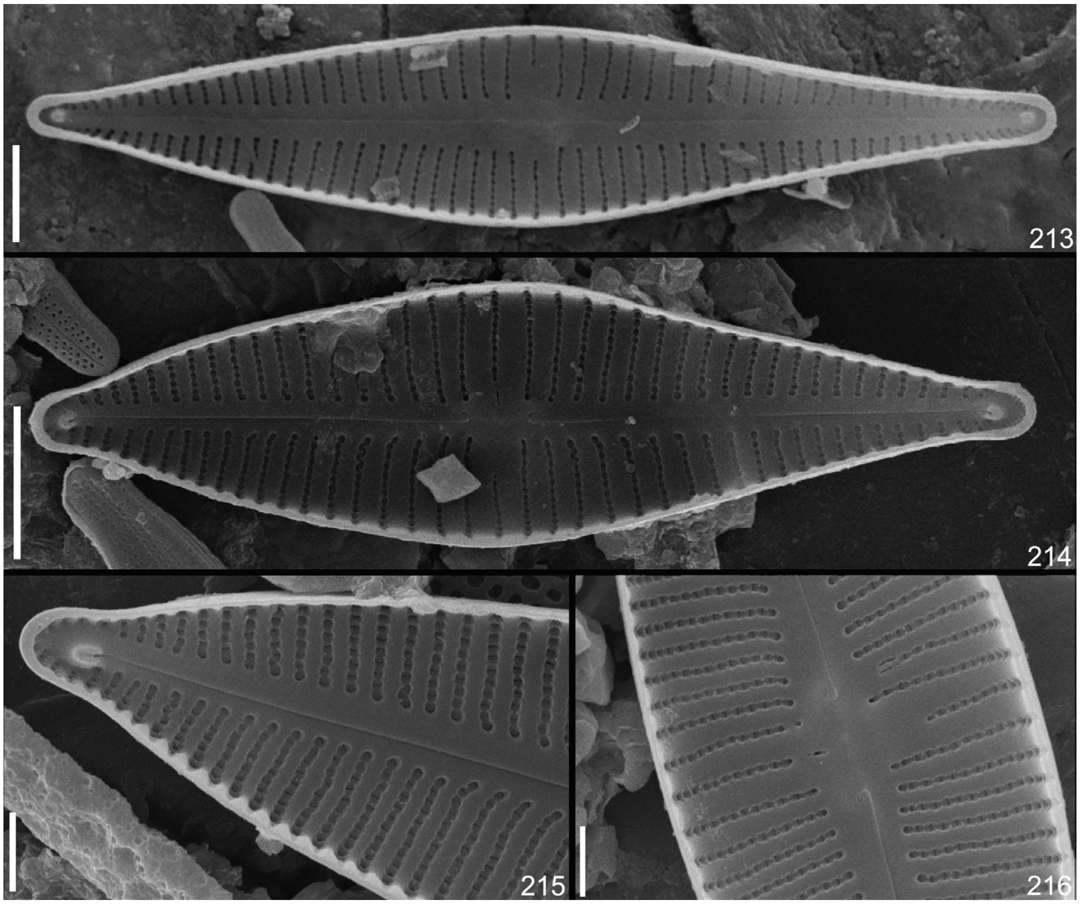
Figures 162-174. Diatoms from Piraquara II reservoir. 162. *Pinnularia latevitatta.* 163. *P. subgibba* var. *undulata.* 164-165. *P. gibba.* 166. *P. butantanum.* 167. *P. similiformis.* 168. *P. divergentissima* var. *minor.* 169. *P. subcapitata.* 170. *P. subbrevistriatta.* 171-172 *Chamaepinnularia brasilianopsis.* 173. *Capartogramma crucicola.* 174. *Hippodonta capitatta* ssp. *iberoamericana.* Scales: 10 µm.



Figures 175-201. Diatoms from Piraquara II reservoir. 175-176. *Navicula angusta.* 177. *N. viridulacalcis.* 178. *N. notha.* 179. *N. cryptotenella.* 180. *N. veneta.* 181-182. *N. tridentula.* 183-184. *Nupela torganiae.* 185-186. *Craticula submolesta.* 187. *Mayamaea permitis.* 188-189. *Naviculadicta ventraloconfusa* var. *chilensis.* 190-191. *Nitzschia perminuta.* 192-193. *Craticula riparia.* 194-195. *Nitzschia palea.* 196-197. *N. gracilis.* 198-199. *N. intermedia.* 200. *Stauroneis anceps.* 201. *S. gracilis.* Scales: 10 μm.



Figures 202-212. Diatoms from Piraquara II reservoir. 202. *Nitzschia vermicularis*. 203. *N. clausii*. 204. *Surirella angusta*. 205. *S. tenuissima*. 206. *Stenopterobia curvula*. 207. *S. delicatissima*. 208. *Surirella lineares* var. *helvetica*. 209. *Surirella* sp. 210. *Rophalodia gibberula*. 211. *Surirella splendida*. 212. *S. biseriata* var. *constricta*. Scales: 10 µm.



Figures 213-216. Diatoms from Piraquara II reservoir (SEM). 213. Internal view of *Gomphonema naviculoides,* scale: 5 µm. 214. Internal view of *G. graciloides,* scale: 5 µm. 215. Headpole of *G. graciloides* in internal view, scale: 1 µm. 216. Median region of *G. graciloides* showing the proximal raphe ends and the stigma opening in internal view, scale: 2 µm.

Fragilaria tenera (W. Smith) Lange-Bertalot, *Fragilaria microvaucheriae* Wetzel & Ector, *Gomphonema graciloides* Hustedt, *Gomphonema lagenula* Kützing and *Nitzschia palea* (Kützing) W. Smith. Altogether the more frequent diatoms totalized 15.3% of 135 taxa identified and 54.7% were sporadic in the reservoir.

Achnanthidium minutissimum and *Brachysira neoexilis* were the most frequent taxa present in 90% of the samples. Among the very frequent diatoms we found other species included in *Achnantidium, Fragilaria* and *Eunotia*. The solitary *Discotella stelligera* and the short chain *Aulacoseira tenella* are free living species that entangled among diatoms from the biofilm.

Description and comments of specimens not identified and first registered to the state of Paraná are bellow.

Aulacoseiraceae

Aulacoseira sp.

Figs 5, 7

Frustules solitary or in short chains. Valves circular, shallow ringleist; inconspicuous striae, areolae and spines.

Aulacoseira sp. resembles *A. simoniae* Tremarin, Torgan & Ludwig and *A. tenella*, differing by the conspicuous ornamentation of the latter species (Tremarin et al. 2014). Specimens were rare in samples, making detailed analysis impracticable.

Eunotiaceae

Eunotia cf. formicina Lange-Bertalot *in* Lange-Bertalot et al., Diatoms of Europe 6: 105; pl. 222, figs 1-7, pl. 223, 2011.

Fig. 53

Valves with dorsal margin convex, ventral margin concave, ends rounded, not detached from the valve, striae parallel to radiate near the apices.

Eunotia formicina was recently proposed (Lange-Bertalot et al. 2011) to nominate morphotypes of *E. formica* Ehrenberg distinguished by rounded ends, narrower valve (6-8 µm) and denser areolae (25-28 in 10 µm) in the striae (8-12 in 10 µm). *Eunotia formica* shows cuneate poles, wider valves (7-14 µm) and less denser striae (6-12 in 10 µm). Central delicate gibbosity at ventral margin of *E. formicina* was not observed in our specimens and the striae are originally less dense.

Gomphonemataceae

Gomphonema guaraniarum Metzeltin & Lange-Bertalot in Lange-Bertalot, Iconogr. Diatomol. 18: 147, pl. 212, figs 9-14, 2007.

Figs 84-87

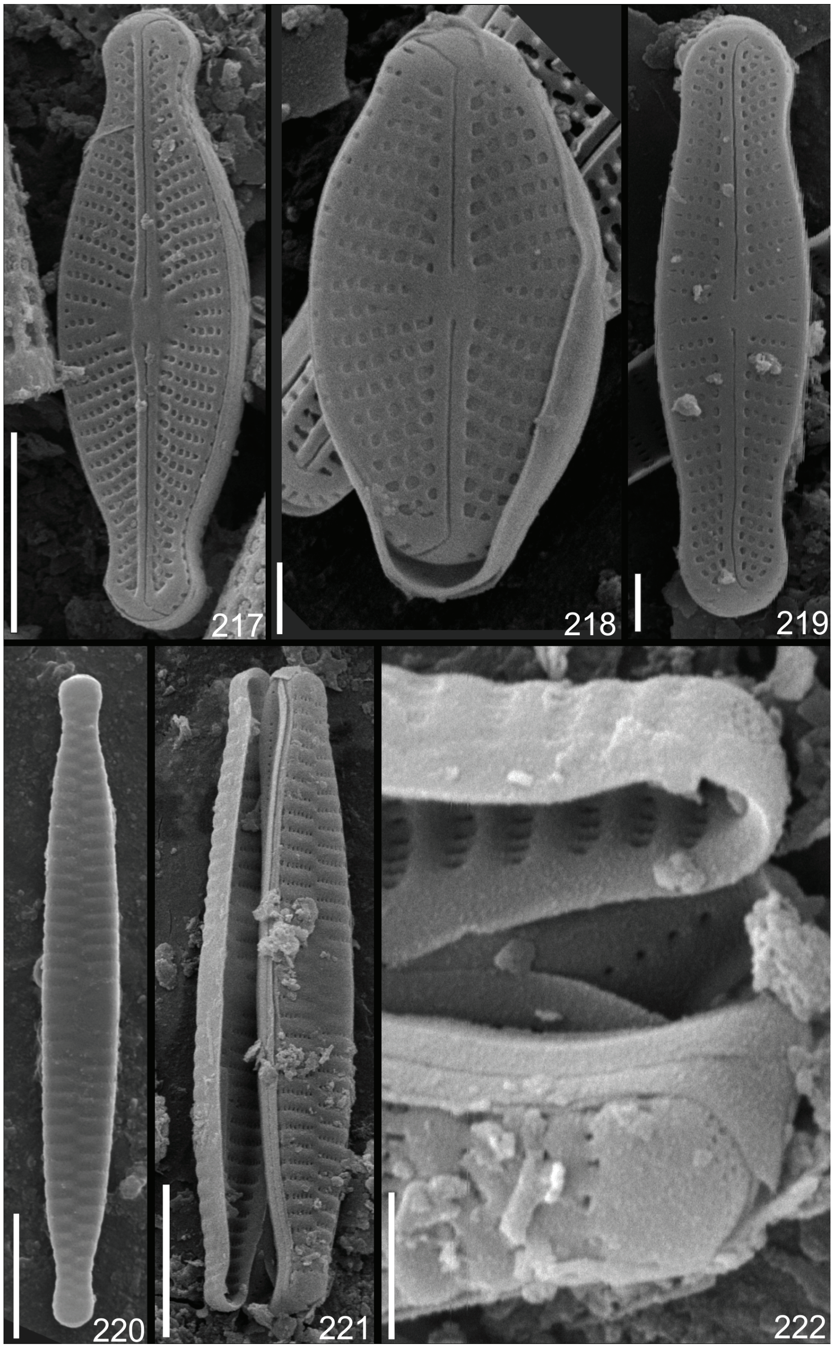
Valves rhombic-lanceolate, slightly heteropolar, ends acute, raphe-sternum linear and straight, central area unilaterally expanded with a stigma at the opposite side, striae distintly punctuate, parallel to radiate toward the ends.

Gomphonema sp.

Figs 118-119

Valves narrowly lanceolate, heteropolar, ends acute, raphe-sternum linear and straight, central area with a stigma at the end of a stria, striae radiate, areolae inconspicuous.

Gomphonema sp. is similar to *G. geisslerae* Reichardt & Lange-Bertalot in outline (lenght 18-27.5 µm, width 2.6-3.8 µm), but is wider (Reichardt 1997).



Figures 217-222. Diatoms from Piraquara II reservoir (SEM). 217. External view of *Sellaphora sassiana* showing the striation pattern, proximal and distal raphe ends, scale: 5 µm. 218. *Sellaphora sardinensis* in external view showing the shape of areolae, proximal and distal raphe ends, scale: 1 µm. 219. Raphe valve of *Achnanthidium macrocephalum* in external view, scale: 1 µm. 220-221. *Fragilaria pectinalis* in external view, scales: 5 µm. 222. Detail of apical pore field of *Fragilaria pectinalis*, scale: 1 µm.

Achnanthidiaceae

Achnanthidium macrocephalum (Hustedt) Round & Bukhtiyarova, Diatom Res. 11: 349, 1996.

Figs. 114-115, 219

Valves lanceolate, ends capitate, sternum narrow and linear, central area round, slightly expanded, raphe straight, striae inconspicuous.

The measurements of analysed specimens agree with the limits given by Krammer & Lange-Bertalot (1991b) of species *Achnanthes minutissima* var. *macrocephala* Hustedt (lenght 6-14 µm, width 2.5-3 µm). *Achnanthidium reimeri* (Camburn) Ponader & Potapova present similar outline, but the valve is wider (9.4-13.5 µm long, 2.9-3.2 µm wide) and the apices are more rounded. Also, *A. latecephalum* Kobayasi has similar outline, but the capitate ends and parallel striae distinguish the species from *A. macrocephalum* (Ponader & Potapova 2007).

Amphipleuraceae

Frustulia quadrisinuata Lange-Bertalot in Lange-Bertalot & Metzeltin, Iconogr. Diatomol. 2: 59-60, pl. 38, figs 10-12, pl. 119, figs 1-1, 1996.

Fig. 157

Valves lanceolate with margins slightly triondulate, ends rostrate, raphe-sternum narrow and linear, with longitudinal costa constricted at the central area, raphe straight, striae inconspicuous.

Sellaphoraceae

Sellaphora sardiniensis Lange-Bertalot, Cavacini, Tagliaventi & Alfinito in Lange-Bertalot, Iconogr. Diatomol. 12: 122; pl. 19, fig. 1-9, pl. 20, fig. 1-5, 2003.

Figs. 149-150, 218

Valves elliptic, ends subcapitate, raphe-sternum narrow and linear, central area elliptic, limited by irregular shortening striae, raphe straight, striae radiate.

Sellaphora sardiniensis resembles *S. subpupula* Levkov & Nakov, but the latter taxon have central area laterally expanded and denser striae (27-30 in 10 µm) (Lange-Bertalot et al. 2003; Levkov et al. 2007).

Sellaphora sp.

Fig. 148

Valves linear-lanceolate, ends subcapitate, raphe-sternum narrow and linear, elliptic central area limited by irregular shortening striae; raphe straight with proximal ends curved to the same side, striae radiate.

Sellaphora sp. is similar to *S. rhombicarea* Metzeltin, Lange-Bertalot & García-Rodriguez in outline, but differs in the dimensions (lenght 24-50 µm, width 9.5-11 µm, 17-19 striae in 10 µm) (Metzeltin et al. 2005). *Sellaphora laevissima* (Kützing) Mann is larger and striae less dense (lenght 6-9.3 µm and 15-19 striae in 10 µm) (Zimmerman et al. 2010).

Surirellaceae

Surirella sp.

Fig. 209

Valves isopolar, linear to lanceolate, slightly constricted in the middle, ends cuneate-rounded. Aliform chanells parallel, straight to slightly radiated near the ends, striae inconspicuous.

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Short Communication

Advertisement and courtship calls of *Dendropsophus nanus* (Boulenger, 1889) (Anura: Hylidae) from its type locality (Resistencia, Argentina)

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Abstract**:** *Dendropsophus nanus* was described from Resistencia, Argentina. The species distribution is widespread in South America east of the Andes. Despite its wide distribution, little information about its advertisement call is available in the literature. Call descriptions from type localities are especially important for the resolution of taxonomic issues, as well as for intraspecific comparisons. Herein we describe the advertisement and the male courtship calls of *D. nanus* from its type locality. The advertisement call of *D. nanus* is composed of two types of pulsed notes, herein referred to as "note A" (long note) and "note B" (short note), both with similar dominant frequencies, but different durations. The courtship call is formed by notes that are similar to notes A of the advertisement call, but emitted at lower amplitude. Previous studies demonstrated that the complex call of *Eleutherodactylus coqui* and *Geocrinia victoriana* convey separated messages to male and female. Although several previous experiments have been conducted to assess the acoustic interactions of some species of *Dendropsophus*, more studies are necessary to understand the functions of the two notes of the advertisement call of *D. nanus* and the calls of other species of the *D. microcephalus* group.

Keywords: *Acoustic communication; Dendropsophus microcephalus group; Behavior.*

Cantos de anúncio e corte de Dendropsophus nanus (Boulenger, 1889) (Anura: Hylidae) de sua localidade tipo (Resistencia Argentina).

Resumo: *Dendropsophus nanus* foi descrito de Resistencia, Argentina. Essa espécie está amplamente distribuída na América do Sul a leste dos Andes. Apesar da ampla distribuição, poucas informações sobre seu canto de anúncio estão disponíveis em literatura. Descrições de cantos de localidades tipo são especialmente importantes para a resolução de problemas taxonômicos, assim como para comparações intraespecíficas. Aqui, nós descrevemos os cantos de anúncio e de corte do macho de *D. nanus* de sua localidade tipo. O canto de anúncio de *D. nanus* é composto por dois tipos de notas, aqui referidas como "notas A" (nota longa) e "notas B" (nota curta), ambas com frequência dominante similar, mas com diferenças nas durações. O canto de corte é formado por notas que são similares à nota A do canto de anúncio, mas emitidas com menor amplitude. Estudos anteriores demonstraram que os cantos complexos de *Eleutherodactylus coqui* e *Geocrinia victoriana* transmitem mensagens separadas para machos e fêmeas. Embora vários experimentos anteriores terem sido realizados a fim de avaliar as interações acústicas de algumas espécies de *Dendropsophus*, mais estudos são necessários para entender as funções das duas notas do canto de anúncio de *D. nanus* e dos cantos de outras espécies do grupo de *D. microcephalus*.

Palavras-chave: *Comunicação acústica, Grupo de Dendropsophus microcephalus, Comportamento.*

Introduction

Sound production by animals is primarily a method of advertising the presence of an individual to another. In Anura, the vocalizations are produced especially by males. The categories of anuran calls are recognized based on the context in which they are emitted, such as advertisement call, courtship call, territorial call, release call, among others. The advertisement calls, main type of sound produced by anuran males, has two functions: (1) the attraction of a conspecific females, and (2) the announcement of an occupied territory to other conspecific and heterospecific males (Duellman & Trueb 1986, Wells 2007). The two primary functions of the advertisement call may be combined into one monophasic signal, which conveys separate messages to males and females, or they may be separated between the components of a diphasic call. In the case of diphasic calls, the notes are combined within a single unit or produced in a sequence (Littlejohn 1977).

Dendropsophus nanus was described by Boulenger (1889) from Resistencia, Argentina. The species distribution is widespread in South America east of the Andes (Frost 2015). Despite its wide distribution, little information on its advertisement call is available in the literature. Brief descriptions were provided by Barrio (1967), Basso et al. (1985), and Marquez et al. (1993), and, more recently, Martins & Jim (2003) recognized that the advertisement call of *D. nanus* was actually composed of two types of notes (diphasic call) that differed in duration and pulse number.

Call descriptions from type localities are especially important for the resolution of taxonomic issues, as well as for intraspecific comparisons. Herein we describe the advertisement call, and for the first time, the male courtship call of *D. nanus* from its type locality (Resistencia, Argentina).

Material and Methods

Fieldwork was carried out on 11 January 2011. Calls were recorded between 20:13–21:08 h (air temperature 25ºC, water temperature 26ºC) using a M-Audio Microtrack II digital recorder set at a sampling rate of 48 kHz and an amplitude resolution of 16 bits, coupled to a ME66/K6 directional microphone. Acoustic traits were analyzed using Raven Pro 1.4 for Windows from The Cornell Lab of Ornithology (Bioacoustic Research Program 2012); spectrogram settings were: window type = Hann, window size = 1024 samples, 3 dB bandwidth = 270 Hz, overlap = 85%, hop size = 0.792 ms, DFT size = 1024 samples, and grid spacing = 46.9 Hz. All other settings followed the 'default' of Raven. Temporal traits were measured from oscillograms and spectral traits were measured from spectrograms. Six acoustic variables were measured: note duration, number of pulses per note, pulse duration, dominant frequency (obtained through the Peak Frequency measurement function), pulse rate (quantified as the number of pulses divided by note duration), and call rate in the case calls were emitted in series (quantified as the number of notes divided by note series duration). Sound figures were obtained in the Seewave package v. 2.0.2 (Sueur et al. 2008), on the R platform (version 3.2.2) (R Core Team 2015); Seewave settings were Hanning window, 256 samples (FFT), and 85% of overlap. Call terminology follows Duellman & Trueb (1986). Voucher specimens are housed in the Collection of frogs at the Universidad Nacional del Nordeste (UNNEC), Corrientes, Argentina, under the following numbers: UNNEC 12429–39.

Results

The advertisement call of *D. nanus* (Figure 1) is composed of two types of pulsed notes (diphasic call), herein referred to as "note A" (long note) and "note B" (short note), both with similar dominant frequencies. Calls are often emitted in series from 2 to 6 notes (mean 2.4; SD = 0.4; N = 236). The series are formed by one note A followed by 1 to 5 notes B (e.g., AB, ABB or ABBB); note A may be emitted alone, whereas note B is only emitted in series. Note A duration ranges from 29 to 56 ms (mean 41.2 ms; SD = 4.4; N = 145). Notes are formed by 7 to 15 pulses (mean 10.9; SD = 1.3; N = 124), pulse duration ranges from 2 to 11 ms (mean 3.7 ms; SD = 0.2; N = 163), and pulse rate ranges from 194 to 351 pulses per second (mean 265.8; SD = 20.9; N = 124). The dominant frequency ranges from 3,703 to 4,546 Hz (mean 4,246 Hz; SD = 165.2; N = 145).

Note B duration ranges from 13 to 31 ms (mean 21.1 ms; SD = 2.7; N = 134), and is formed by 3 to 9 pulses (mean 4.9; SD = 1.0; N = 110). Pulse duration ranges from 2 to 14 ms (mean 4.2 ms; SD = 0.7; N = 113), and pulse rate ranges from 143 to 360 pulses per second (mean 244.5; SD = 34.9; N = 113). The dominant frequency ranges from 3,937 to 4,593 Hz (mean 4,259 Hz; SD = 135.4; N = 134). When in series (e.g., ABB), notes are emitted at rates from 2.63 to 4.73 per second (mean 3.8; SD = 0.3; N = 86). Interval of notes within series ranges from 165 to 320 ms (mean 221.8; SD = 18.6; N = 117). The amplitude modulation in notes A and B is incomplete and variable in shape; in note B, the last pulse is longer than the other ones (Figure 1).

While recording the advertisement calls, two males suddenly decreased their note rate and amplitude in response to the approach of conspecific females. These calls were interpreted as male courtship calls, once the males kept emitting them until the amplexus. The courtship call (Figure 2; N = 2 courtship calls) is formed by notes that are similar to notes A of the advertisement call, emitted at a lower amplitude than advertisement calls (Figure 3). The calls are formed by 12 and 17 notes, with a note

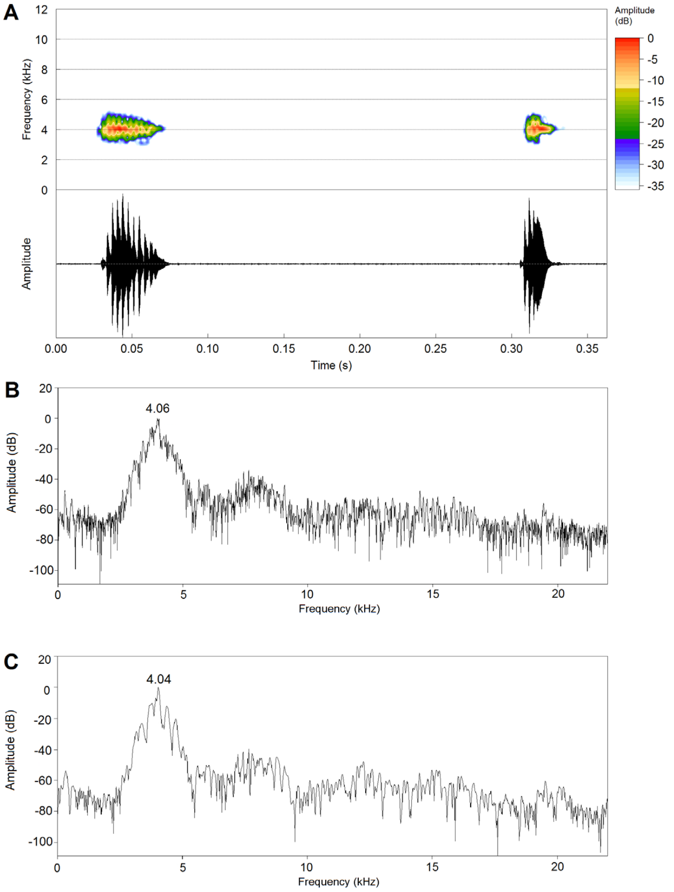

Figure 1 – Advertisement call of *Dendropsophus nanus* from its type locality (Resistencia, Argentina). A) Spectrogram and its respective oscillogram of the notes A and B, B) power spectrum of the note A, and C) power spectrum of the note B. Sound file: Dendrop_nanus_Resistencia_AR_1a_BFVT_Mtc.

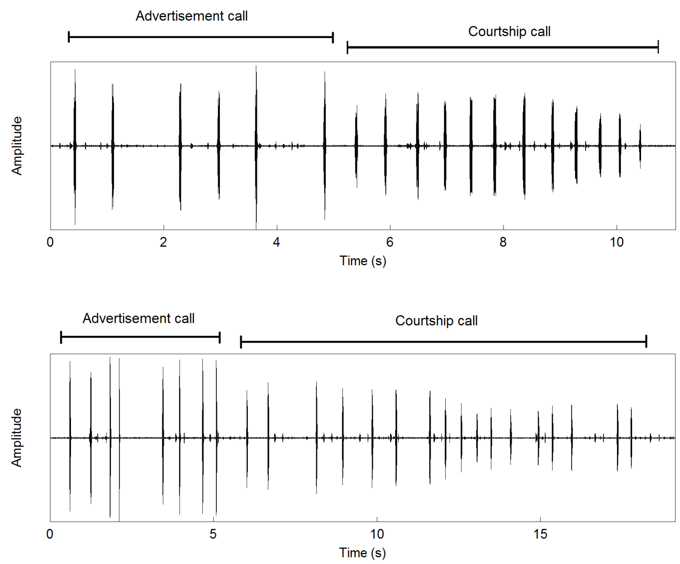

Figure 2 – Comparative oscillograms of advertisement calls and male courtship calls from two males of *D. nanus* (Resistencia, Argentina). Sound files: Dendrop_nanus_Resistencia_AR_5a_BFVT_Mtc; Dendrop_nanus_Resistencia_AR_10a_BFVT_Mtc.

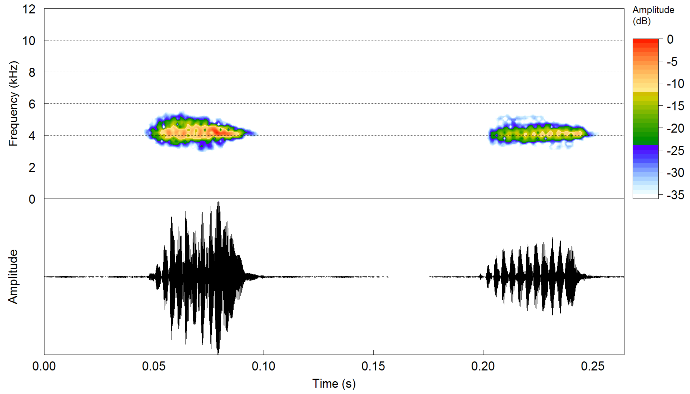

Figure 3 – Spectrogram and its respective oscillogram of a note A of the advertisement call in comparison with a note of the male courtship call. Notice that the main difference is related to the relative sound amplitude of the calls. Sound file: Dendrop_nanus_Resistencia_AR_5a_BFVT_Mtc.

repetition rate of 2.4 and 1.4 notes per second, respectively. Note duration ranges from 37 to 54 ms (mean 47.1 ms; SD = 1.8; N = 29), pulse number from 7 to 13 (mean 11.8; SD = 0.3; N = 29). Pulse duration ranges from 3 to 10 ms (mean 4.0 ms; SD = 0.1; N = 39), and pulse repetition rate from 189 to 289 pulses per second (mean 251.4 ms; SD = 17.1; N = 29). The dominant frequency ranges from 3,750 to 4,547 Hz (mean 4,138 Hz; SD = 60.7; N = 29).

Discussion

Herein, we describe the courtship call of *D. nanus* composed of similar notes compared to notes A of the advertisement call, but emitted at lower amplitude and lower note repetition rate than in the advertisement call. Courtship calls are probably widespread in anurans, but have not been reported for many species because of the lack of detailed observations in courtship behavior (Wells 2007). Courtships calls may vary from simply lengthening their advertisement calls, increasing calling rates, or by giving calls that are modified versions of the advertisement call, to complex calls composed of more than one type of courtship call. Sometimes, courtship calls are given at lower intensity than advertisement calls, perhaps to avoid alerting other males to the presence of a female (Wells 2007).

The values presented here for the advertisement call of *D. nanus* are in accordance with those described by Martins & Jim (2003) for a population from the Municipality of Botucatu, State of São Paulo, Brazil, distant about 1,200 km from Resistencia, Argentina. Although Barrio (1967), Basso et al. (1985) and Marquez et al. (1993) did not recognize two different types of notes in the call of *D. nanus* (diphasic call), the values presented by us encompass the ones presented by those authors for spectral and temporal traits of the calls.

In the *D. microcephalus* group, other seven species have their advertisement calls composed of two types of notes: *D. anataliasiasi* (Teixeira & Giaretta 2015), *D. gryllatus* (Duellman 1973), *D. microcephalus* (Duellman 1970), *D. rhodopeplus* (Duellman 1972), *D. phlebodes, D. robertmertensi*, and *D. sartori* (Duellman 1968). The advertisement call of *D. nanus* differs from that of *D. anataliasiasi* by different amplitude modulation (AM) patterns (low AM in *D. nanus*, high AM in *D. anataliasiasi*). From those of *D. gryllatus* (note A: 90–380 ms; note B: 20–80 ms), *D. microcephalus* (note A: 110–180 ms; note B: 50–140 ms), *D. rhodopeplus* (note A: 100–220 ms), *D. phlebodes* (note A: 70–160 ms; note B: 40–120 ms), *D. robertmertensi* (note A: 70–110 ms; note B: 30–60 ms), and *D. sartori* (note A: 70–90 ms; note B: 40–70 ms) (Duellman 1968, 1970, 1972, 1973, Teixeira & Giaretta 2015), by a shorter note duration (*D. nanus*: note A: 29–56 ms; note B: 13–31 ms).

A part from the typical diphasic calls, in some species as *Afrixalus brachycnemis* Boulenger 1896, the two components of the call are not linked in a single unit or produced in sequence. Males often produce only one component for long periods of time (Backwell 1988). Other species possess more than two notes on the advertisement call, and they may represent a graded set of signals as reported by Smith & Roberts (2003) for *Litoria adelaidensis* Gray, 1841. Presumably, diphasic and graded calls have evolved from the simpler monophasic signals, more than once and in different groups, because they offer added advantages in the efficiency of communication. In functionally partitioned calls (Littlejohn & Harrison 1985; Narins & Capranica 1978), the male is capable of selectively modifying the proportion of call components in different social contexts (Arak 1983), in order to maximize the efficiency of response to their vocalizations (Backwell 1988).

Narins & Capranica (1978) and Littlejohn & Harris (1985) demonstrated that the calls of *Eleutherodactylus coqui* Tomas, 1966 and *Geocrinia victoriana* (Boulenger, 1888), composed of two different types of notes, convey separated messages to male and female. While the first note of the call conveys message to males, the second note conveys message to females. Similar experiments have never been conducted to test the functions of the two different note types in species of the *D. microcephalus* group, nor are there available descriptions of male courtship calls for this species group. However, several experiments were conducted to assess the intra-and interspecific acoustic interactions between the syntopic species *D. ebraccatus* (Cope, 1974), *D. microcephalus* (Cope, 1886) and *D. phlebodes* (Stejneger, 1906) (Schwartz & Wells 1984a, b, Schwartz 1987, Wells & Schwartz 1984, Wells & Greer 1981). The results showed that isolated males emitted introductory notes and, when in chorus (in intra- and interspecific interactions), males added secondary and/or aggressive notes to the call as a response to male interactions. Females preferred complex calls (composed of the two note types) instead of those only composed of introductory notes, even if these complex calls were composed of aggressive notes followed by secondary notes (Schwartz & Wells 1984a, b, Wells & Schwartz 1984, Schwartz 1987). Wells & Greer (1981) suggested for *D. ebraccatus* that the introductory note probably represents the principal female-attracting signal, once males respond to the approach of non-calling individuals by emitting a rapid series of primary notes, and the secondary notes may serve a similar function as their structure resembles short segments of primary notes, which is reinforced by the female preference of complex calls for *D. microcephalus* (Schwartz 1987), but it was also demonstrated that the secondary notes have influence on the interactions between males (Schwartz & Wells 1984a, b, Wells & Schwartz 1984, Schwartz 1987).

As the male courtship call of *D. nanus* is composed of similar notes compared to notes A of the advertisement call, it seems that the patterns described for *E. coqui* and *G. victoriana* (Narins & Capranica 1978, Littlejohn & Harris 1985) are not the same pattern that is described here for *D. nanus*, whereas the results presented for *D. ebraccatus*, *D. microcephalus,* and *D. phlebodes* (Schwartz & Wells 1984a, b, Schwartz 1987, Wells & Schwartz 1984, Wells & Greer 1981) are more compatible with those presented here, which is expected because these species are more closely related. Once the results presented for *D. ebraccatus*, *D. microcephalus,* and *D. phlebodes* are not conclusive with respect to the messages conveyed by the two notes of their advertisement calls, more studies are necessary to understand the functions of the two notes of the call of *D. nanus* and those of other species in the *D. microcephalus* group.

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Reproductive biology of *Artibeus fimbriatus* Gray 1838 (Chiroptera) at the southern limit of its geographic range

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Abstract: Bats of the Phyllostomidae family exhibit different reproductive patterns in Neotropical regions and the strategy adopted depends on the regional climate. Here we studied the reproductive biology of *Artibeus fimbriatus* at the southern limit of their distribution in Brazil. This region has no rainy season, and the climate is characterized by high temperatures and variable photoperiods. We examined 129 *A. fimbriatus* females over several months, and used histological procedures where necessary in order to determine whether bats were pregnant. Females exhibited a long reproductive period and were pregnant from June until February. The reproduction events were found to be dependent on the photoperiod, but independent of annual accumulated precipitation. Our results show that at the southern limit of their distribution, *A. fimbriatus* exhibit seasonal-dependent reproductive patterns, with parturition events occurring during spring and summer, in which the days are longer and temperature is warmer.

Keywords: *Phyllostomidae; Photoperiod; Reproduction; Seasonal.*

Biologia reprodutiva de Artibeus fimbriatus Gray 1838 (Chiroptera) no limite sul de sua distribuição geográfica

Resumo: Os morcegos Phyllostomidae apresentam diferentes padrões reprodutivos no Neotropico e a estratégia adotada depende do clima regional. Neste trabalho nós estudamos a biologia reprodutiva de *A. fimbriatus* no Brasil, na região que determina o limite sul de sua distribuição geográfica, onde não há estação chuvosa e o clima é caracterizado por variações na temperatura e fotoperíodo. Nós examinamos 129 fêmeas de *A. fimbriatus* e utilizamos procedimentos histológicos, quando necessário, para classificar as fêmeas como prenhe ao longo dos meses. As fêmeas exibem um longo período reprodutivo e estão grávidas de junho até fevereiro. Nossos resultados mostram que as fêmeas de *A. fimbriatus* apresentam uma estratégia reprodutiva que é dependente da sazonalidade com os nascimentos ocorrendo quando os dias são mais longos e a temperatura é maior (primavera e verão), no limite sul de sua distribuição geográfica.

Palavras-chave: *Phyllostomidae; Fotoperíodo; Reprodução; Sazonal.*

Introduction

Phyllostomidae are a family of Neotropical bats that are distributed from southern United States to northern Argentina. Within this wide geographic range they inhabit a great diversity of habitats in tropical and subtropical regions, and therefore, are submitted to a variety of abiotic factors, such as variations in latitude, temperature, rainfall and photoperiods (Fleming et al. 1972; Beguelini et al. 2013a). In response to these factors, bats of the Phyllostomidae family have evolved different reproductive patterns in Neotropical regions, such as seasonal polyestry, aseasonal polyestry and monoestry (Fleming et al. 1972; Estrada & Coates-Estrada 2001). Considering the high diversity of bats in this region, the available information about their reproductive biology is lacking (Zortéa 2003), and only few species have had their reproductive aspects analyzed in detail (Godoy et al. 2014).

Reproduction in bats is energetically expensive and is strongly associated with specific environmental conditions (Wilson 1979). Thus, in areas where food production is seasonal, bats meet their energetic requirements for reproduction during periods of maximum food availability (Racey & Entwistle 2000). Bats from temperate latitudes reproduce during periods of higher temperatures, when there is increased abundance of insects. In tropical regions, however, reproductive periods are associated with the rainy season, because variations in rainfall may affect the seasonality of food (Fleming et al. 1972; Racey & Swift 1985). Therefore, variations in rainfall in the Neotropics affect food availability, directly interfering with the reproductive cycles of the bats over their distribution area and consequently, sub-populations may exhibit different reproductive patterns (Crichton & Krutzsch 2000).

Artibeus fimbriatus Gray 1838 is a Phyllostomidae bat with a wide geographic distribution, found in east Paraguay, Northwest Argentina and in Brazil, from Bahia to Rio Grande do Sul (Rui & Fabián 1999). Although most studies that have investigated tropical species generally focus on aspects of female reproduction (Beguelini et al. 2013b), the reproductive biology of *A. fimbriatus* is poorly studied and is only known in a region in southeastern of Brazil (Ésberard et al. 1998). The southern limit of the geographic range of this species is the south of Brazil, where the climate differs from other regions due to the absence of a rainy season, in addition to its characteristic high variability in temperatures and photoperiods (Kuinchtner & Buriol 2001; Alvares et al. 2013).

There is a lack of information on the reproductive biology of *A. fimbriatus*, and on the effect of the different environment at the southern limit its distribution. Therefore, the objective of this study was to investigate the reproductive biology of *A. fimbriatus* females at their southern limit, and their relationship with environmental factors. Specifically, we aimed to determine: (1) the annual period of female *A. fimbriatus* reproduction at the southern limit of their distribution; and (2) whether the reproductive events are associated with the photoperiod, temperature or annual accumulated precipitation of this region.

Materials and methods

We investigated specimens that had been deposited in scientific collections to investigate the reproductive pattern of *A. fimbriatus* females. These specimens had been deposited at the University of Rio Grande do Sul and Fundação Zoobotânica do Rio Grande do Sul, and were collected between 1989 and 2011. The specimens were from Brazilian localities at the southern limit of the species distribution, located at 28°26'06.94" S 49°11'5.25" W north, 29°22'28.97" S 51°07'31.23" W east and 28°36'55.53" S 49°01'31.73" W west. These regions are characterized by the absence of a rainy season. Instead, the annual accumulated precipitation is constant throughout the year, and the climate (Köppen Cfa) is characterized by high temperatures and photoperiods that vary between the four well-defined seasons.

We determined the age of females by verifying their epiphyseal ossification, and only adults were included in this study (Anthony, 1988). We analyzed their gonads to determine whether the females were pregnant. Histological confirmation was performed on some females to confirm the initial stages of pregnancy. The histological slides were prepared with a Leica® Historesin Embedding Kit or paraffin and were stained with hematoxylin and eosin. Females were classified as either lactating, pregnant, pregnant and lactating or inactive. Fetuses were measured to determine their developmental stage (Reis 1989), and were classified into five groups: group I, initial stages of pregnancy (histologically confirmed); group II, less than 1 cm; group III, between 1 and 2 cm; group IV, between 2 and 3 cm; and group V, between 3 and 4 cm.

We used generalized linear models (GLM) with a binomial distribution to test the effect of the photoperiods and annual accumulated precipitation on the probability of reproductive events over the year. For the residual analysis and model validation, we followed the method described by Zuur et al. (2009). The photoperiods, annual accumulated precipitation (hereafter called rainfall) and temperature data were obtained from the Brazilian National Weather Institute (INMET). All analyses were performed using R software (R Development Core Team 2012) with the lme4 package (Bates et al. 2015).

Results

A total of 129 specimens were included in the analysis. Female *A. fimbriatus* bats were found to be pregnant between June and February (Figure 1) in the south of their geographical distribution range. The reproduction events were dependent on the photoperiod ($P = < 0.001$), and were independent of the annual accumulated precipitation ($P = 0.83$; Figure 2). We only included the photoperiod and rainfall for this analysis as photoperiod and temperature are correlated. As days become longer, the temperature also increases, and therefore, the probability of pregnancy is higher.

Fetuses at different developmental stages were observed throughout the year. Fetuses in advanced stages were found in September and February, whereas fetuses were smaller during the other months of the year (Figure 3). This may suggest the existence of two distinct parturition events during the year. Thus, our results show that *A. fimbriatus* females exhibit a seasonal reproductive strategy, with parturition events occurring around September and October (spring) and February (summer) when the days are longer and the temperature is warmer at the southern limit of their geographic range.

Discussion

Artibeus fimbriatus exhibits seasonally-dependent reproduction at the southern limit of its geographic range, and parturition events occur in September and October (spring) and February (summer), when the days are longer and temperature is warmer. The only previous study that has focused on the reproduction of *A. fimbriatus* was performed in a tropical

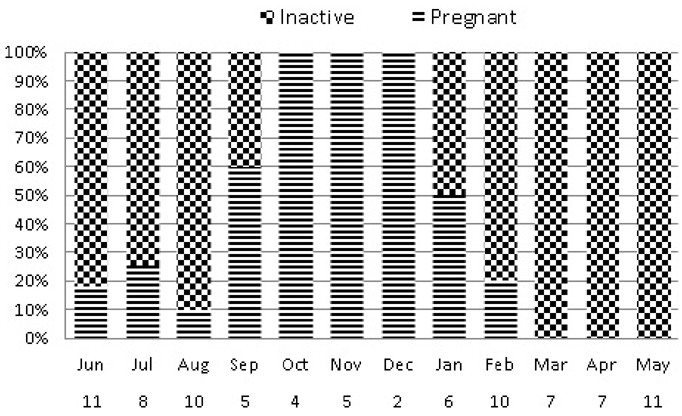

Figure 1. Reproductive status of *Artibeus fimbriatus* females at the southern limit of their distribution over different months of the year.

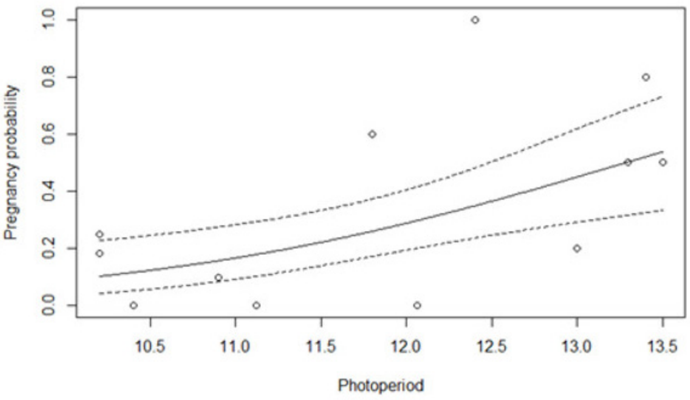

Figure 2. Relationship between reproductive events (pregnancy probability) and photoperiods at the southern limit of *Artibeus fimbriatus* distribution.

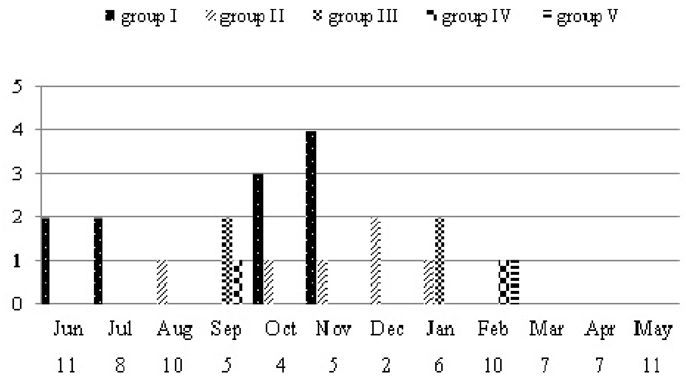

Figure 3. Different developmental stages of *Artibeus fimbriatus* fetuses over different months of the year.

area in Brazil (Rio de Janeiro state), where the species was also reported to exhibit seasonal reproduction, with the parturition events occurring in the rainy season (Esbérard et al. 1998). Other species of the *Artibeus* genus, including *A. lituratus* and *A. jamaicensis* Leach, 1821, also show seasonal reproduction, with the highest rates of pregnancy observed during the warmest seasons in Panama (Fleming et al. 1972; Bonaccorso 1978), Venezuela (Sosa & Ramoni-Perazzi 1995) and in different localities of Brazil (Taddei 1976; Willig 1985; Reis 1989). This pattern has also been observed for other species of the Phyllostomidae family, such as *Uroderma bilobatum* Peters, 1866, *Carollia perspicillata* Linnaes 1758 (Fleming et al. 1972), *Sturnira lilium* (E. Geoffroy, 1810) and *Platyrrhinus lineatus* E. Geoffroy, 1819 (Estrada & Coates-Estrada 2001; Stoner 2001; Costa et al. 2007).

The reproduction of bats is usually synchronized so that parturition and lactation events occur during periods of highest food availability, which coincide with periods of highest rainfall in tropical regions (Fleming et al. 1972; Willig 1985; Zortéa 2003). At the southern limit of *A. fimbriatus* distribution there is little variation in rainfall, however, the photoperiod and temperature can vary significantly (Kuinchtner & Buriol 2001; Alvares et al. 2013). Within these localities we found that the parturition events occur in the spring and summer, when days are longer and the temperature is warmer. Synchronizing parturition and lactation with spring and summer in the south of Brazil, a region in which winter brings low temperatures, also increases the survival rate of growing pups (Racey & Swift 1985). In addition, spring and summer likely correspond to periods of higher food availability in the south of Brazil. While there is no phenological information in the literature about the diet of *A. fimbriatus* in these regions, it is known that the abundance of insects is higher in spring and summer (Fabián et al. 1990), which are consumed by *Artibeus* as part of their diet (Passos et al. 2003; Passos & Graciolli 2004).

Female *A. fimbriatus* bats have a long reproductive period of 9 months, which lasts from June until February at the southern limit of its geographic range. Ésberard et al. (1998) also reported that the reproductive period of *A. fimbriatus* in southeast Brazil lasts about 9 months, however, they reported that the reproductive period lasts from July until March. While the reproduction period of *A. fimbriatus* appears to be the same for these two localities, the reproduction period of other species within the Phyllostomidae family may vary. In Costa Rica, *A. jamaicensis* was reported to have a 9-month reproduction period. In southeast Brazil, *Sturnira lilium* was reported to have an 11-month reproduction period (Godoy et al. 2014) and *Platyrrhinus lineatus* presented a 10-month reproduction period (Costa et al. 2007).

Seasonal polyestry is the most common reproductive strategy in Phyllostomidae bats, with females exhibiting bimodal peaks for pregnancy and also for lactation, as well as monthly increases in embryo size (Fleming et al. 1972). Our data only allowed us to determine the period in which *A. fimbriatus* reproduces at the southern limit of its geographic range, in addition to the embryo size. We were unable to collect information about the lactation period, as the analyzed specimens were from scientific collections, therefore, we cannot verify that *A. fimbriatus* have a bimodal pregnancy pattern. However, Ésberard et al. (1998) also concluded that *A. fimbriatus* exhibit seasonal reproduction, and suggested that the species may exhibit a seasonally polyestry with bimodal peaks. Therefore, although the results presented from our study and the study by Ésberard et al. (1998) are informative about the reproductive biology of *A. fimbriatus*, these questions remains to be answered. A bimodal reproductive pattern has also been observed for other *Artibeus* species, including *A. lituratus* in Panama (Fleming et al. 1972; Bonaccorso 1978), Venezuela (Sosa & Ramoni-Perazzi 1995) and Brazil (Taddei 1976; Willig 1985; Reis 1989). This reproductive pattern has also been recorded for other species of Phyllostomidae, including *Uroderma bilobatum* Peters, 1866 and *Carollia perspicillata* Linnaes 1758 (Fleming et al. 1972).

In conclusion, our study shows that *A. fimbriatus* exhibit seasonal reproduction at the southern limit of their distribution, coinciding with variations in seasonal photoperiods. The parturition events occur during spring and summer when the days are longer.

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Inventory

Malvoideae Burnett (Malvaceae) in the Environmental Protection Area Serra Branca, Raso da Catarina, Jeremoabo, Bahia, Brazil

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Abstract: Malvoideae is the largest subfamily of Malvaceae, including 110 genera and 1,730 species distributed predominantly in tropical regions, with a few representatives in temperate regions. In Brazil, the subfamily occurs throughout the country and all phytogeographic domains. The floristic survey of Malvoideae in the Environmental Protection Area Serra Branca included analysis of 43 specimens collected from August 2011 to February 2013. The analysis were supplemented with dried collections from the following herbaria: ALCB, HUEFS and MAC. Six genera and sixteen species were recorded. *Sida* L. was the most representative genus with five species [*S. angustissima* A.St.-Hil., *S. castanocarpa* Krapov., *S. cordifolia* L., *S. galheirensis* Ulbr., *S. linifolia* Cav. and *S. spinosa* L.], followed by *Pavonia* Cav. with three species [*P. blanchetiana* Miq., *P. cancellata* (L.) Cav. and *P. glazioviana* Gürke], *Sidastrum* Baker with three species [*S. micranthum* (A.St.-Hil.) Fryxell, *S. multiflorum* (Jacq.) Fryxell and *S. paniculatum* (L.) Fryxell] and *Herissantia* Medik. with two species [*H. crispa* (L.) Brizicky and *H. tiubae* (K.Schum .) Brizicky]. The remainging genera were represented by one species each: *Pseudabutilon virgatum* (Cav.) Fryxell and *Malvastrum tomentosum* (L.) S.R.Hill. The majority of the species recorded in the area have a Neotropical distribution, and six species are endemic to Brazil, among which the species *Herissantia tiubae*, *Sida galheirensis*, *Pavonia blanchetiana* and *Pavonia glazioviana* are endemic to the Northeast Region, the latter two species occurring exclusively in the Caatinga biome. The taxonomic treatment includes a key for the identification, descriptions, illustrations, photos, data of the geographical distribution, economic potential and reproductive phenology and comments about the species.

Keywords: *biodiversity, morphology, taxonomy, Caatinga, semiarid.*

Malvoideae Burnett (Malvaceae) na Área de Proteção Ambiental Serra Branca, Raso da Catarina, Jeremoabo, Bahia, Brasil

Resumo: Malvoideae é a maior subfamília de Malvaceae, incluindo 110 gêneros e 1.730 espécies, distribuídas nas regiões tropicais, com alguns representantes em regiões temperadas. No Brasil, a subfamília está representada em todo o território nacional e domínios fitogeográficos. O levantamento florístico das Malvoideae na Área de Proteção Ambiental Serra Branca compreendeu a análise de 43 espécimes coletados no período de agosto/2011 a fevereiro/2013. As analises foram complementadas com coleções herborizadas depositadas nos seguintes herbários ALCB, HUEFS e MAC. Foram catalogados seis gêneros e dezesseis espécies. *Sida* L. foi o gênero mais representativo com cinco espécies [*S. angustissima* A.St.-Hil., *S. castanocarpa* Krapov., *S. cordifolia* L., *S. galheirensis* Ulbr., *S. linifolia* Cav. e *S. spinosa* L.], seguido de *Pavonia* Cav. com três espécies [*P. blanchetiana* Miq., *P. cancellata* (L.) Cav. e *P. glazioviana* Gürke], *Sidastrum* Baker com três espécies [*S. micranthum* (A.St.-Hil.) Fryxell, *S. multiflorum* (Jacq.) Fryxell e *S. paniculatum* (L.) Fryxell] e *Herissantia* Medik. com duas espécies [*H. crispa* (L.) Brizicky e *H. tiubae* (K.Schum.) Brizicky]. Os demais gêneros estão representados por uma espécie cada um, *Pseudabutilon virgatum* (Cav.) Fryxell e *Malvastrum tomentosum* (L.) S.R.Hill. A maioria das espécies ocorrentes na área possui distribuição neotropical e seis espécies são endêmicas do Brasil, destas *Herissantia tiubae*, *Sida galheirensis*, *Pavonia blanchetiana* e *Pavonia glazioviana* são endêmicas da região Nordeste, as duas últimas espécies de ocorrência exclusiva no bioma caatinga. São apresentados comentários sobre morfologia e taxonomia, ilustrações, e dados sobre distribuição geográfica e fenologia, além de uma chave para os táxons estudados. O tratamento taxonômico inclui uma chave de identificação, descrições, ilustrações, fotos, dados de distribuição geográfica, potencial econômico, fenologia reprodutiva e comentários sobre as espécies.

Palavras-chave: *biodiversidade, morfologia, taxonomia, Caatinga, semiárido.*

Introduction

Malvaceae *s.l.* includes nine subfamilies: Grewioideae Hochr., Tilioideae Arn., Brownlowioideae Burret, Bombacoideae Burnett, Malvoideae Burnett, Byttnerioideae Burnett, Helicterioideae (Schott & Endl.) Meisn., Sterculioideae Burnett and Dombeyoideae Beilschm. (Bayer et al. 1999). The subfamily Malvoideae embraces all genera of Malvaceae *s.s.,* and some genera traditionally placed in Bombacaceae and Sterculiaceae, showing as synapomorphy simple leaves (Baum et al. 2004). The subfamily is the largest within of Malvaceae *s.l.* including 110 genera and 1,730 species distributed in the tropics, especially in the New World, with a few representatives in temperate regions (Bayer & Kubitzki 2003). In Brazil, Malvoideae is represented throughout the country and in all phytogeographical domains, with *Pavonia* Cav., *Abutilon* Mill., *Sida* L. and *Hibiscus* L. being the most represented genera (Bovini et al. 2016).

In Brazil, Malvoideae were treated in various lists or monographic studies of local floras and state, such as: Flórula of Mucugê, BA (Fryxell 1986), Flora of the Pico das Almas, BA (Fryxell 1995), Agreste Paraibano, PB (Alves et al. 2011), Flora de Mirandiba, PE (Amorim et al., 2009), Flora of the San Francisco River, CE, PB and PE (Siqueira Filho et al. 2012), Flora da Serra do Cipó, MG (Esteves, 1986), Flora de Grão-Mogol, MG (Esteves & Krapovickas 2009), Parque Estadual do Rio Doce, MG (Bovini et al. 2001), Flora de São Paulo (Takeuchi & Esteves 2012), Reserva do Rio das Pedras, RJ (Bovini 2010), Flora da Reserva Ducke, AM (Esteves 2006), *Pavonia* do Rio Grande do Sul (Grings 2011), Malvaceae Brasiliensis (Monteiro Filho 1955), Catálogo de Plantas e Fungos do Brasil (Bovini et al. 2010) and Lista da flora do Brasil (Bovini et al. 2016).

Economically, members of Malvoideae are important in the textile industry and as food, such as species of *Gossypium* L. and *Abelmoschus* Medik., respectively. Some species are used mainly as ornamentals, such as *Hibiscus*, *Malvaviscus* Fabr., *Abutilon* and *Pavonia*. The subfamily also includes several species of *Abutilon*, *Sida, Urena* L., *Malvastrum* A.Gray. and *Herissantia* Medik., that produce fibers used in the strings with medicinal potential and weeds species or ruderal (Takeuchi 2011, Souza & Lorenzi 2012).

Given the importance of the subfamily Malvoideae, and the scarcity of information about the subfamily for the Caatinga biome, the present study aimed to survey species of Malvoideae (Malvaceae) occurring in the Environmental Protection Area Serra Branca (EPASB), in order to contribute to knowledge about the flora of the semiarid region of Bahia as well provide support for the development of plans to manage the conservation unit.

Material and Methods

The Evironmental Protection Area Serra Branca, Raso da Catarina (EPASB, Figure 1) comprises 67,237 ha, located in the municipality of Jeremoabo in Northeastern Bahia fully inserted into the "polígono das secas" (Fundação CTI/NE 2016), delimited by the coordinates 09º53'15.5" to 09º44'34.6"S and 38º49'36.1"to 38º52'20.4"W, limited to the South with the Vaza-Barris River and North to the Ecological Station Raso da Catarina (ESEC). The predominant vegetation is the sandy, very dense bushy Caatinga. The climate of the Ecoregion is semiarid, with average rainfalls of 500 mm/year and annual temperature is approximately 23ºC (Szabo et al. 2007). The soils are generally sandy deep and very fertile relief plan with sandstone formations (Velloso et al. 2002).

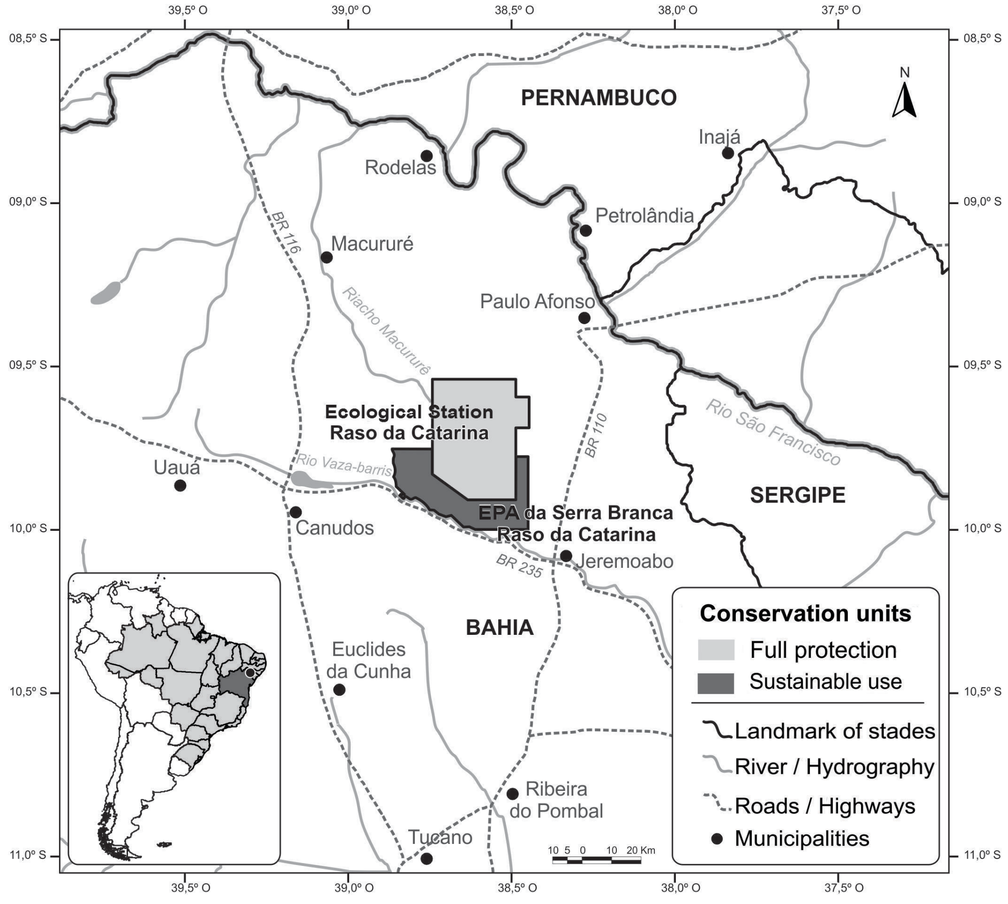

Figure 1. Location EPA Serra Branca, Raso da Catarina, Bahia, Brazil (Varjão et al. 2013).

The study was based on fieldwork carried out in the period August/2011 to February/2013, besides information complemented by the analysis of specimens deposited in the following herbaria: ALCB, MAC and HUEFS, acronyms according to Thiers 2016 (continuously updated). The field collections and observations were performed during random walks exploring most of the study area. The herborization and material processing followed the methodology by Fosberg & Sachet (1965) and Mori et al. (1989), where fertile material was collected with flowers and/or fruit. Observations were made about the distribution of the species and the type of soil (Tricart 1972, Sampaio 1995). The specimens were deposited in the herbarium of the State University of Bahia (HUNEB – Collection Paulo Afonso) and the duplicates will be sent to the main herbaria in the state of Bahia (ALCB, HRB and HUEFS).

The identifications were made based mainly on specialized bibliographies, protologues, photos of type collections and comparison of the collections in the herbaria that were visited. For the taxonomic descriptions, the terminologies proposed by Harris & Harris (2001) and Gonçalves & Lorenzi (2011) were adopted. The taxonomic treatment includes a key for the identification, descriptions, illustrations, photos, data of the geographical distribution, economic potential and reproductive phenology and comments about the species.

Results and Discussion

Malvoideae *Burnett*

Subshrubs or shrubs. Branches with simple, stellate or glandular trichomes. Leaves simple, alternate, petiolate, stipulate. Perfect flowers, showy, solitary and/or inflorescence terminal or axillary; with or without epicalyx; calyx with five sepals, gamosepalous, pentalobed, aestivation valvate; corolla with five petals, free each other, adnate at the base of the staminal tube, aestivation imbricate, differently colored, with or without a basal spot; numerous stamens, monadelphous, free parts of stamens concentrated in the apex of staminal tube or variously distributed along it, anthers monothecal, dorsifixed, rimoses, usually yellow; ovary superior, carpels 5-many, uni to pluriovulate, placentation axile, styles in equal or double the number of carpels, stigmas capitate. Fruits schizocarps, mericarps 5-many, rostrate, aristate or muticous; 1-many seeds, glabrous or hairy.

In the EPASB, Malvoideae are represented by sixteen species encompassing six genera: *Herissantia* Medik., *Malvastrum* A.Gray, *Pavonia* Cav., *Pseudabutilon* R.E.Fr., *Sida* L. and *Sidastrum* Baker. *Sida*, with six species, was the most representative genus, followed by *Pavonia* and *Sidastrum,* with three species each. *Pavonia glazioviana* Gürke and *Sida galheirensis* Ulbr. were the most collected species in subshrubby and shrubby-arborescent Caatinga environments associated with sandy soils predominant in the area. The least representative species, were *Sida angustissima* A.St.-Hil., *Sida linifolia* Cav., *Sida spinosa* L. and *Sidastrum micranthum* (A.St.-Hil.) Fryxell, collected only once.

The majority of species occurring in the EPASB have a Neotropical distribution. *Sida angustissima*, *Sida castanocarpa* Krapov., *Herissantia tiubae* (K.Schum.) Brizicky, *Sida galheirensis, Pavonia blanchetiana* and *Pavonia glazioviana* are endemic to Brazil, among these four species are endemic to the Northeast, latter two species occurring exclusively in the Caatinga biome (Fryxell 1973, Bovini 2016a, d, Esteves 2016).

Many species that occur in the EPASB are of economic importance, such as having potential value for beekeeping. *Sida galheirensis*, *Sida cordifolia* L. and *Herissantia* spp. are used as fodder, while *Pavonia cancellata* (L.) Cav., *Sida cordifolia*, *Sida spinosa* and *Sidastrum micranthum* (A.St.-Hil.) Fryxell all have potential medicinal value (Sampaio et al. 2005).

Identification key for the representatives of the subfamily Malvoideae

1. Epicalyx present.
  2. Epicalyx with 3 bracteoles. Free portion of the stamens concentrated at the apex of the staminal tube. Styles in equal number of carpels. Mericarps 3–awned................................ **3. *Malvastrum tomentosum***
  2'. Epicalyx with more than 3 bracteoles. Free portion of the stamens distributed along of the staminal tube. Styles in double the number of carpels. Mericarps muticous to rostrate.
    3. Epicalyx with 20-22 bracteoles. Mericarps winged laterally…... **4. *Pavonia blanchetiana***
    3'. Epicalyx with 12-14 bracteoles. Mericarps not winged.
      4. Bracteoles filiforms, green. Petals yellow with vinaceous basal spot .... **5. *Pavonia cancellata***
      4'. Bracteoles linear-lanceolate, green at the basal portion, pink at the apical portion, sometimes entirely pink. Petals pink........... .... **6. *Pavonia glazioviana***
1'. Epicalyx absent.
  5. Schizocarp inflated.
    6. Branches with trichomes stellate. Petals 5-8 mm long. Stamens c. 30. Mericarps 10, with trichomes simple......... **1. *Herissantia crispa***
    6'. Branches with glandular trichomes predominantly, simple sparse trichomes. Petals 18-20 mm long. Stamens c. 50. Mericarps 12-17, with trichomes stellate................. **2. *Herissantia tiubae***
  5'. Schizocarp not inflated.
    7. Schizocarp with three seeds per mericarp... ....**7. *Pseudabutilon virgatum***
    7'. Schizocarp with one seed per mericarp.
      8. Calyx with prominent venation.
        9. Leaf with blade linear to narrow elliptic.
          10. Leaf with margin serrate. Petals yellow-orange with reddish base. Mericarps long biaristate .... **8. *Sida angustissima***
          10'. Leaf with margin entire. Petals white with vinaceous basal spot. Mericarps muticous ……...... **12. *Sida linifolia***
        9'. Leaf with blade ovate to elliptic.
          11. Subshrubs not prostrate. Mericarps not muricate, biaristate, with white simple trichomes, only in the aristas. Seeds glabrous.
            12. Petiole with a purple spine. Petals white with yellow basal spot. Mericarps 5............................... .... **13. *Sida spinosa***
            12'. Petiole without spine. Petals yellow-orange with reddish-vinaceous basal spot. Mericarps more than 5.
              13. Branches and leaves velutinous; blade with base cordate. Inflorescences glomeruliforms dense. Mericarps c. 5 mm long, biaristate, arista parallel between them............ **10. *Sida cordifolia***
              13'. Branches hirsute and leaves pubescents; blade with base obtuse to subcordate. Flowers solitary. Mericarps c. 3 mm long, biaristate, arista divergent...................... **11. *Sida galheirensis***
          11'. Subshrubs prostrate. Mericarps muricate, not aristate, with brown stellate trichomes, on the mericarp. Seeds pilose........................ **9. *Sida castanocarpa***
      8'. Calyx without prominent venation.
        14. Petals yellow, more than 5 mm long. Mericarps 10.. ....**15. *Sidastrum multiflorum***
        14'. Petals vinaceous or yellow with pink basal spot, 4-5 mm long. Mericarps 5.

15. Inflorescences glomeruliform; flowers subsessiles or pedicels 0.5-1.5 mm long; petals yellow with pink basal spot...................... **14. *Sidastrum micranthum***
15'. Inflorescences paniculate, flowers pedicellate 1.5-2 cm long; petals vinaceous.. **16. *Sidastrum paniculatum***

1. *Herissantia crispa* (L.) Brizicky, J. Arnold Arbor. 49: 279. 1968. Iconografia: Schumann (1891: 70), Fryxell (1988: 191), Rondón (2009: 609). Figures 2a, 3a

Subshrubs decumbent c. 50 cm tall; branches tomentose, trichomes stellate. Stipules linear 6-9 mm long. Leaf with blade 2-6 × 2-5 cm, ovate, discolorous, membranaceous, pubescent on both faces, trichomes stellate, apex acuminate, basis cordate, margin dentate; petioles 1-2.5 cm long, tomentose. Flowers solitary, axillary or terminal; pedicels 1-2.5 cm long; epicalyx absent; calyx 4-6 mm long; cupuliform, not prominent venation, externally with simple and stellate trichomes, internally with simple trichomes only at the apex, lobes acute-acuminate; petals 5-8 × 3-6 mm, obovate, white with yellow basal spot, glabrous; stamens c. 30, staminal tube 2-3 mm long, free portion of the stamens 3-4 mm long, concentrated at the apex of the tube; ovary c. 1 × 1.5 mm, subglobose, glabrous; carpels 10, uniovulate; styles 10, 3-5 mm long. Schizocarp subglobose, inflated, pendulum, mericarps 10, c. 1.5 × 1.5 cm, trichomes simple, white, lateral face fragile; seeds 1 per mericarps, c. 2.1 × 2 mm, reniform, nigrescent, sparsely hairy.

Material examined: APA Serra Branca, Caminho sentido Serra no Navio, 9º51'58.1"S 38º38'46.9"W, 482 m, 03.XI.2011, fl., J.B. Lima 09 (HUNEB); Estrada do Tamburi, próximo a baixa dos Quelés, 9º57'43.0"S 38º25'33.3"W, 514 m, 09.VII.2012, fl.; fr., J.B. Lima 24 (HUNEB).

A species with a Pantropical distribution (Fryxell 1997). In Brazil it occurs only in the Northeast Region (Alagoas, Bahia Pernambuco and Sergipe), in areas of Caatinga and Cerrado environments (Bovini 2016a).

Figure 2. Representatives of the Malvoideae in the EPASB. a. *Herissantia crispa*; b. *Herissantia tiubae*; c. *Malvastrum tomentosum* subsp. *tomentosum*; d. *Pavonia blanchetiana*; e. *Pavonia cancellata*; f. *Pavonia glazioviana*; g. *Pseudabutilon virgatum*; h. *Sida angustissima;* i. *Sida castanocarpa*; j. *Sida cordifolia*; l. *Sida galheirensis*; m. *Sida linifolia;* n. *Sida spinosa;* o. *Sidastrum micranthum*; p. *Sidastrum multiflorum*; q. *Sidastrum paniculatum*.

The species shares with *H. tiubae* morphological characters as white corolla with a yellow base and an inflated schizocarp and pendulum. However, *H. crispa* can easily be differentiated by its decumbent habit, indument consisting predominantly of stellate trichomes, always having smaller leaves and flowers and mericarps with simple trichomes (*vs*. mericarps with stellate trichomes). In EPASB, *H. crispa* was found along edges of trails and on mountain slopes in Caatinga on sandy soils. Specimens were collected with flowers and fruits virtually all year round. The species has beekeeping and forage potential (Sampaio et al. 2005).

2. *Herissantia tiubae* (K.Schum.) Brizicky, J. Arnold Arbor. 49: 279. 1968. Figures 2b, 3i, 4a-e

Subshrush 0.5-1.2 m tall; branches tomentose, glandular trichomes predominantly, simple sparse trichomes. Stipules linear 2-3 mm long. Leaf with blade 2.5-8 (-14) × 1.5-5 (-9) cm, ovate, discolorous, membranaceous, adaxial face pubescent, abaxial face tomentose, trichomes stellate, apex acuminate, basis cordate, margin serrate; petioles 1-8 cm long, tomentose. Flowers solitary, axillary or terminal; pedicels 1.5-2.5 cm long; epicalyx absent; calyx 6-8 mm long, cupuliform, not prominent venation, externally with stellate trichomes, internally simple trichomes only at the apex, lobes acuminate; petals 18-20 × 13-15 mm, obovate, white with yellow basal spot, glabrous; stamens c. 50, staminal tube 3-3.5 mm long, free portion of the stamens 3-4 mm long, concentrated at the apex of the tube; ovary c. 1.5 × 2 mm, subglobose, glabrous; carpels 12-17, uniovulate, styles 12-17, 5-7 mm long. Schizocarp subglobose, inflated, pendulum; mericarps 12-17, 1.6-2 × c. 1.8 cm, trichomes stellate, white, lateral face fragile; seeds 1 per mericarp, c. 1.8 × 2 mm, reniform, nigrescent, sparsely hairy.

Figure 3. Habits of the Malvoideae in the EPASB. a. *Herissantia crispa*; b. *Sida castanocarpa*; c. *Pseudabutilon virgatum*; d. *Pavonia blanchetiana*; e. *Pavonia cancellata*; f. *Pavonia glazioviana*; g. *Malvastrum tomentosum* subsp. *tomentosum*; h. *Sida spinosa;* i. *Herissantia tiubae*; j. *Sida cordifolia*; l. *Sida galheirensis*; m. *Sidastrum micranthum.*

Material examined: APA Serra Branca, Caminho da Judite próximo a Serra do Navio, 9°51'55.5"S 38°38'45"W, 469 m, 03.XI.2011, fl., J.B. Lima 05 (HUNEB); Base da vaca morta, 9°55'17,2"S 38°42'06"W, 392 m, 10.VII.2012, fl.; fr., J.B. Lima 33 (HUNEB); Trilha sentido Saco do Cedro, 9°52'05.1"S 38°38'12.8"W, 489 m, 30.VII.2009, fl., A.S. Conceição 1848 (HUNEB); Fazenda Serra Branca, trilha sentido Serra do Navio, 9°52'49.1"S 38°39'22,0"W, 481 m, 31.VII.2009, fl.; fr., A.S. Conceição 1882 (HUNEB).

A species endemic to the Northeast Region of Brazil, it is found in Caatinga and Cerrado environments of all states of that region (Bovini 2016a).

In the study area it can be recognized mainly by its indument consisting predominantly of glandular trichomes, size of the leaves (2.5-8 cm to 14 cm) and mericarps (ca. 1.8 × 2 mm) higher than in other congeners species. In the study area, *H. tiubae* is associated with shrubby and shrubby-arborescent Caatinga on sandy soils. Specimens were collected with flowers and fruits virtually all year round. The species has beekeeping and forage potential (Sampaio et al. 2005).

3. *Malvastrum tomentosum* (L.) S.R.Hill **subsp. *tomentosum***, Brittonia 32: 466. 1980. Figures 2c, 3g, 4f-h

Subshrubs 25-30 cm tall; branches pubescent, trichomes stellate. Stipules linear 2-3 mm long. Leaf with blade 1.5-4.5 × 1.5-4 cm, ovate, discolorous, membranaceous, tomentose on both faces, trichomes stellate, apex acuminate, basis truncated to obtuse, margin serrate; petioles 5-10 mm long, pubescent. Inflorescences cymes, axillary. Flowers with pedicel 1-2 mm

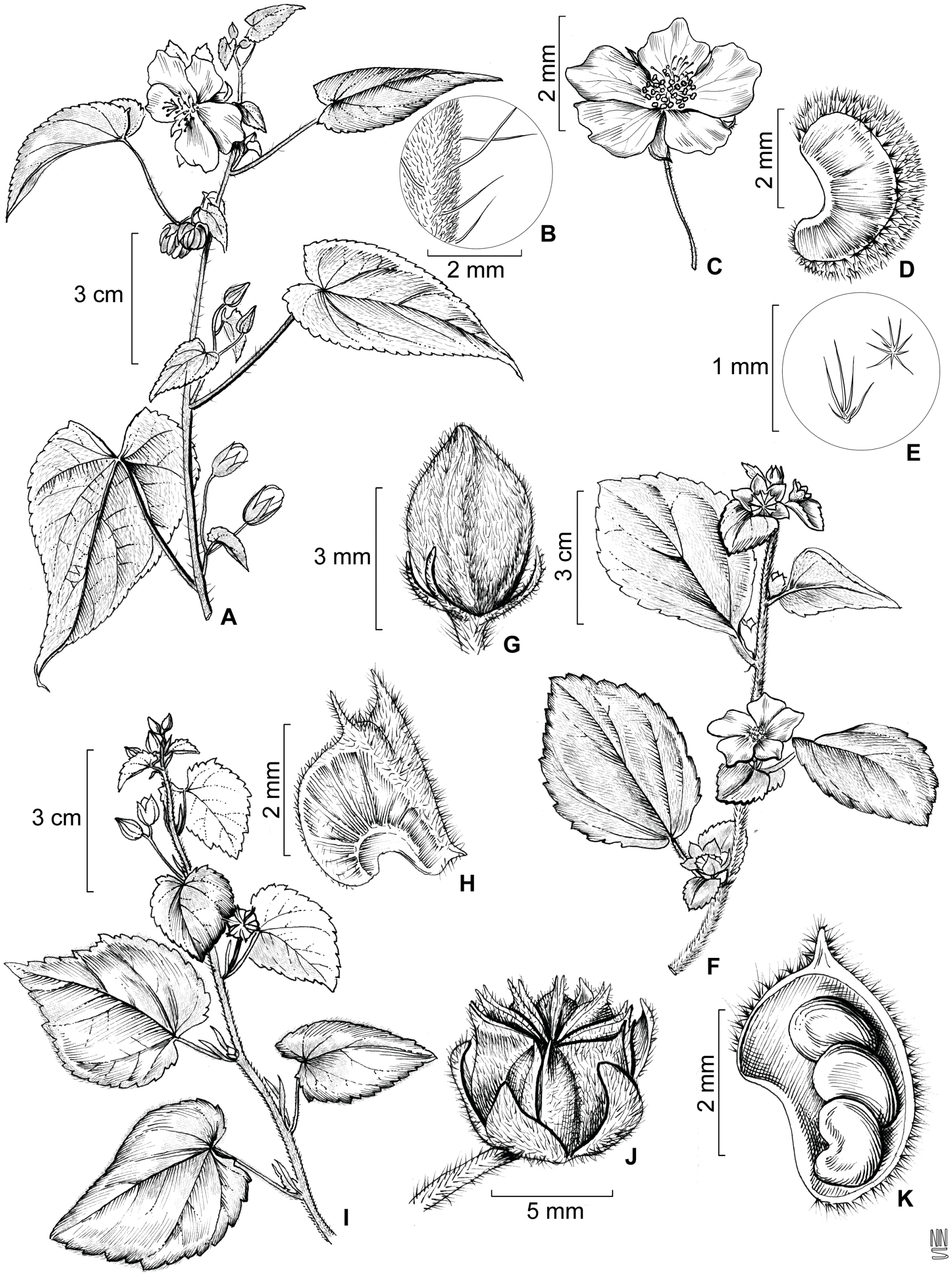

Figure 4. A-E. *Herissantia tiubae*. A. flowering branch; B. detail of branch indumentum; C. Flower; D. mericarp; E. detail of mericarp indumentum. F-H. *Malvastrum tomentosum* subsp. *tomentosum*; F. flowering branch; G. bud with epicalyx; H. mericarp; I-K. *Pseudabutilon virgatum*; I. branch; J. fruit; K. mericarp with three seeds. A-E from A.S. Conceição 1882; F-H from J.B. Lima 39; I-K from J.B. Lima 88.

long; bracteoles of epicalyx 3, 4-5 mm long, linear, trichomes simple, green, pubescent; calyx 7-8 mm long, cupuliform, not prominent venation, lobes acute at the apex, externally with stellate trichomes, internally simple trichomes only at the apex; petals 5-7 × 4-5 mm, obovate, entirely yellow, glabrous; stamens c. 35, staminal tube 2-2.5 mm long, free portion of the stamens 0.5-1 mm long, concentrated at the apex of the tube; ovary c. 1 × 2 mm, discoid, glabrous, carpels 10-12, uniovulate, styles 10-12, 3-4 mm long. Schizocarp not inflated, mericarps 10-12, 2-2.5 × 2-4 cm, laterally compressed wedge-shaped, simple trichomes white, 3-awned, one central and two larger lateral awns; seeds 1 per mericarp c. 1.8 × 1.5 mm, reniform, nigrescent, slightly hairy.

Material examined: APA Serra Branca, Próximo a Serra do Navio, 9°52'43.3"S 38°39'12.1"W, 473 m, 10.VII.2012, fl.; fr., J.B. Lima 38 (HUNEB); 10.VII.2012, fl.; fr., J.B. Lima 39 (HUNEB).

This taxon occurs in Peru, Ecuador, Venezuela and Brazil (Hill 1980), in the latter of which it occurs in the northeast (Bahia, Ceará, Paraíba, Pernambuco), midwest (Mato Grosso) and southeast (Minas Gerais), in Caatinga, Cerrado and Atlantic Forest environments (Bovini 2016b).

In EPASB, this species is easily recognized by having a epicalyx with 3 bracteoles, linear, mericarps laterally compressed wedge-shaped, 3-awned, one central and two larger side awn. It was collected with flowers and fruits in July in shrubby-arborescent Caatinga.

4. *Pavonia blanchetiana* Miq., Linnaea 22: 801. 1849. Iconografia: Gürke (1892: 101), Esteves (1998: 224), Fryxell (1999: 39). Figures 2d, 3d

Subshrubs 1.20-1.30 m tall; branches pubescent, trichomes stellate, trichomes simple forming 1-2 dense longitudinal lines. Stipules linear 3-4 mm long, pubescent. Leaf with blade 2-3 × 1.3-3.5 cm, entire to trilobed, central lobe larger than lateral lobes, discolorous, chartaceous, apex acute, basis cordate to hastate, margin serrate, 3-5-nerved from the base, pubescent on both faces, trichomes stellate and simple; petiole 1.5-5 cm long, pubescent. Flowers solitary, axillary; pedicels 1-2.5 cm long; bracteoles of epicalyx 20-22, 2.4-2.8 cm long, linear, green, long ciliate; calyx 0.8-1.2 cm long, campanulate, not prominent venation, externally with simple trichomes, internally trichomes only at the apex, lobes acute at the apex; petals 3.5-5 × 2.5-4 cm, obovate, pink with vinaceous basal spot, externally with stellate trichomes; stamens c. 40, staminal tube 1.3-1.5 mm long, free portion of the stamens 1-1.5 mm long, distributed 2/3 at apex of the tube and some concentrated at the base of the tube, anthers purple; ovary c. 2 × 3 mm, ellipsoid, trichomes glandular, carpels 5, uniovulate, styles 10, 1-1.3 cm long. Schizocarp not inflated; mericarps 5, c. 1.1 × 0.7 cm, rostrate at the apex, winged laterally, trichomes stellate, ferruginous; seeds 1 per mericarp, c. 4.5 × 2 mm, reniform, nigrescent, glabrous.

Material examined: APA Serra Branca, Estrada do Tamburi, próximo a baixa dos Quelés, 9°57'43"S 38°25'33.3"W, 514 m, 09.VII.2012, fl.; fr., J.B. Lima 21 (HUNEB); Baixa Grande, sentido Areia Branca, 9°58'43.1"S 38°27'14.0"W, 561 m, 19.III.2009, fl., A.S. Conceição 1573 (HUNEB).

This species is endemic to the Northeast Region of Brazil and is found in the states of Alagoas, Bahia, Pernambuco and Sergipe, occurring exclusively in Caatinga environments (Esteves 1998, Esteves 2016).

Pavonia blanchetiana can be easily distinguished from other species occurring in EPASB by its pink petals with a vinaceous base, epicalyx with 20-22 bracteoles, linear, green, long ciliate and mericarps winged laterally. The species was collected with flowers and fruits in July and March on sandy soils, near mountain slopes.

5. *Pavonia cancellata* (L.) Cav., Diss. 3: 135. 1787. Iconografia: Gürke (1892: 98), Esteves (1998: 225), Rondón (2009: 610), Esteves & Krapovickas (2009: 69), Esteves (2001: 166). Figures 2e; 3e

Subshrubs prostrate; ascending branches when flowering, hirsute, trichomes simple. Stipules linear 3-5 mm long. Leaf with blade 1.5-4 × 1-4 cm, ovate to triangulate, discolorous, chartaceous, apex acute, basis subcordate, cordate to hastate in general asymmetric, margin irregularly serrate, 5-7-nerved from the base, pilose on both faces, trichomes simple, adpressed; petioles 1-2.5 cm long, hirsute. Flowers solitary, axillary; pedicels 3-6 cm long; bracteoles of epicalyx 12-14, 1.2-1.4 cm long, filiform, green, ciliate; calyx 6-8 mm long, cupuliforme, not prominent venation, externally with simple trichomes, internally trichomes only at the apex, lobes acute at the apex; petals 2.5-3 × 2-2.5 cm, obovate, yellow with vinaceous basal spot, glabrous; stamens c. 38, staminal tube 1.5-2.1 mm long, free portion of the stamens 1-2 mm long, distributed along of the tube, anthers vinaceous; ovary c. 1.2 × 2 mm, subglobose, glabrous, carpels 5, uniovulate, styles 10, 2-2.2 cm long. Schizocarp not inflated; mericarps c. 5.5 × 3 cm, muticous to shortly rostrate, glabrous, lateral face resistant; seeds 1 per mericarp c. 3 × 2 mm, reniform, orange, simple trichomes.

Material examined: APA Serra Branca, Estrada do Tamburi, próximo a baixa dos Quelés, 9°57'43"S 38°25'33.3"W, 514 m, 09.VII.2012, fl.; fr., J.B. Lima 22 (HUNEB); 9°57'41.9"S 38°25'32.3"W, 509 m, 03.IX.2012, fl.; fr., J.B. Lima 47 (HUNEB); Caminho da ESEC em direção ao povoado Quelés, 9°53'01"S 38°32'39"W, 650 m, 22.IX.2010, fl., D.D. Vieira 98 (HUNEB); Estrada saindo dos Quelés sentido ESEC Raso da Catarina, 9°58'00.8"S 38°26'11.7"W, 497 m, 29.VII.2009, fl., A.S. Conceição 1798 (HUNEB).

A species with a Neotropical distribution occurring from North America (Mexico) to South America (Esteves 1998). In Brazil it occurs in almost all regions and phytogeographical domains. In the Northeast Region it was found in the states of Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí and Sergipe (Esteves 2016).

Pavonia cancellata show a large polymorphism in the leaves, especially in the form and dimensions of the blades. It can be easily recognized when flowering by its ascending branches and yellow petals with a vinaceous basal spot. It was found in EPASB with flowers and fruits in July and September in open areas on sandy soils. The species has beekeeping and medical potential (Sampaio et al. 2005).

6. *Pavonia glazioviana* Gürke, Fl. Bras. (Martius) 12(3): 524. 1892. Iconografia: Esteves (1998: 221). Figures 2f; 3f

Subshrubs 2-2.5 m tall; branches pubescent, trichomes stellate, dense at the apical portion. Stipules linear 3-4 mm long. Leaf with blade 3-10 × 3-8 cm, ovate, discolorous, chartaceous, apex acute, basis cordate, margin serrate, 5-7-nerved from the base, pubescent on both faces, trichomes stellate; petioles 5-4 cm long, pubescent. Flowers solitary, axillary; pedicels 2.5-4.5 cm long; bracteoles of epicalyx 12-14, 1.5-3.0 cm long, linear-lanceolate, green at the basal portion, pink at the apical portion, sometimes entirely pink, pubescent, ciliate; calyx 1-2 cm long, tubiform, not prominent venation, greenish at the basal portion, pink at the apical portion, externally pubescent, trichomes stellate, internally glabrous, lobes rounded at the apex; petals c. 2.0 × 0.8 mm, obovate, pink, trichomes stellate externally; stamens c. 50, staminal tube 1.3-2.5 mm long, free portion of the stamens 2-4 mm long, distributed along of the tube, anthers purple; ovary 2.5-3 × 4-5 mm, globose to ovoid, glabrous, carpels 5, uniovulate, styles 10, 2-2.3 cm long. Schizocarp not inflated; mericarps 5, c. 1.3 × 0.3 cm, shortly rostrate, trichomes stellate white, lateral face resistant; seeds 1 per mericarp c. 3 × 1.5 mm, reniform, brown, trichomes stellate.

Material examined: APA Serra Branca, Estrada próxima a roça velha, 9°53'03.6"S 38°39'46.8"W, 380 m, 04.XI.2011, fl., J.B. Lima 12 (HUNEB); Trilha para a vaca morta, 9°55'15.7"S 38°42'04.3"W, 365 m, 04.XI.2011, fl., J.B. Lima 17 (HUNEB); Estrada que vai da ESEC Raso da Catarina em direção ao povoado Quelés, 9°53'01"S 38°32'39"W, 650 m, 22.IX.2010, fl., D.D. Vieira 94 (HUNEB); Trilha da vaca morta. 9°55'17"S 38°42'06"W, 392 m, 20.XII.2011, fl.; fr., J.V. dos Santos 01 (HUNEB); Fazenda Serra Branca, há 9,5 Km da distância da Base, trilha do Araçá, 9°52'49"S 38°38'14"W, 535 m, 08.V.2008, fl.; fr., M.V. Romão 130 (HUNEB); Fazenda Serra Branca, c. 2 km da base da Vaca Morta, 9°53'15"S 38°40'08"W, 424 m, 17.IV.2008, bot.; fl., A.S. Conceição 1309

(HUNEB); Trilha do tanque das pedrinhas, 9°53'27.9"S 38°40'48"W, 474 m, 26.VI.2008, fl., A.S. Conceição 1403 (HUNEB).

An endemic species of the Northeastern Region of Brazil, occurring in the states of Piauí, Ceará and Pernambuco to Bahia and found exclusively in Caatinga environments (Esteves 1998, Esteves 2016).

Pavonia glazioviana can be clearly distinguished from other species by epicalyx with 12-14 bracteoles, linear-lanceolate, green in the basal portion, pink in the apical portion, sometimes entirely pink and pink corolla. It exhibits wide variation in the dimensions of the leaves, and is abundant in EPASB being found in both dry as wet periods in areas of shrubby-arborescent Caatinga and in a transition zone between Caatinga and semideciduous forest on sandy soils.

7. *Pseudabutilon virgatum* (Cav.) Fryxell. Contr. Univ. Michigan Herb. 21: 191. 1997. Figures 2g; 3c; 4i-k

Subshrubs 25-30 cm tall; branches pubescent, trichomes stellate and glandular. Stipules linear 6-10 mm long, trichomes stellate. Leaf with blades 2.3-6 × 1.5-4.9 cm, ovate, discolorous, chartaceous, apex acuminate to acute, basis cordate, margin sparsely serrate, pubescent on both sides, stellate trichomes; petioles 1-2.8 cm long, tomentoses. Inflorescences fasciculate or flowers solitary, axillary; pedicels 0.8-1.2 cm long; epicalyx absent; calyx 7-8 mm long, campanulate, venation prominent, externally with stellate trichomes, internally with simple trichomes only at the apex, lobes acute at the apex; petals 0.6-0.7 × 0.5 cm, obovate, yellow, glabrous; stamens c. 38, staminal tube c. 2 mm long, free portion of the stamens c. 1 mm long, concentrated at the apex of the tube; ovary c. 2 × 2 mm, subglobose, glabrous, carpels 6-8, 3 ovules per locule, styles 6-8, c. 3 mm long. Schizocarp subglobose, not inflated; mericarps 6-8, 6-7 × 3-4 cm, shortly biaristate, arista with trichomes stellate white, fragile sides; seeds 3 per mericarp, 2 × 2 mm, reniform, dark brown, pilose.

Material examined: APA Serra Branca, Próximo a Serra do Navio, 9°52'43.3"S 38°39'12.1"W, 473 m, 10.VII.2012, bot.; fr., J.B. Lima 40 (HUNEB); 9°31′54″S 38°38′44″W, 463 m, 09.V.2013, fr., J.B. Lima et al. 88 (HUNEB); 9°31′54″S 38°38′44″W, 463m, 06.VI.2014, fl.; fr., J.B. Lima et al. 416 (HUNEB); Baixa do Tamburi, perto do *Enterolobium*, 9°57'46.3"S 38°26'12.7"W, 473 m, 26.III.2013, fr., J.V. dos Santos 64 (HUNEB).

This species occurs in Ecuador, Peru, Bolivia, Paraguay, Argentina and Brazil, in the latter of which it is spread throughout the northeast (Bahia and Pernambuco), midwest (Mato Grosso do Sul) and south (Paraná), occurring in Caatinga and Pantanal (Fryxel 1997, Bovini 2016c).

Pseudabutilon virgatum can be easily distinguished from other species occurring in EPASB by having an ovate leaf with a sparsely serrate margin and fruits with 3 seeds per mericarp. In the study area the species was collected on sandysoils with flowers and fruits virtually all year round.

8. *Sida angustissima* A.St.-Hil., Fl. Bras. Merid. 1: 179. 1827. Iconografia: Brandão (2014: 101). Figures 2h; 5a-c

Subshrubs 50-70 cm tall; branches pubescent to glabrescent, trichomes stellate. Stipules linear 3-5 mm long, trichomes stellate. Leaf with blade 1.8-3.5 × 0.2-0.3 cm, linear to narrow elliptic, slightly discolores, chartaceous, apex acute, basis acute, margin serrate, uninerve, pubescent on both faces, trichomes stellate; petioles 3-5 mm long, pubescent, not spine. Flowers solitary, axillary or terminal; pedicels 0.5-1 cm long; epicalyx absent; calyx 4-7 mm long, cupuliform, venation prominent, externally with stellate trichomes, internally with trichomes only at the apex, lobes acute-acuminate at the apex; petals c. 1.2 × 1 cm, obovate, yellow-orange with reddish basal spot, glabrous; stamens c. 40, staminal tube 2-3 mm long, free portion of the stamens 0.8-1 mm long, concentrated at the apex of the tube; ovary c. 1 × 1 mm, subglobose, glabrous, carpels 7, uniovulate, styles 7, 5-6 mm long. Schizocarp not inflated; mericarps 7, 7-8 × c. 2 mm, long biaristate, ariste parallel between them, with simple trichomes retrorse, white, lateral face reticulate, resistant; seeds 1 per mericarp c. 2 × 1.5 mm, reniform, nigrescent, glabrous.

Material examined: APA Serra Branca, Baixa grande após o povoado Quelés, roça de Mané de Chico, 9°58'30.7"S 38°26'20"W, 504 m, 03.IX.2012, bot.; fl.; fr., J.B. Lima 57 (HUNEB).

A species endemic to Brazil, occurring only in the southeast (Minas Gerais), midwest (Federal District) and northeast (Piauí, Ceará, Rio Grande do Norte, Paraiba, Pernambuco, Sergipe and Bahia), in Caatinga, Cerrado and Atlantic Forest environments (Bovini 2016d).

In the study area, *Sida angustissima* can be confused with *S. linifolia* Cav. because both have linear to narrow-elliptic leaves. However, *S. angustissima* can be distinguished from *S. linifolia* by having uninerve leaf blades with serrate margin (*vs*. trinerve leaf blades with entire margin) and yellow-orange petals with a reddish base (*vs*. white petals with a vinaceous basal spot). Esteves & Krapovickas (2009) differentiate these species by mericarps long aristate in *S. angustissima* and muticous mericarps in *S. linifolia*. The species has beekeeping potential (Sampaio et al. 2005) and was collected only once during the rainy season.

9. *Sida castanocarpa* Krapov., Bonplandia 16(3-4): 226. 2007. Iconografia: Krapovickas (2007: 227). Figures 2i; 3b

Subshrubs prostrate; branches pubescent, trichomes stellate. Stipules linear to lanceolate 5-9 mm long, ciliate, trichomes stellate on the abaxial faces. Leaf with blade 0.6-1.7 × 0.5-0.8 cm, ovate to elliptic, discolorous, chartaceous, apex acute, basis obtuse, margin serrate at the portion apical, pubescent on both faces, trichomes stellate adpressed denser on abaxial face; petioles 3-6 mm long, pubescent, not spine. Inflorescences cymes terminal. Flowers pedicels 1-2 mm long; epicalyx absent; calyx 4-5 mm long, cupuliform, venation prominent, externally with simple trichomes, internally trichomes only at the apex, lobes acute-acuminate at the apex; petals c. 1 × 0.4 cm, obovate, white to salmon with red base, trichomes glandular on the dorsal face; stamens c. 16, staminal tube 1.8-2 mm long, free portion of the stamens c. 15 mm long, concentrated at the apex of the tube; ovary c. 1 × 1.2 mm, subglobose, simple trichomes, carpels 7, uniovulate, styles 7, 4-5 mm long. Schizocarp not inflated; mericarps 7, c. 3 × 2 mm, muricate with brown stellate trichomes, lateral face reticulate, resistant; seeds 1 per mericarp c. 2 × 2 mm, reniform, brown, pilose.

Material examined: APA Serra Branca, Estrada do Tamburi, próximo a baixa dos Quelés, 9°57'43"S 38°25'33.3"W, 514 m, 09.VII.2012, bot.; fl.; fr., J.B. Lima 25 (HUNEB); Povoado Quelés, 9°58'49.5"S 38°26'15"W, 516 m, 26.III.2013, bot.; fl.; fr., J.B. Lima 74 (HUNEB); 26.III.2013, bot.; fl.; fr., J.V. dos Santos 66 (HUNEB).

This species is endemic to Brazil, found in the midwest (Goiás) and northeast (Maranhão, Piauí, Ceará, Rio Grande do Norte and Bahia), in Caatinga and Cerrado environments (Bovini 2016d, Krapovickas 2007).

Sida castanocarpa in the study area is the only species of the genus that has a prostrate habit. Furthermore, it can be differentiated by white to salmon-colored petals and muricate mericarps with brown stellate trichomes. It was collected with flowers and fruits in March and July, in anthropized areas on sandy soils.

10. *Sida cordifolia* L., Sp. Pl. 2: 684. 1753. Iconografia: Rondón (2009: 613), Esteves & Krapovickas (2009: 66), Brandão (2014: 105). Figures 2j; 3j

Subshrubs 50-60 cm tall; velutinous branches, trichomes stellate. Stipules linear 4-6 mm long, trichomes stellate. Leaf with blade 2.5-5.5 × c. 2-5 cm, ovate, slightly discolorous, membranaceous, apex obtuse to acute, base cordate, margin crenata, velutinous on both faces, trichomes stellate more dense on the abaxial face; petioles 3-6 mm long, velutinous, not spine. Inflorescences glomeruliforms dense, axillary and terminal. Flowers pedicels 3-6 mm long; epicalyx absent; calyx 6-8 mm long, cupuliform, venation prominent, externally with stellate trichomes, internally simple trichomes only at the apex, lobes acute-cuspidate at the apex; petals c. 1 × 0.8 cm, obovate, yellow-orange with pink base, externally with simple trichomes at the apex; stamens c. 60, staminal tube 2-3 mm long, free portion of the stamens c. 15 mm long, concentrated at the apex of the tube;

ovary 1-2 × c. 2 mm, subglobose, glabrous, carpels 10, uniovulate, styles 10, 5-8 mm long. Schizocarp not inflated; mericarps 10, c. 5 × 2 mm, long biaristate, arista parallel between them, with simple trichomes retrorse, white, lateral face reticulate, resistant; seeds 1 per mericarp c. 2 × 1.5 mm, reniform, nigrescent, glabrous.

Material examined: APA Serra Branca, Estrada para o povoado Quelés, ao lado do *Enterolobium*, 9°57'46.3"S 38°26'12.7"W, 478 m, 26.III.2013, bot.; fl.; fr., J.B. Lima 71 (HUNEB); Povoado Quelés, 9°58'49.5"S 38°26'15"W, 516 m, 26.III.2013, bot.; fl.; fr., J.B. Lima 73 (HUNEB).

A species with a Pantropical and Subtropical distribution (Fryxell 1988). It is found in all regions of Brazil, occurring in Caatinga, Cerrado, Amazon Rainforest and Atlantic Forest environments. In the northeast the species was recorded in the states of Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco and Sergipe (Bovini 2016d).

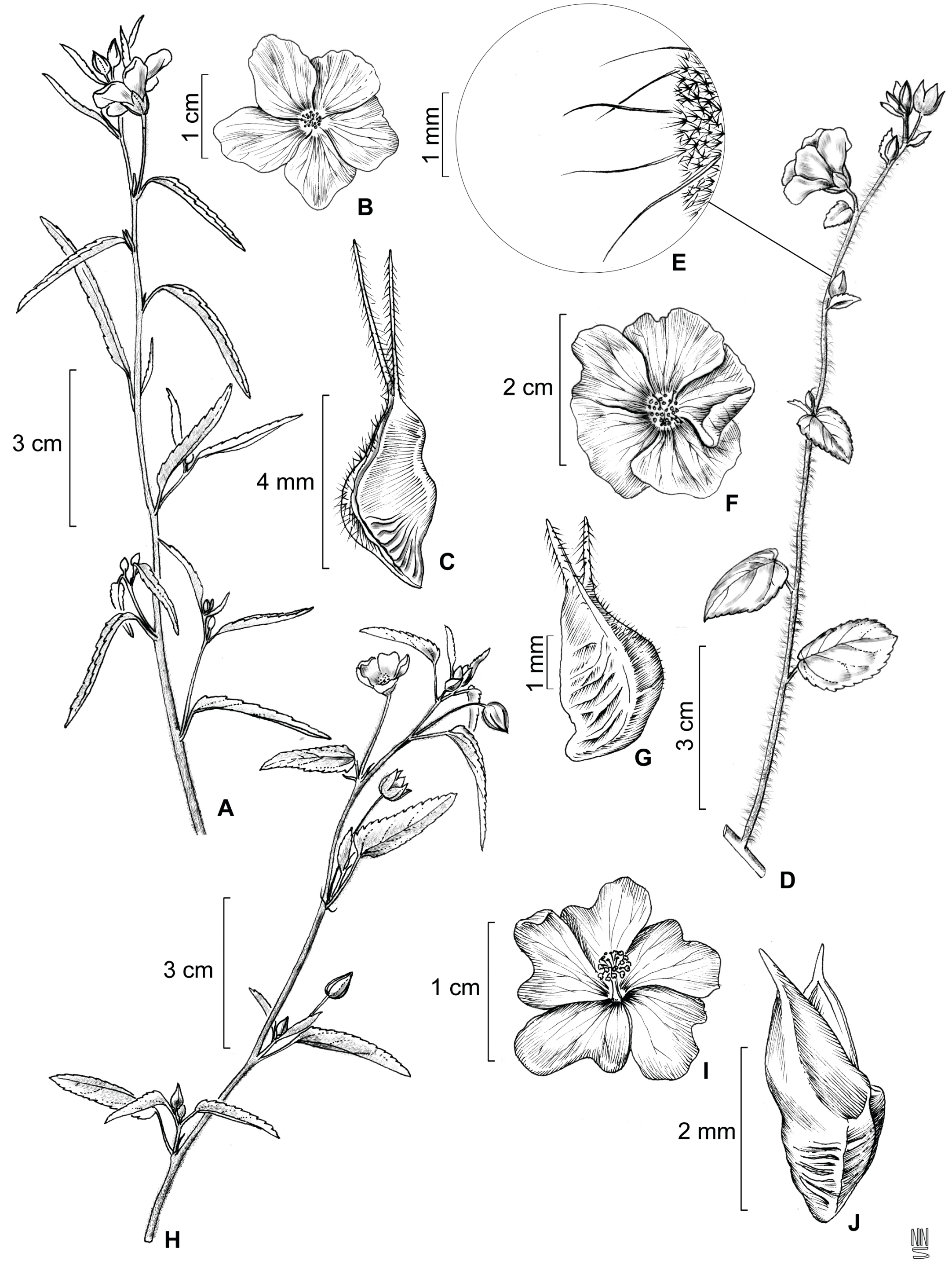

Figure 5. A-C. *Sida angustissima*. A. flowering branch; B. flower; C. mericarp. D-G. *Sida galheirensis*; D. flowering branch; E. detail of branch indumentum; F. flower; G. mericarp. H-J. *Sida spinosa*; H. flowering branch; I. flower; J. mericarp. A-C from J.B. Lima 57; D-G from A.S. Conceição 1288; H-J from J.B. Lima 80.

In EPASB, *Sida cordifolia* occurs in open areas and along roadsides associated with sandy soils. It can be distinguished from all other congeners species by velutinous leaf and branches, leaf blades ovate with cordate base and mericarps 5 mm long, biaristate, arista parallel between them. It was collected with flowers and fruits during almost all year. The species has beekeeping, forage and medical potential (Sampaio et al. 2005).

11. *Sida galheirensis* Ulbr., Notizbl. Bot. Gart. Berlin-Dahlem 9: 40. 1924. Iconografia: Brandão (2014: 107). Figures 2l; 3l; 5d-g

Subshrubs 35-40 cm tall; branches hirsute, short stellate trichomes and simple longer. Stipules linear 3-5 mm long, trichomes stellate. Leaf with blade 1.5-4.5 × 1-3 cm, ovate to elliptical, discolorous, chartaceous, apex acute-acuminate, basis obtuse to subcordate, margin serrate, pubescent on both faces, trichomes stellate; petioles 9-11 mm long, hirsute, not spine. Flowers solitary, axillary or terminal. Pedicels 0.5-3 cm long; epicalyx absent; calyx 7-9 mm long, cupuliform, venation prominent, externally with stellate trichomes, internally trichomes only at the apex, lobes acute-acuminate at the apex; petals c. 1.5 × 1.8 cm, obovate, yellow-orange with red-vinaceous base, glabrous; stamens c. 50, staminal tube 2-3 mm long, free portion of the stamens 1.5-2 mm long, concentrated at the apex of the tube; ovary c. 1 x 1, subglobose, glabrous, carpels 7-8, uniovulate, styles 7-8, 4-5 mm long. Schizocarp not inflated; mericarps 7-8, c. 3 × 3 mm, shortly biaristate, arista divergent, simple retrorse trichomes, white, lateral face reticulated, resistant; seeds 1 per mericarp c. 2 × 1 mm, reniform, brown, glabrous.

Material examined: APA Serra Branca, Base da vaca morta, 9°55’17,2”S 38°42’06”W, 392 m, 10.VII.2012, bot.; fl., J.B. Lima 35 (HUNEB); Estrada principal sentido Serra do Navio, 9°53’37.2”S 38°40’29.2”W, 429 m, 10.VII.2012, bot.; fl.; fr., J.B. Lima 36 (HUNEB); trilha da Serra do Morro. 9°52’49”S 38°39’22”W, 481 m, 30.VII.2009, fl., T.M.S. Melo 52 (HUNEB); 1km da base da base da vaca morta, 9°54’23”S 38°41’22”W, 367 m, 17.IV.2008, fl., A.S. Conceição 1288 (HUNEB); 1 km da Vaca Morta, 9°53’17.3”S 38°40’10.5”W, 384 m, 17.IV.2008, fl., A.S. Conceição 1293 (HUNEB).

Sida galheirensis is endemic from Northeastern Region of Brazil, and is found in the states of Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí and Rio Grande do Norte, in Caatinga and Cerrado environments (Bovini 2016d).

It is recognized by flowers with yellow-orange petals, a red-vinaceous base and mericarps 7-8-mm long, shortly biaristate with divergent arista. In the EPASB, *S. galheirensis* is widely distributed in the undergrowth and shrub borders on sandy soils. It blooms during almost the entire year and fruits in May and July. Reported by Sampaio et al. (2005) as a species for beekeeping and forage.

12. *Sida linifolia* Cav., Diss. 1: 14. 1785. Iconografia: Schumann (1891: 57), Rondón (2009: 615), Brandão (2014: 109). Figure 2m

Subshrubs 50-60 cm tall; branches hirsute, trichomes simple, rare fasciculate. Stipules linear 4-5 mm long, simple trichomes. Leaf with blade 3.5-7 × 0.2-1.5 cm, linear to narrow elliptic, discolorous, chartaceous, apex acute-acuminate, basis obtuse, margin entire, trinerve, pubescent on both faces, trichomes simple; petioles 4-10 mm long, not spine. Inflorescences corymb, terminal. Flowers pedicels 0.5-1 cm long; epicalyx absent; calyx 5-6 mm long, cupuliform, venation prominent, externally with simple trichomes, internally trichomes only at the apex, lobes acute-cuspidate at the apex; petals c. 0.8 × 1.2 cm, obovate, white with vinaceous basal spot, glabrous; stamens c. 40, staminal tube 2-3 mm long, free portion of the stamens c. 1 mm long, concentrated at the apex of the tube; ovary c. 1 × 1, subglobose, glabrous, carpels 8, uniovulate, styles 8, 3-4 mm long. Schizocarp not inflated; mericarps 8, c. 3 × 2.5 mm, muticous, glabrous, lateral face reticulate, resistant; seeds 1 per mericarp, c. 2 × 1 mm, subreniforms, light brown, simple trichomes around at the hilum.

Material examined: APA Serra Branca, Baixa grande após o povoado Quelés, roça de Mané de Chico, 9°58’30.7”S 38°27’01”W, 564 m, 03.IX.2012, fl., J.B. Lima 55 (HUNEB).

A widely distributed species, it has been reported from America and Tropical Africa. In Brazil it occurs in all regions in Caatinga, Cerrado, Amazon Rainforest, Atlantic Forest and swamp environments. In the Northeast Region it occurs in the states of Bahia, Paraíba, Pernambuco, Piauí and Rio Grande do Norte (Bovini 2016d).

The species can be confused with *S. angustissima* (see comments in *S. angustissima*). However, it is recognized by its linear to narrow-elliptic leaves trinerved, entire margin, white petals with a vinaceous basal spot and, muticous and glabrous mericarps. In the EPASB, this species was collected only once with flowers and fruits in the rainy season. *Sida linifolia* has beekeeping potential (Sampaio et al. 2005).

13. *Sida spinosa* L., Sp. Pl. 2: 683. 1753. Iconografia: Rondón (2009: 616), Brandão (2014: 113). Figures 2n; 3h; 5h-j

Subshrubs 25-30 cm tall; branches pubescent, trichomes stellate. Stipules linear 2-3 mm long. Leaf with blade 0.8-1.1 × 0.3-0.6 cm, narrow elliptic to elliptic, discolorous, chartaceous, apex acuminate, basis obtuse, margin serrate, pubescent on both faces, trichomes stellate; petioles 5-8 mm long, pubescent, with a purple spine. Flowers solitary, axillary or terminal; pedicels 0.5-1.5 cm long; epicalyx absent; calyx 4-5 mm long, cupuliform, venation prominent, externally with stellate trichomes, internally trichomes only at the apex, lobes acute to acuminate at the apex; petals 6-7 × c. 9 mm, obovate, white with yellow basal spot, glabrous; stamens c. 27, staminal tube 2-4 mm long, free portion of the stamens 0.8-1 mm long, concentrated at the apex of the tube; ovary c. 1.2 × 1.8 mm, subglobose, glabrous, carpels 5, uniovulate, styles 5, 2-2.5 mm long. Schizocarp not inflated; mericarps 5, c. 3.5 × 2 mm, biaristate, simple trichomes white, lateral face reticulated, resistant; seeds 1 per mericarp c. 1 × 1.5 mm, reniform, brown, glabrous.

Material examined: APA Serra Branca, Caminho da judite próximo a Serra do Navio, 9°51’55.5”S 38°38’45”W, 469 m, 03.XI.2011, fl.; fr., J.B. Lima 01 (HUNEB).

A species widely distributed in the New World, and with few records in the Old World. In Brazil it is well represented in the Northeast Region (Bahia, Ceará, Paraíba, Pernambuco and Rio Grande do Norte), in areas of Caatinga, Cerrado and Atlantic Forest. The species does not occur in the Northern Region (Bovini 2016d).

In the EPASB, *Sida spinosa* is the only species of the genus with white petals with a yellow basal spot and only 5 mericarps. It was collected once with flowers and fruits in November on sandy-clayey soils. It is a species that holds medicinal and beekeeping potential (Sampaio et al. 2005).

14. *Sidastrum micranthum* (A.St.-Hil.) Fryxell, Brittonia 30(4): 452 (1978). Iconografia: Schumann (1891: 59), Rondón (2009: 618), Bovini (2010: 295). Figures 2o; 3m

Subshrub 45-50 cm tall; branches pubescent to tomentose, trichomes stellate. Stipules linear 5-7 mm long. Leaf with blade 2-6 × 1.5-5 cm, ovate, discolorous, chartaceous, apex acute, basis obtuse to cordate, margin crenate, velutinous on both faces, trichomes stellate; petiole 0.5-3 cm long, tomentose, not spine. Inflorescences glomeruliform, dense, axillary and terminal. Flowers subsessile or pedicels 0.5-1.5 mm long; epicalyx absent; calyx 2-3 mm long, cupuliform, not prominent venation, externally with stellate trichomes, internally simple trichomes on the apex, lobes acute; petals c. 4 × 2 mm, obovate, clear yellow with pink basal spot, glabrous; stamens c. 19, staminal tube c. 2 mm long, glabrous, free portion of the stamens 0.8-1 mm long, concentrated at the apex of the tube; ovary c. 1 × 1 mm, subglobose, simple trichomes on the apex, carpels 5, uniovulate, styles 5, 2-3 mm long, stigmas capitate. Schizocarp not inflated; mericarps 5, 2-3 × c. 2 mm, muticous, pubescent, stellate trichomes white, lateral face lightly reticulate, fragile; seeds 1 per mericarp c. 1 × 1 mm, ovate, brown, glabrous.

Material examined: APA Serra Branca, Baixa Grande, roça de Mané de Chico, 9°58'30.7"S 38°27'01"W, 564 m, 26.III.2013, bot.; fl.; fr., J.V. dos Santos 67 (HUNEB).

This species is distributed in the Neotropics (Fryxell 1997), in Brazil it is spread-out over the midwest (Goiás), northeast (Bahia, Ceará, Paraíba), southeast (Minas Gerais, São Paulo, Rio de Janeiro) and south (Paraná), and is found in the phytogeographical domains of Caatinga, Cerrado and Atlantic Forest (Bovini 2016e).

In the study area, *S. micranthum* can be distinguished by its dense glomerule inflorescences, shortly pedicellate small flowers and clear yellow petals with a pink basal spot. It was collected just once with flowers and fruits in March. The species holds medicinal potential (Sampaio et al. 2005).

15. *Sidastrum multiflorum* (Jacq.) Fryxell, Brittonia 31(2): 298. 1979. Figures 2p; 6a-d

Subshrub 25-30 cm tall; branches tomentose, trichomes stellate. Stipules linear 3-4 mm long. Leaf with blade 1.5-4 × 0.6-1.8 cm, ovate to elliptical, discolorous, chartaceous, apex acute to acuminate, basis obtuse, margin serrate, tomentose on both faces, trichomes stellate; petioles 1-4 mm long, pubescent, not spine. Inflorescences glomerule or flowers solitary, axillary; pedicels 1.5-3 mm long; epicalyx absent; calyx 4-5 mm, cupuliform, not prominent venation, externally with stellate trichomes, internally simple trichomes only at the apex, lobes acute at the apex; petals 6-7 × 5-6 mm, obovate, yellow, trichomes simple at the base; stamens c. 20, staminal tube 2-3 mm long, glabrous, free portion of the stamens 1-2 mm long,

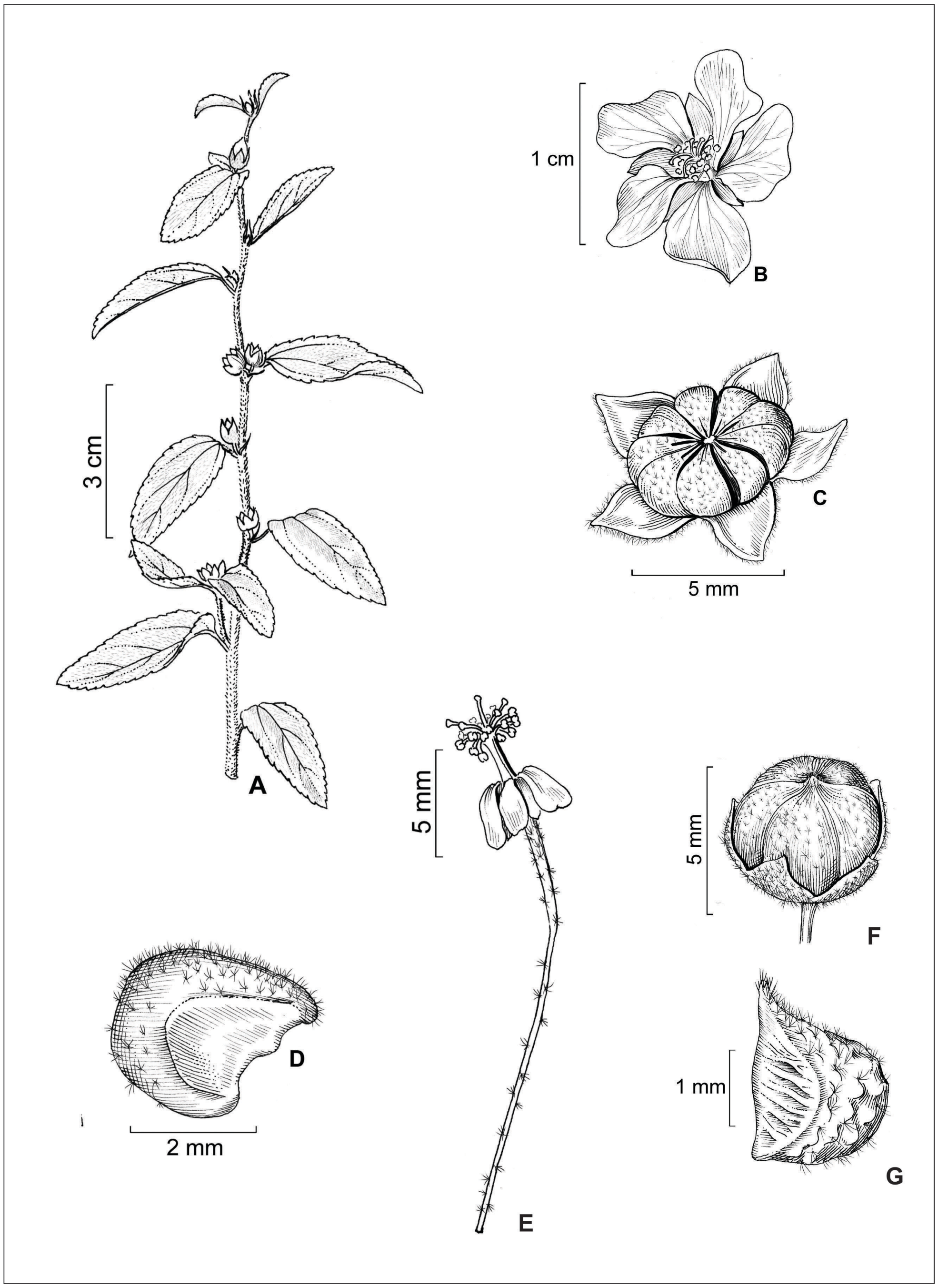

Figure 6. A-D. *Sidastrum multiflorum*; A. flowering branch; B. flower; C. fruit; D. mericarp. E-G. *Sidastrum paniculatum*; E. flower; F. fruit; G. mericarp. A-D from J.B. Lima 34; E-G. J.B from Lima 86.

concentrated at the apex of the tube; ovary c. 1 × 1.5 mm, subglobose, glabrous, carpels 10, uniovulate, styles 10, 4-5 mm long, stigmas capitate. Schizocarp not inflated; mericarps 10, 2-3 mm long, muticous, stellate trichomes white, lateral face lightly reticulate, fragile; seeds 1 per mericarp c. 1.8 × 1.5 mm, reniform, nigrescent, slightly pilose.

Material examined: APA Serra Branca, Caminho da Judite próximo a Serra do Navio, 9°51'55.5"S 38°38'45"W, 469 m, 03.XI.2011, fl.; fr., J.B. Lima 06 (HUNEB); Base da Vaca Morta, 9°55'17,2"S 38°42'06"W, 392 m, 10.VII.2012, bot.; fl.; fr., J.B. Lima 34 (HUNEB); Baixa Grande, após o povoado Quelés, roça de Mané de Chico, 9°58'30.7"S 38°27'01"W, 564 m, 26.III.2013, fr., J.B. Lima 75 (HUNEB); Vaca Morta. 9°54'03"S 38°40'58"W, 386 m, 22.VIII.2008, fl., M.V. Romão 285 (HUNEB).

Sidastrum multiflorum occurs in the Bahamas, Cuba, Spain and the Antilles south to Argentina (Fryxell 1978, 1979). In Brazil it occurs in the northeast (Bahia, Maranhão, Paraíba, Pernambuco) and southeast (Espírito Santo) of the country in phytogeographic domains of Caatinga, Amazon Rainforest and Atlantic Forest (Bovini 2016e).

In the study area, it differs from its congeners by yellow petals that are more than 5 mm long and twice the number of mericarps (10). Specimens were collected with flowers in March, August, September and November and fruits in September and November in hyperxerophytic environments of Caatinga vegetation and in areas of contact with seasonal Caatinga-forest on sandy soils.

16. *Sidastrum paniculatum* (L.) Fryxell, Brittonia 30(4): 453. 1978. Iconografia: Schumann (1891: 58). Figures 2q; 6e-g

Subshrub 50-70 cm tall; branches pubescent, trichomes stellate. Stipules linear 3-6 mm long. Leaf with blade 1.3-3 × 0.9-2 cm, ovate to elliptical, discolorous, chartaceous, apex acute, basis obtuse to subcordate, margin serrate, pubescent on both faces, trichomes stellate; petioles 2-5 mm long, pubescent, not spine. Inflorescences paniculate, axillary and terminal; pedicels 1.5-2 cm long; epicalyx absent; calyx 2-3 mm long, cupuliform, not prominent venation, externally with stellate trichomes, internally simple trichomes on the apex, lobes acute at the apex; petals 4-5 × 2.5-4 mm, obovate, vinaceous, glabrous; stamens c. 20, staminal tube 2-3 mm long, free portion of the stamens 1-2 mm long, concentrated at the apex of the tube; ovary c. 1 × 1 mm, globose, simple trichomes at the apex, carpels 5, uniovulate, styles 5, 4-5 mm long., stigmas capitate. Schizocarp not inflated; mericarps 5, 3-5 mm long, muticous, pubescent, stellate trichomes white, lateral face lightly reticulate, fragile; seeds 1 per mericarp c. 1 × 1 mm, subglobose, brown, glabrous.

Material examined: APA Serra Branca, Caminho da Judite próximo a Serra do Navio, 9°51'55.5"S 38°38'45"W, 469 m, 03.XI.2011, fl.; fr., J.B. Lima 08 (HUNEB); Serra do Navio, próximo ao barreiro, 9°51'56"S 38°38'45"W, 479 m, 10.VII.2012, fl.; fr., J.V. dos Santos 40 (HUNEB).

Sidastrum paniculatum is a species with a Neotropical distribution (Wagner et al. 1999). In Brazil it has been recorded in the northeast (Bahia, Pernambuco, Paraíba), midwest (Mato Grosso do Sul, Mato Grosso) and southeast (Minas Gerais, Rio de Janeiro, São Paulo), in Caatinga, Cerrado, Amazon Rainforest and Atlantic Forest environments (Bovini, 2016e).

In the study area, it differs from its congeners by paniculate inflorescences with very small flowers (until 5 mm) with long pedicels and vinaceous petals. In the EPASB it was found in edge shrubby-arborescent Caatinga on sandy and sandy-clayey soils. Specimens were collected with flowers and fruits in July and November. The species holds beekeeping potential (Sampaio et al. 2005).

Appendix

List of additional material examined

Bandeira, F.P. 154 (11); **Bandeira, F.P.** 91 (2); **Cardoso, D.** 955 (4); **Carneiro-Torres, D.S.** 512 (3); **Carvalho-Sobrinho, J.G. de** 563 (1); **Castro, M.S de** s/n (1); **Castro, M.S. de** s/n (11); **Castro, M.S. de** s/n (6); **Castro, M.S. de** s/n (8); **Castro, R.M.** 1274 (1); **Colaço, M.** 70 (2); **Conceição, A.A.** 3022 (11); **Conceição, S.F.** 500 (15); **Esteves, G.L.** 2500 (1); **Esteves, G.L.** 2503 (6); **Esteves, G.L.** 2505 (2); **Esteves, G.L.** 2507 (14); **Esteves, G.L.** 2509 (6); **Gomes, F.S.** 184 (4); **Leal, S.** 42 (5); **Lima, L.C.L.** 179 (14); **Melo, E.** 10675 (11); **Melo, E.** 6430 (13); **Melo, E.** 6658 (11); **Melo, E.** 6711 (1); **Melo, E.** 6712 (5); **Melo, E.** 6713 (12); **Melo, E.** 6716 (10); **Melo, E.** 6776 (1); **Melo, E.** 6780 (8); **Melo, E.** 6801 (10); **Miranda, E.B.** 812 (11); **Miranda, E.B.** 820 (6); **Miranda, E.B.** 859 (2); **Moraes, A.O.** 88 (5).

Moraes, A.O. 91 (11); **Noblick, L.R.** 2950 (16); **Pedreira, E.M.** 19 (15); **Pinto, G.** 49 (3); **Queiroz, L.P. de** 435 (6); **Queiroz, L.P. de** 6562 (6); **Queiroz, L.P. de** 7164 (6); **Queiroz, L.P. de** 7210 (11); **Queiroz, L.P. de** 7260 (2); **Queiroz, L.P. de** 9036 (16); **Rodarte, A.** 03 (11).

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Ichthyofauna of the humid forest enclaves in the tablelands of Ibiapaba and Araripe, Northeastern Brazil

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Abstract: Humid highland forest enclaves are remnants of Atlantic Forest found in tablelands within the Caatinga biome (Northeastern Brazil), which emerged during interglacial periods in the Pleistocene. These ecosystems have a highly diverse and endemic fish fauna. Most earlier surveys have focused on the tableland of Borborema (Pernambuco and Paraíba States). In this study we surveyed the fish fauna of the humid forest enclaves in the tablelands of Ibiapaba and Araripe, based on samples collected in the rainy season (March and April) between 2009 and 2014. The 45 sampling points covered rivers, streams and reservoirs in five river basins belonging to three ecoregions. The species were listed according to drainage divide, and endemism was determined for each ecoregion and for the Caatinga. Our area was more species-rich (n=59) than Borborema (n=27). The samples included five introduced species and 29 species endemic to the Caatinga (49.1% of the sampled species). The distribution of *Parotocinclus haroldoi* was expanded to the Mid-Northeastern Caatinga ecoregion (Timonha river basin, Ceará State). Our study intends to make a significant contribution to current knowledge of the ichthyofauna in humid highland forest enclaves of semiarid Northeastern Brazil, identified as a priority in the conservation of the biodiversity in the Caatinga.

Keywords: *Neotropical Region, Endemism, Conservation, Fishes of the Caatinga.*

Ictiofauna dos enclaves de floresta úmida nos planaltos da Ibiapaba e do Araripe, Nordeste do Brasil

Resumo: Florestas úmidas são enclaves de Mata Atlântica em regiões elevadas inseridas no bioma Caatinga que surgiram no Pleistoceno em eventos interglaciais. Esses ecossistemas abrigam alta diversidade de espécies para diversos táxons e elevadas taxas de endemismo. A maioria dos levantamentos de peixes nesses ecossistemas foi realizada no Planalto da Borborema, nos Estados de Pernambuco e Paraíba. Dessa forma, visando conhecer a ictiofauna de dois enclaves de florestas úmidas no nordeste brasileiro, foram feitas coletas no período chuvoso (Março e Abril) entre 2009 e 2014 no Planalto da Ibiapaba e na Chapada do Araripe. Foram amostrados 45 pontos em rios, riachos e reservatórios em cinco bacias hidrográficas e três ecorregiões. A lista de espécies por drenagem e o endemismo foi definido para cada ecorregião e para a Caatinga. A riqueza de peixes (59 espécies) foi superior quando comparada a dos enclaves da Borborema (27), com cinco espécies introduzidas e 29 endêmicas para a Caatinga, o que representa 49,1% das espécies capturadas. Destaca-se a expansão de ocorrência de *Parotocinclus haroldoi* para a ecorregião do Nordeste Médio-Oriental, na microbacia do rio Timonha, no Estado do Ceará. Este estudo pretende contribuir com informações inéditas para o conhecimento ictiofaunístico dos ecossistemas aquáticos dos brejos de altitude do semiárido brasileiro, apontadas como prioritárias para conservação da biodiversidade da Caatinga.

Palavras-chave: *Região Neotropical, Endemismo, Conservação, Peixes da Caatinga.*

Introduction

The Brazilian territory may be divided into six large morphoclimatic zones, each with its own climatic, pedological, hydrological and phytogeographic characteristics (Ab'Sáber 2003). One of these, the Caatinga, a predominantly Northeast Brazilian biome, is characterized by a semiarid climate with a relatively short rainy season (four months) of sporadic and unevenly distributed rainfalls. Due to the paucity of rain (240-800 mm annually) and high evaporation rate (Tabarelli & Santos 2004), most aquatic systems are intermittent. This probably results in a smaller fish diversity than that observed in other tropical aquatic systems (Medeiros & Maltchik 2001). However, the Caatinga features minor contrasting areas, such as humid highland forest enclaves locally referred to as '*brejos de altitude*' (Ab'Sáber 2003). Acting as drainage divides between the main hydrographic ecoregions of Northeastern Brazil (Maranhão-Piauí, Mid-Northeastern Caatinga, São Francisco and Northeastern Atlantic Forest), these highland enclaves receive more rain than the surrounding Caatinga due to orographic rainfalls, favoring the maintenance of aquatic systems throughout the year. Moreover, the expansion and posterior recession of the Atlantic and Amazon forest in Northeastern Brazil due to climate changes in the Pleistocene (Andrade-Lima 1982, Santos et al. 2007) resulted in the emergence of unique ecosystems with high levels of diversity and endemism, which serve as refuges for regional fauna and flora (Andrade-Lima 1982).

Unfortunately, little is known about the aquatic biota of the Brazilian semiarid region and how fish assemblages and richness are impacted by environmental degradation and the introduction of exotic species (Santos et al. 2011, Botero et al. 2014). In addition, efforts at freshwater fish conservation have been feeble at best (Lévêque et al. 2008, Abell et al. 2008). Fish fauna surveys not only help define biogeographic regions, but also provide important subsidies for environmental policy decisions (especially with regard to the establishment and effectiveness of conservation areas) and serve as an important first step for research in related fields (Albert et al. 2011).

Rosa & Groth (2004) published the first comprehensive study on fish assemblages in humid highland forest enclaves. The study covered the Borborema tableland which drains into the Paraíba do Norte and Mamanguape river basins (Paraíba State) and the Ipojuca river basin (Pernambuco State) located in the eastern part of the Mid-Northeastern Caatinga ecoregion. Other initiatives, such as the PROBIO Project for Conservation and Sustainable Use of Brazilian Biological Diversity (Projeto de Conservação e Utilização Sustentável da Diversidade Biológica Brasileira) and the PPBio Program for Research in Biodiversity (Programa de Pesquisa em Biodiversidade), are helping expand current knowledge on fish diversity in the region. In addition, Ramos et al. (2014) recently evaluated the richness of the ichthyofauna of the Parnaíba river basin (a semiarid region shared by Ceará, Piauí and Maranhão States) and identified 146 species of freshwater fishes, 54 (36.9%) of which were endemic to the basin. Their survey added significantly to the list of 95 species of Albert et al. (2011) for the Maranhão-Piauí ecoregion, highlighting the need for additional inventories. Nevertheless, many gaps remain in the knowledge of the ichthyofauna of the São Francisco and Mid-Northeastern Caatinga ecoregions, especially with regard to humid forest enclaves (Rosa & Groth 2004, Langeani et al. 2009). Thus, the purpose of this study was to provide a list of fish species from forest enclaves and streams in the tablelands of Ibiapaba (between Piauí and Ceará States) and Araripe (between Ceará and Pernambuco States) which drain into the Parnaíba, Coreaú, Timonha, Jaguaribe and São Francisco river basins.

Materials and methods

1. Study area

The surveys were conducted in humid forest enclaves in two tablelands, Ibiapaba and Araripe, which act as drainage divides between the Maranhão-Piauí, São Francisco and Mid-Northeastern Caatinga ecoregions (Rosa et al. 2003, Albert et al. 2011) (Figure 1). The two tablelands make up the Araripe-Ibiapaba complex, which extends along the confines from Northwestern Ceará to Northeastern Piauí and from Southern Ceará to Central Piauí. The complex displays great altitude variations between the highlands and the central lowlands (*depressão sertaneja*). In the highlands, soils (latosols) tend to be deep, sandy and poor, and surface water is scarce. In Ibiapaba, water infiltrating the soil drains mainly towards Piauí State. In Araripe, water drains towards Ceará State.

Araripe and Ibiapaba have a maximum elevation of 900-1,000 m (Claudino-Sales & Lira 2011), average rainfalls of 1,000 mm in the rainy season (Sá et al. 2004) and perennial or intermittent streams. The humid forests of Ibiapaba drain westward into the Parnaíba basin (Maranhão-Piauí) in Piauí and eastward into the Coreaú basin (Mid-Northeastern Caatinga) in Ceará, whereas Araripe drains northward into the Jaguaribe basin (Mid-Northeastern Caatinga) in Ceará and southward into the São Francisco basin (Rosa et al. 2003) in Pernambuco State (Figure 1).

The eastern slope of the Ibiapaba tableland intercepts the humid coastal wind producing orographic rainfalls and making this region the wettest (mean annual rainfall: ~1000 mm) and coolest (mean annual temperature: 22-26°C) in Ceará. On the other hand, Araripe has 8,000 km^2 of highland forest and elevations up to 1,000 m (Köppen type BSh'), with mean annual temperatures around 25ºC (MME 1996, SRH 2005). These enclaves were previously considered a remnant of the Atlantic Forest (due to the geographic proximity), but recent studies have shown the flora to be more akin to that of the Amazon Forest (Santos et al. 2007).

2. Sampling

Fish were sampled in the rainy season (March-April) during six surveys from 2009 to 2014, covering 45 sampling points—24 in Araripe and 21 in Ibiapaba (Table 1, Figure 2). The sampling sites included first to third-order rivers (n=9), streams (n=27) and small reservoirs (n=9) (100-1,000 m^2). The sampling points in Araripe were located within the Jaguaribe river basin (n=7) and the São Francisco river basin (n=17), while the sampling points in Ibiapaba were located within the Coreaú river basin (n=12), the Parnaíba river basin (n=8) and the Timonha river basin (n=1) (Table 1). Each sampling site was georeferenced using a portable GPS and later plotted on a map to avoid errors of attribution in areas near drainage divides. Using the definition of Rosa et al. (2003), only species restricted to a single ecoregion (Albert et al. 2011) were considered endemic.

Seventeen of the 45 sampling points were located inside conservation units. Thus, seven of the sampling points in the Jaguaribe river basin and one in the São Francisco river basin were located inside the Chapada do Araripe Environmental Protection Area (EPA) (1,063,000 ha). In Ibiapaba, one sampling point in the Timonha river basin was located in the Serra da Ibiapaba EPA

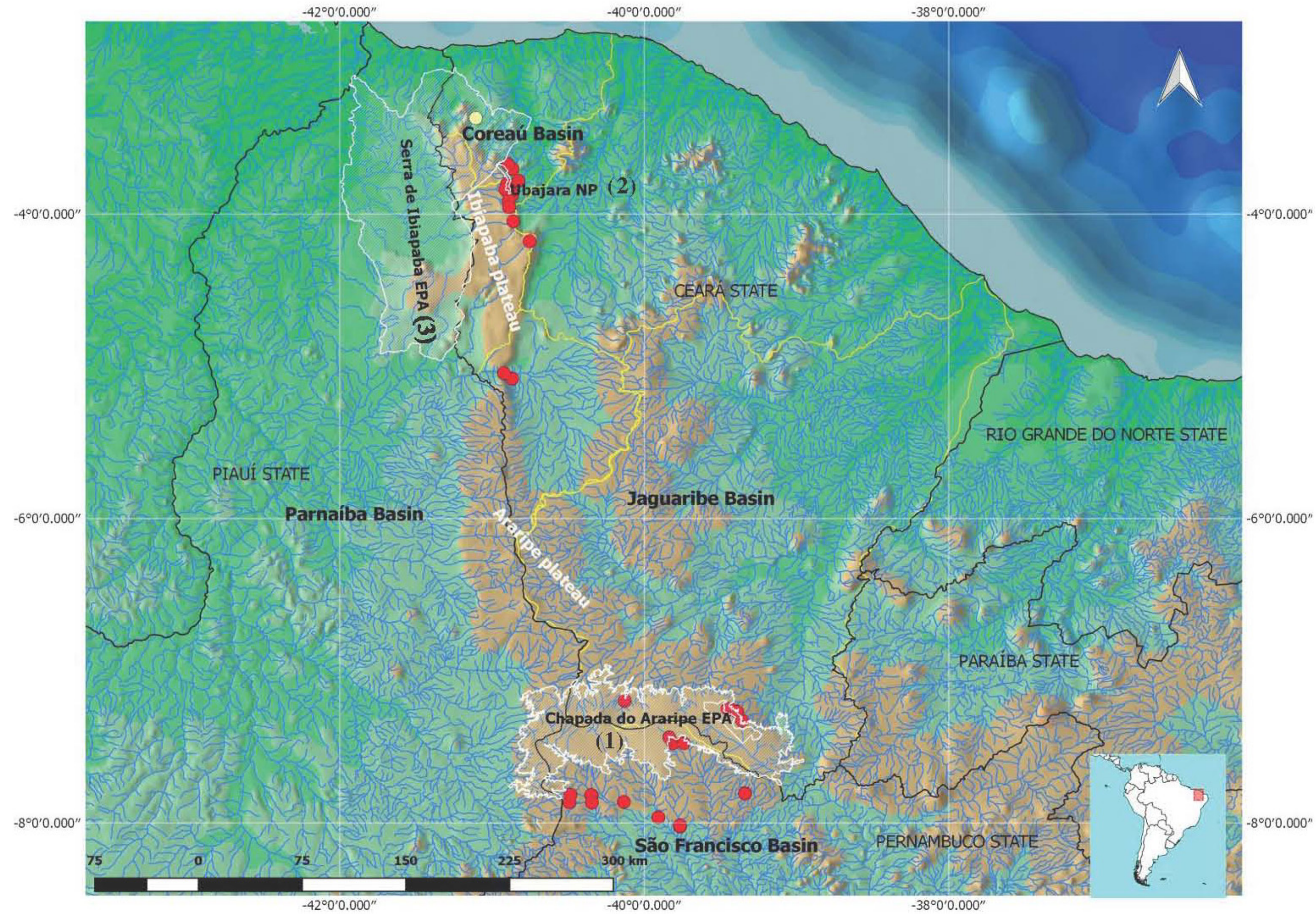

Figure 1. Study area and sampling points in Northeastern Brazil. The sampling sites are represented by red dots (the Coreaú, Jaguaribe, Parnaíba and São Francisco basins) and yellow (Timonha river basin). The tablelands are shown in brown. Conservation units: (1) Chapada do Araripe EPA; (2) Ubajara National Park (NP); (3) Serra da Ibiapaba EPA.

(1,592,550 ha) and eight sampling points in the Coreaú river basin were located in the Ubajara National Park (NP) (6,271 ha).

The fish were captured with casting nets (5.3 m^2; 14 mm between opposing knots), sieves (0.7 m^2; 1 mm between opposing knots) and seines (1.3 m^2; 2 mm between opposing knots) in all accessible habitats (aquatic macrophytes, ponds, pools, rapids and waterfalls) with a fishing effort of four man-hours, under licenses (#26174-2, #32656 and #32921-4) issued by the Ministry of the Environment (MMA) and the Chico Mendes Institute of Biodiversity Conservation (ICMBio). The ichthyological material was deposited in the fish collection of the Universidade Federal do Rio Grande do Norte (UFRN) and the Universidade Federal da Paraíba (UFPB). Vouchers for each species are included in the appendix.

Results and discussion

1. Ichthyofauna and endemism

Fifty-nine fish species, belonging to 38 genera, 16 families and five orders, were identified in our samples from the two tablelands (Table 2). This is more than twice the number of species (27) reported by Rosa & Groth (2004) for nine humid forest enclaves in the tableland of Borborema (Mid-Northeastern Caatinga ecoregion). As pointed out by the authors, the low diversity observed in that study, when compared to that of larger regional river basins, may be the result of sampling or logistic limitations. We do not intend to have fully overcome the difficulties described over a decade ago (for example, not all stretches of the sampled tributaries were accessible due to steep banks, dense riparian vegetation and fast-flowing waters), but with the help of new research teams from several universities in semiarid Northeastern Brazil and taxonomic advances, we believe to have produced a comprehensive and fairly accurate list of the fish species in these ecosystems.

Current knowledge of fish diversity and endemicity in the Caatinga is mainly based on surveys conducted in the largest basins of Northeastern Brazil (Rosa et al. 2003, Rosa & Groth 2004). Miranda-Ribeiro (1937) were the first to describe the fish fauna of humid highland forests in the region (Granjeiro river basin, Araripe). Nijssen and Isbrüker (1976) identified species of *Aspidoras* in highland streams in Northeastern Brazil (mostly in Ceará). More recently, Rosa & Groth (2004) published a seminal study on humid highland forest fish fauna, with emphasis on the question of endemicity and the urgent need for conservation.

None of the species registered in this study (37 in Araripe and 33 in Ibiapaba) is on Brazil's official list of endangered fishes and aquatic invertebrates (MMA, 2014). When introduced species were excluded (n=5) from the analysis, the two tablelands had nine species in common, and

Table 1. Sampling points in the Jaguaribe and São Francisco river basins (Araripe) and the Coreaú, Timonha and Parnaíba river basins (Ibiapaba)**.** Ecoregions: MNC=Mid-Northeastern Caatinga; SFR=São Francisco; MPI=Maranhão-Piauí. Conservation Units (CU): 1=Chapada do Araripe EPA; 2=Ubajara National Park; 3=Serra da Ibiapaba EPA.

Tableland	Basin	Ecoregion	Habitat	CU	Geographic coordinates
Araripe	Jaguaribe	MNC	Stream	1	7°16’01”S 39°23’36”W
Araripe	Jaguaribe	MNC	Stream	1	7°14’56”S 39°27’12”W
Araripe	Jaguaribe	MNC	Stream	1	7°16’12”S 39°23’20”W
Araripe	Jaguaribe	MNC	Reservoir	1	7°11’38”S 40°07’41”W
Araripe	Jaguaribe	MNC	Reservoir	1	7°11’58”S 40°07’45”W
Araripe	Jaguaribe	MNC	River	1	7°15’18”S 39°25’58”W
Araripe	Jaguaribe	MNC	River	1	7°19’41”S 39°21’26”W
Araripe	São Francisco	SFR	Stream	-	7°11’58”S 40°07’45”W
Araripe	São Francisco	SFR	Stream	-	7°48’19”S 39°20’19”W
Araripe	São Francisco	SFR	Stream	-	7°28’34”S 39°48’45”W
Araripe	São Francisco	SFR	Stream	-	7°28’34”S 39°48’45”W
Araripe	São Francisco	SFR	Stream	-	7°26’11”S 39°50’10”W
Araripe	São Francisco	SFR	Stream	-	7°49’06”S 40°20’37”W
Araripe	São Francisco	SFR	Stream	-	7°51’40”S 40°08’02”W
Araripe	São Francisco	SFR	Stream	-	8°00’52”S 39°45’54”W
Araripe	São Francisco	SFR	Stream	-	8°01’25”S 39°45’54”W
Araripe	São Francisco	SFR	Stream	-	7°48’58”S 40°20’56”W
Araripe	São Francisco	SFR	Reservoir	1	7°26’30”S 39°50’01”W
Araripe	São Francisco	SFR	Reservoir	-	7°51’49”S 40°29’29”W
Araripe	São Francisco	SFR	Reservoir	-	7°49’06”S 40°20’37”W
Araripe	São Francisco	SFR	Reservoir	-	7°48’50”S 40°29’03”W
Araripe	São Francisco	SFR	Reservoir	-	7°51’59”S 40°20’37”W
Araripe	São Francisco	SFR	Reservoir	-	7°57’44”S 39°54’27”W
Araripe	São Francisco	SFR	River	-	7°48’58”S 40°20’56”W
Ibiapaba	Coreaú	MNC	Stream	2	3°50’00”S 40° 54’00”W
Ibiapaba	Coreaú	MNC	Stream	2	3°50’22”S 40°54’29”W
Ibiapaba	Coreaú	MNC	Stream	2	3°50’07”S 40°54’03”W
Ibiapaba	Coreaú	MNC	Stream	2	3°50’00”S 40°53’22”W
Ibiapaba	Coreaú	MNC	Stream	2	3º49’48”S 40º54’02”W
Ibiapaba	Coreaú	MNC	Stream	2	3°48’05”S 40°54’06”W
Ibiapaba	Coreaú	MNC	Stream	2	3°50’16”S 40°54’46”W
Ibiapaba	Coreaú	MNC	Stream	-	3°52’06”S 40°51’59”W
Ibiapaba	Coreaú	MNC	Stream	-	3°40’17”S 40°53’44”W
Ibiapaba	Coreaú	MNC	Stream	-	3°42’09”S 40°51’53”W
Ibiapaba	Coreaú	MNC	River	2	3°49’32”S 40°53’30”W
Ibiapaba	Coreaú	MNC	Reservoir	-	3°46’51”S 40°49’32”W
Ibiapaba	Timonha	MNC	Stream	3	3°22’07”S 41°06’23”W
Ibiapaba	Parnaíba	MPI	Stream	-	5°19’13”S 40°26’43”W
Ibiapaba	Parnaíba	MPI	Stream	-	5°04’49’S 40°52’01”W
Ibiapaba	Parnaíba	MPI	Stream	-	5°08’09”S 40°46’03”W
Ibiapaba	Parnaíba	MPI	River	-	5°02’42”S 40°55’16”W
Ibiapaba	Parnaíba	MPI	River	-	3°54’47”S 40°53’25”W
Ibiapaba	Parnaíba	MPI	River	-	4°02’48”S 40°51’37”W
Ibiapaba	Parnaíba	MPI	River	-	3°57’11”S 40°53’13”W
Ibiapaba	Parnaíba	MPI	River	-	4°10’41”S 40°45’09”W

29 species (53.7%) endemic to the Caatinga (Araripe n=18, 56.2%; Ibiapaba n=15; 51.7%) (Table 2) (Rosa et al. 2003). When only the endemic species were considered, endemism was greater in Araripe (28.1%) than in Ibiapaba (20.0%) (Figure 3).

The most species-rich ecoregion was Mid-Northeastern Caatinga (n=29), followed by Maranhão-Piauí (n=26) and São Francisco (n=24). The ecoregions did not differ regard the number of endemic species: six (24.0%) in Mid-Northeastern Caatinga, four (20.0%) in São Francisco and five (19.0%) in Maranhão-Piauí (Figure 3). In view of the fact that only a small part of each ecoregion was sampled, the observed levels of endemism may be considered high.

In addition to harboring a large number of fishes of the Caatinga (~56% endemicity), humid forest enclaves play a crucial role in the maintenance and conservation of the regional ichthyofauna (Rosa & Groth 2004). In this study, the most species-rich river basin was Parnaíba (n=26), followed by São Francisco (n=24), Jaguaribe (n=20), Coreaú (n=16) and Timonha

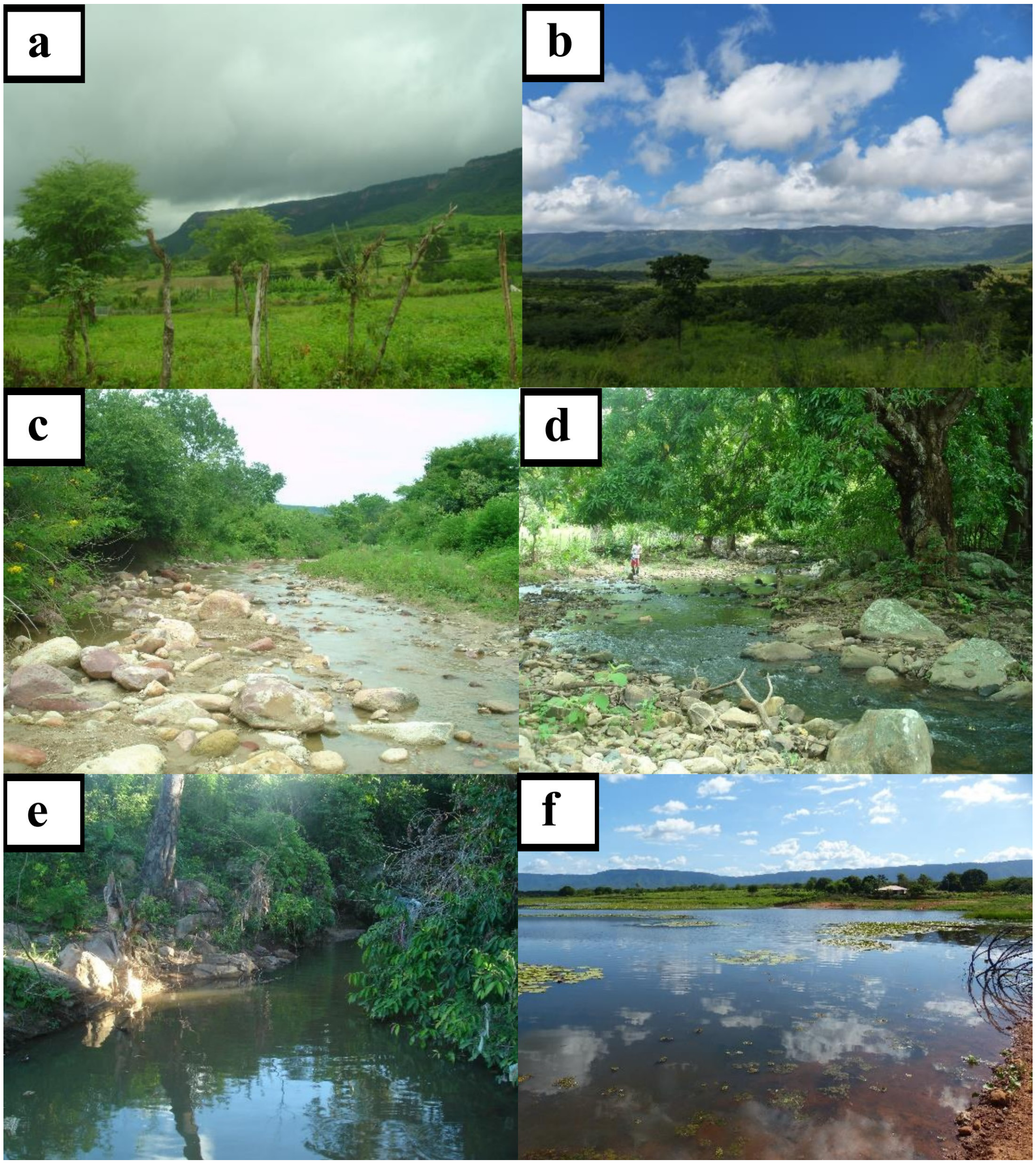

Figure 2. The tablelands of Araripe (a) and Ibiapaba (b), with some sample points: (c) Salamanca river, (d) Tamundé stream, (e) Passagem stream, and (f) Barreira reservoir.

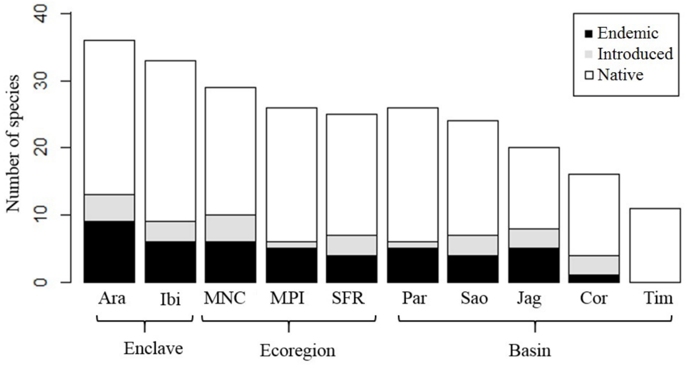

Figure 3. Number of fish species registered for the tablelands of Ibiapaba (Ibi) and Araripe (Ara), for the ecoregions Mid-Northeastern Caatinga (MNC), Maranhão-Piauí (MPI) and São Francisco (SFR), and for the river basins of Parnaíba (Par), São Francisco (Sao), Jaguaribe (Jag), Coreaú (Cor) and Timonha (Tim). The number of endemic species was determined for each ecoregion.

(n=11) (Table 2). When analyzed according to ecoregion, Jaguaribe and Parnaíba both yielded five endemic species, followed by São Francisco (n=4), Coreaú (n=1) and Timonha (n=0) (Figure 3).

The introduced species registered in this study (*Cichla* sp., *Coptodon rendalli, Oreochromis niloticus, Poecilia reticulata* and *Xiphophorus helleri*) (Table 2) have a potentially negative impact on native fish diversity mainly through taxonomic homogenization of assemblages and species extinction (Vitule et al. 2009, Villéger et al. 2014). The introduced species (except the last one) were also observed by Rosa & Groth (2004) in the humid forest enclaves of Borborema. The introduction of species into humid forest enclaves in Northeastern Brazil is of particular concern in view of the high level of endemism, the scarcity of information and related anthropic impacts (e.g., removal of riparian vegetation, building of reservoirs and use of agricultural pesticides) (Rosa & Groth 2004). For example, due to the predominance of small fishes in the local assemblage, the abundance and wide distribution of *P. reticulata* may lead to the competitive exclusion of native species, especially poeciliids (Rosa & Groth 2004), as *Poecilia* sp., observed in the Timonha river basin.

Table 2. List of fish species in the tablelands of Ibiapaba and Araripe, Conservation Units (CU: 1,2,3 in Figure 1) and Status (endemic, native or introduced) for the Caatinga. The taxonomic positions are consistent with Reis et al. (2003). Endemic, native and introduced species were defined according to Rosa et al. (2003), Reis et al. (2003) and Ramos et al. (2014).

Taxon	Ibiapaba			Araripe		CU	Status Caatinga
	Parnaíba (MPI)	Coreaú (MNC)	Timonha (MNC)	Jaguaribe (MNC)	São Francisco (SFR)		
CHARACIFORMES							
Parodontidae							
Apareiodon hasemani[1] Eigenmann, 1916					X(E)		Endemic
Curimatidae							
Curimatella lepidura[2] (Eigenmann & Eigenmann, 1889)					X		Endemic
Steindachnerina elegans[3] (Steindachner, 1875)					X		Native
Steindachnerina notonota[4] (Miranda Ribeiro, 1937)	X	X	X	X		1,3	Endemic
Prochilodontidae							
Prochilodus brevis[5] Steindachner, 1875					X		Endemic
Prochilodus lacustris[6] Steindachner, 1907	X(E)						Endemic
Anostomidae							
Leporinus piau[7] Fowler, 1941	X						Endemic
Crenuchidae							
Characidium bimaculatum[8] Fowler, 1941	X	X	X	X	X	1,2,3	Endemic
Characidae							
Astyanax aff. *bimaculatus*[9] (Linnaeus, 1758)	X	X	X	X		1,2,3	Native
Astyanax aff. *fasciatus*[10] (Cuvier, 1819)	X	X	X	X		1,3	Native
Astyanax lacustris[11] (Lütken, 1875)					X		Native
Astyanax rivularis[12] (Lütken, 1875)					X		Native
Compsura heterura[13] Eigenmann, 1915	X						Endemic
Creagrutus sp.[14]	X						Native
Hemigrammus marginatus[15] Ellis, 1911	X						Native
Hemigrammus rodwayi[16] Durbin,1909	X						Native
Knodus victoriae[17] (Steindachner, 1907)	X(E)						Endemic
Moenkhausia costae[18] (Steindachner, 1907)					X		Endemic
Orthospinus franciscensis[19] (Eigenmann, 1914)					X(E)		Endemic
Phenacogaster calverti[20] (Fowler, 1941)	X	X					Endemic
Psellogrammus kennedyi[21] (Eigenmann, 1903)					X		Native
Serrapinnus heterodon[22] (Eigenmann, 1915)	X		X	X	X	1,3	Native
Serrapinnus piaba[23] (Lütken, 1875)	X	X	X			3	Native
Tetragonopterus chalceus[24] Spix & Agassiz, 1829					X		Native
Serrasalmidae							
Pygocentrus nattereri[25] Kner, 1858	X						Native
Erythrinidae							
Hoplerythrinus unitaeniatus[26] (Spix & Agassiz, 1829)	X						
Hoplias malabaricus[27] (Bloch, 1794)	X	X		X	X	1,2	Native
Triportheidae							Native
Triportheus guentheri[28] (Garman, 1890)					X(E)		Endemic
SILURIFORMES							
Callichthyidae							
Aspidoras menezesi[29] Nijssen & Isbrücker, 1976				X(E)		1	Endemic
Aspidoras raimundi[30] (Steindachner, 1907)	X(E)						Endemic
Aspidoras rochai[31] Ihering, 1907					X		Endemic
Aspidoras sp.[32]					X		Native
Aspidoras spilotus[33] Nijssen & Isbrücker, 1976		X(E)				2	Endemic
Corydoras garbei[34] Ihering, 1911					X(E)		Endemic
Loricariidae							
Hypostomus carvalhoi[35] (Miranda Ribeiro, 1937)				X(E)		1	Endemic
Hypostomus jaguribensis[36] (Fowler, 1915)				X(E)		1	Endemic
Hypostomus johnii[37] (Steindachner, 1877)	X(E)						Endemic
Hypostomus pusarum[38] (Starks, 1913)					X		Endemic
Hypostomus sp.[39]	X						Native

(E) Endemic species of the each ecoregions Maranhão-Piauí (MPI), Mid-Northeastern Caatinga (MNC) and São Francisco (SFR). (I) Introduced species. (FR) First report for the ecoregion. The number of each species represented the order in Appendix.

Table 2. Continued...

Taxon	**Ibiapaba**			**Araripe**		**CU**	**Status Caatinga**
	Parnaíba (MPI)	**Coreaú (MNC)**	**Timonha (MNC)**	**Jaguaribe (MNC)**	**São Francisco (SFR)**		
Parotocinclus cearensis^{40} Garavello, 1977	X	X		X		1,2	Endemic
Parotocinclus haroldoi^{41} Garavello, 1988			X$^{(FR)}$			3	Endemic
Parotocinclus jumbo^{42} Britski & Garavello, 2002				X$^{(E)}$		1	Endemic
Parotocinclus sp.^{43}				X		1	Native
Heptapteridae							
Pimelodella parnahybae^{44} Fowler, 1941	X$^{(E)}$						Endemic
Rhamdia quelen^{45} (Quoy & Gaimard, 1824)				X	X	1	Native
Auchenipteridae							
Trachelyopterus galeatus^{46} (Linnaeus, 1766)				X		1	Native
Trachycorystes cf. *cratensis*^{47} (Miranda Ribeiro, 1937)				X$^{(E)}$		1	Endemic
CYPRINODONTIFORMES							
Poeciliidae							
Poecilia reticulata^{48} Peters, 1859	X$^{(I)}$	X$^{(I)}$		X$^{(I)}$	X$^{(I)}$	1,2	Introduced
Poecilia vivipara^{49} Bloch & Schneider, 1801	X	X			X	2	Native
Poecilia sp.^{50}			X			3	Native
Xiphophorus helleri^{51} Heckel, 1848				X$^{(I)}$		1	Introduced
SYNBRANCHIFORMES							
Synbranchidae							
Synbranchus marmoratus^{52} Bloch, 1795		X	X			2,3	Native
PERCIFORMES							
Cichlidae							
Cichla sp.^{53} Agassiz, 1831		X$^{(I)}$					Introduced
Cichlasoma orientale^{54} Kullander, 1983		X	X	X		1,2,3	Endemic
Cichlasoma sanctifranciscense^{55} Kullander, 1983	X						Endemic
Crenicichla menezesi^{56} Ploeg, 1991	X	X	X			3	Native
Geophagus brasiliensis^{57} (Quoy & Gaimard, 1824)				X	X	1	Native
Oreochromis niloticus^{58} (Linnaeus, 1758)		X$^{(I)}$		X$^{(I)}$	X$^{(I)}$	1	Introduced
Coptodon rendalli^{59} (Boulenger, 1897)					X$^{(I)}$		Introduced
Total endemic species	5	1	0	5	4	11	29
Total exotic species	1	3	0	3	3	3	5
Total species	26	16	11	20	25	27	59

$^{(E)}$ Endemic species of the each ecoregions Maranhão-Piauí (MPI), Mid-Northeastern Caatinga (MNC) and São Francisco (SFR). $^{(I)}$ Introduced species. $^{(FR)}$ First report for the ecoregion. The number of each species represented the order in Appendix.

2. Expansion of distribution

In this study, *Parotocinclus haroldoi* is for the first time reported for the Mid-Northeastern Caatinga ecoregion based on individuals captured in Passagem, a stream in the Timonha river basin (Granja, Ceará State). A small detritivorous catfish, *P. haroldoi* lives in small groups, with a preference for shallow streams with clear or slightly turbid water and a substratum of rocks, twigs, sand and mud. The present report expands the distribution of the species, previously considered endemic to the Maranhão-Piauí ecoregion (Ramos et al. 2014), although the river mouth of the Timonha basin is close to the small coastal basins of the Maranhão-Piauí ecoregion (Figure 1). The occurrence of the species in this stream may be explained by the geomorphological slope northwest of Ibiapaba, which may have formed as a result of headwater capture during intense neotectonic activity in the region (Claudino-Sales & Lira 2011) or during periods of marine regression in the Pleistocene when the basins were connected. The new occurrence of Poeciliidae (*Poecilia* sp.) was registered in the only basin (Timonha) where the exotic species *P. reticulata* was not observed. Despite the limited sampling in this basin (a single point), 11 species were registered, three (27.2%) of which endemic to the Caatinga (Table 2).

3. Conservation perspectives

Approximately 38% (n=17) of the sampling points were located inside conservation units (Table 1). These points accounted for 45.7% (n=27) of the captured species. Eleven of these species (37.9%) were considered endemic to the Caatinga (Table 3). Chapada do Araripe EPA harbored the greatest number of species (n=20), corresponding to 51.5% of all non-introduced species registered in Araripe, nine (45.0%) of which were endemic to the Caatinga. The two CUs in Ibiapaba accounted for 16 species (48.4% of all non-introduced species registered in Ibiapaba), six (11.1%) of which were endemic to the Caatinga. More specifically, the Serra da Ibiapaba EPA yielded 11 species, of which four were endemic and seven were native (none were introduced), whereas the Ubajara NP yielded nine species, of which four were endemic, four were native and one was introduced (Table 3).

Interestingly, seven of the endemic (Caatinga) species captured in the three conservation units were observed in one unit only (in Chapada do Araripe EPA = *Aspidoras menezesi*, *Hypostomus carvalhoi*, *Hypostomus jaguaribensis*, *Parotocinclus jumbo* and *Trachycorystes* cf. *cratensis*; in Ubajara NP = *Aspidoras spilotus*; in Serra da Ibiapaba EPA = *Parotocinclus haroldoi*), while only two species occurred in all three units: *Characidium*

Table 3 . Total number of endemic, native and introduced species of the Caatinga sampled in the tablelands of Araripe and Ibiapaba and in the three conservation units (CU) (1=Chapada do Araripe EPA; 2=Ubajara NP; 3=Serra da Ibiapaba EPA), with an indication of the number of units in which each was observed.

	Total	CU 1	CU 2	CU 3	In 1 CU	In 2 CUs	In 3 CUs	CUs [% total]
Endemic	29	9	4	4	7	2	2	11 [37.9%]
Native	25	8	4	7	8	4	1	13 [52.0%]
Introduced	5	3	1	0	2	1	0	3 [60.0%]

bimaculatum and *Cichlasoma orientale* (Table 3). In general, the conservation units in the study area protected a relatively small proportion of the total number of species, and even fewer endemic species, whereas more than 60% of the introduced species were observed at sampling points inside the units (Table 3). The low representativeness of native and endemic species inside these units may be explained by inadequate CU design: most of the headwaters streams which flow through the units are located in urbanized areas where they are exposed to adverse environmental impacts (removal of riparian vegetation, contamination with agricultural pesticides and fertilizers, etc.) and possibly the introduction of non-native species (Blackburn et al. 2015).

The highland forest enclaves of Northeastern Brazil not only represent important remnants of rain forest (Tabarelli et al. 2005, Santos et al. 2007), but boast a highly endemic fauna and flora. The enclaves in Borborema (Pernambuco and Paraíba) have been comprehensively surveyed, revealing high levels of endemism for bromeliads (33% in a single enclave), birds (13%) and mammals (7%) (Siqueira-Filho 2004, Souza et al. 2004). Some of these species have a limited geographical distribution and are endemic to the Caatinga, making them more vulnerable to extinction, especially when populations are small (Gaston et al. 1998). The swift and relentless degradation of the Caatinga and the processes of desertification and climate change which threaten the local biodiversity highlight the need for greater efforts at protecting both terrestrial and aquatic ecosystems (Maltchik & Medeiros 2012).

The present study provides new information on the fish assemblages of humid highland forest enclaves in two tablelands (Araripe and Ibiapaba) in semiarid Northeastern Brazil which serve as drainage divides between the ecoregions Maranhão-Piauí (Parnaíba river basin), Mid-Northeastern Caatinga (Timonha, Coreaú and Jaguaribe river basins) and São Francisco. Nearly half the sampled species (29/59) were considered endemic to the Caatinga, and five were introduced. Only 11 of the species endemic to the Caatinga were captured in conservation units, but it should be kept in mind that the study was not specifically designed to evaluate the diversity of these units (with the exception of Ubajara NP). Most sampling points inside the units were located in basins of the Mid-Northeastern Caatinga ecoregion (n=16; 94.1%). Thus, further studies are necessary to determine the ability of these units to protect the fish fauna of the Caatinga, especially in the São Francisco and Parnaíba river basins.

In addition, the distribution of *P. haroldoi* was expanded to include the Timonha river basin in the westernmost reaches of the Mid-Northeastern Caatinga ecoregion. The fact that all samplings were carried out in the rainy season leaves unanswered questions about the impact of drought periods on the dynamics of the fish fauna in these ecosystems. According to Rosa & Groth (2004), humid highland forest enclaves serve as permanent refuges. Future research may shed light on the role of these ecosystems in the maintenance of the local and regional fish fauna.

The diversity of endemic species and the singularity of these highland enclaves justify the creation of new conservation units (or the expansion of existing ones) in order to include important areas of aquatic ecosystems, such as riverheads, thereby reducing upstream anthropic impacts.

The present study provides new taxonomic information to subsidize future investigations into such fields as biogeography, ecology, conservation, bioinvasion and macroecology, and evidences the need for greater efforts to protect the highly endemic fish fauna of the highland forest enclaves of Northeastern Brazil.

Appendix

List of vouchers of the Universidade Federal do Rio Grande do Norte (UFRN) and the Universidade Federal da Paraíba (UFPB). The numbers refer to the numbering of each species in Table 2.

[1](UFPB 7154), [2](UFPB 7108), [3](UFPB 7146, UFPB 7160), [4](UFRN 357, UFRN 1884, UFRN 1593), [5](UFPB 7150), [6](UFPB 9258), [7](UFPB 9259), [8](UFPB 9256, UFRN 1320, UFRN 1512, UFRN 1675), [9](UFPB 7103, UFPB 9254, UFRN 358, UFRN 1195), [10](UFRN 1879, UFPB 7102, UFRN 1193), [11](UFPB 7103), [12](UFPB 7102, UFPB 7156), [13](UFPB 10612), [14](UFPB 10610), [15](UFPB 10616), [16](UFPB 10611), [17](UFPB 10615), [18](UFPB 7101), [19](UFPB 6751), [20](UFRN 2511), [21](UFPB 7111), [22](UFPB 7110, UFRN 1677, UFRN 1883), [23](UFRN 2677), [24](UFPB 6750), [25](UFPB 9269), [26](UFPB 10614), [27](UFPB 6754, UFPB 7100, UFPB 7117, UFPB 9275, UFRN 348, UFRN 604, UFRN 1261, UFRN 1325, UFRN 2684), [28](UFPB 6760), [29](UFPB 9427, UFRN 1521, UFRN 1580), [30](UFPB 9415), [31](UFRN 1879), [32](UFPB 7140), [33](UFRN 1466), [34](UFRN 2685), [35](UFRN 1810), [36](UFRN 352, UFRN 359, UFRN 1506), [37](UFPB 9267), [38](UFPB 7115), [39](UFPB 9265), [40](UFPB 9248, UFRN 1505), [41](UFRN 1294), [42](UFRN 350), [43](UFRN 1250), [44](UFPB 9279), [45](UFRN 1201), [46](UFPB 9286), [47](UFRN 356), [48](UFPB 6755, UFRN 1476), [49](UFPB 9252), [50](UFRN 1468), [51](UFRN 1259), [52](UFPB 9280), [53](UFPB 9263), [54](UFPB 9249, UFRN 361), [55](UFPB 9260), [56](UFRN 943, UFPB 9278), [57](UFPB 7099, UFRN 589), [58](UFPB 7116, UFRN 355), [59](UFRN 2512).

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Article

Melosira (Diatomeae) taxa from the Iguaçu River in southern Brazil

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Abstract: The study of the genus *Melosira* in plankton samples from the lower Iguaçu River revealed the presence of four taxa: *Melosira undulata* (Ehrenberg) Kützing var. *undulata*, *M. undulata* var. *normanni* Arnott, *M. varians* C. Agardh and *M. muscigena* Iwahashi. We present illustrations of the frustules using light microscopy (LM), descriptions, and comments about the morphology of the four taxa. The analysis of *Melosira muscigena* under scanning electron microscopy revealed unprecedented details of the ultrastructure, such as the shape and distribution of the rimoportulae at the valve mantle. This is the first record of *Melosira undulata* var. *undulata* and the second of *M. muscigena* in Brazil.

Keywords: *diatoms, southern Brazil, taxonomy, ultrastructure.*

Táxons de *Melosira* (Diatomeae) para o rio Iguaçu, sul do Brasil

Resumo: O estudo do gênero *Melosira* em amostras de plâncton do baixo rio Iguaçu revelou a presença de quatro táxons: *Melosira undulata* (Ehrenberg) Kützing var. *undulata, M. undulata* var. *normanni* Arnott, *M. varians* C. Agardh e *M muscigena* Iwahashi. Apresentam-se ilustrações das frústulas usando microscopia óptica (MO), descrições e comentários sobre a morfologia dos quatro táxons. A análise de *Melosira muscigena* sob microscopia eletrônica de varredura revelou detalhes sem precedentes da ultraestrutura, como a forma e distribuição das rimopórtulas no manto da valva. Este é o primeiro registro de *Melosira undulata* var. *undulata* e o segundo de *M. muscigena* para o Brasil.

Palavras-chave: *diatomáceas, sul do Brasil, taxonomia, ultraestrutura.*

Introduction

Diatoms from the genus *Melosira* C. Agardh are characterized by cylindrical to subspherical frustule, usually united at the valve faces by mucilage pads and small irregular spines (Crawford 1975) in pairs or chains of three cells (Van Heurck 1896). The valve face can be flat or convex and may be bordered by a corona, with granules more or less developed, and a carina (collar-like structure) (Crawford 1975). The areolae are loculated with loculi open to the outside through small pores. The cingulum presents ligulate bands perforated by longitudinal rows of small pores (Round et al. 1990). Rimoportulae usually occur near the edge, scattered or grouped at the valve mantle (Round et al. 1990).

Previously, the genus *Melosira* included most of the centric diatoms that grew in chains with cells strongly connected by the valve face (Stoermer & Julius 2003), accommodating a wide range of taxa gradually transferred to different genera, such as: *Aulacoseira* Thwaites, *Paralia* Heiberg, *Orthoseira* Thwaites, and *Ellerbeckia* Crawford (Round et al. 1990, Houk & Klee 2007).

Melosira taxa occur in marine, brackish and freshwater benthic ecosystems (Round et al. 1990). Currently, there are at least five morphologically and ecologically heterogeneous groups within the genus: (1) **marine and brackish taxa**, this group includes the generic type, e.g., *M. nummuloides* C. Agardh and *M. arctica* Dickie, species with a very convex valve face with prominent carina and bands with fine poroids; (2) **brackish**, e.g. *M. moniliformis* (O.F. Müller) C. Agardh, with convex valve face and bands distinctively perforated by fine poroids, in partly radiating, mostly irregular short lines; (3) **freshwater to slightly brackish**, e.g., *M. varians* C. Agardh and *M. lineata* (Dillwyn) C. Agardh, with dome-shaped valve face has smaller and much more delicate valves with inconspicuous ornamentation, difficult to see in LM. ; (4) **recent fossil and freshwater**, e.g. *M. undulata* (Ehrenberg) Kützing, *M. muscigena* Iwahashi (=*M. ruttneri* Hustedt), *M. anastomosans* Grunow, with distinct areolate valve face; (5) **freshwater, epilithic, and epiphytic**, e.g., *M. dickiei* (Thwaites) Kützing, with a cingulum composed of many narrow bands, forming internal valves (Crawford 1988, Houk & Klee 2007).

Fifty-eight *Melosira* species are known (Novelo 2012), but the number of freshwater species are limited (Stoermer & Julius 2003). In Brazil, 10 taxa have been recorded: marine taxa - *M. borreri* Greville, *M. nummuloides, M. moniliformis, M. octogona* Schmidt, *M. setosa* Greville and freshwater taxa- *M. dickiei, M. lineata*, *M. muscigena* Iwahashi (=*M. ruttneri* Hustedt), *M. undulata* var. *normanni* Arnott and *M. varians* (Rosa et al. 1994, Garcia 2009, Tremarin et al. 2009, Nardelli et al. 2014). Of these, six occurred in Paraná state: *M. dickiei*, *M. lineata*, *M. nummuloides, M. varians, M. undulata* var. *normanni*, and *M. muscigena* (Tremarin et al. 2009, Nardelli et al. 2014).

Nardelli et al. (2014) have already recorded four species of *Melosira* in Iguaçu River —*M. varians, M. muscigena*, *M. undulata* var. *normanni* and *Melosira* sp.

Here, we presented a taxonomic survey of *Melosira* taxa for the Iguaçu River, showing unprecedented ultrastructural details of *Melosira muscigena* and the first citation of *M. undulata* var. *undulata* to Brazil.

Material and Methods

The Iguaçu River runs westward 1275 km from its source in the Serra do Mar to its confluence with the Paraná River (Paraná 2010). Considered a large river, part of the river is located in Iguaçu National Park, a protected area important for its great biodiversity (Paraná 2010).

Station 1 (S1) is located upstream of the falls (25º39’12,8” S and 54º25’34,0” W), where the river is wider, with variable depth from 1.4 m to 3.0 m. The station was classified as oligo-mesotrophic for the sampling period, with maximum and minimum values according the Table 1 (Nardelli et al. 2016).

Station 2 (S2) is downstream from the falls (25º38’55,4” S and 54º27’31,0” W). In this region, the river is narrower, deeper (11.7 to 27.4 m), and flows faster than at Station 1. Station 2 was classified as ultra-oligotrophic to oligotrophic for the sampling period, with maximum and minimum chemical and physical values according the Table 1 (Nardelli et al. 2016).

Table 1. Maximum and minimum chemical and physical values in Station 1 and Station 2. Water temperature (T °C); pH; Dissolved oxygen (DO mg.L^{-1}); Biochemical Oxygen Demand (BOD mg.L^{-1}); Chemical Oxygen Demand (COD mg.L^{-1}); Electrical Conductivity (Cond µS.cm^{-1}); Secchi Transparency (SD m); Turbidity (NTU); Ammonium (NH4 µg.L^{-1}); Total Nitrogen (TN µg.L^{-1}); Nitrate (NO3 µg.L^{-1}); Total phosphorus (TP µg.L^{-1}) (Nardelli et al. 2016).

Stations	**Station 1**		**Station 2**	
Parameters	**Min**	**Max**	**Min**	**Max**
Water T ºC	15.5	28.6	15.9	28.8
pH	6.1	8.7	5.9	8.3
DO mg.L^{-1}	6.4	12.2	6.6	13.1
BOD mg.L^{-1}	0.9	11.4	1.8	13.9
COD mg.L^{-1}	6.8	21.6	4.7	25.9
Cond µ S.cm^{-1}	32.8	105.0	34.0	87.0
SD m	0.9	3.6	0.7	3.6
NTU	2.0	26.1	2.8	23.2
NH$_4^+$ µg.L^{-1}	0.8	123.2	0.4	70.4
TN µg.L^{-1}	100.0	500.0	110.0	500.0
NO$_3^-$ µg.L^{-1}	100.0	2140.0	100.0	1730.0
TP µg.L^{-1}	20.0	450.0	50.0	390.0

Monthly collections were performed between September 2010 and September 2011, from the subsurface water of the river with a phytoplankton net. Samples were cleaned according to the Simonsen (1974) method modified by Moreira-Filho & Valente-Moreira (1981). Permanent slides were mounted with Naphrax® (RI = 1.73) and analyzed with an Olympus® BX60 microscope. Images were obtained with an Olympus DP71 digital camera. The slides are deposited in the herbarium of the *Universidade Estadual do Oeste do Paraná* (UNOP-Algae, Western Paraná State University), Cascavel campus (Table 2).

Part of the oxidized material was placed on aluminum stubs and sputter-coated with gold in a Balzers SCD 030 at 1 kV for 5 min. Scanning electron microscopy (SEM) analysis was performed in a JEOL JSM 6360LV microscope operating at 15 kV and 8 mm working distance. The terminology used in the species descriptions follows Round et al. (1990) and Houk & Klee (2007).

Results and Discussion

Coscinodiscophyceae Round & Crawford in Round et al. 1990

Melosirales Crawford 1990 in Round et al. 1990

Melosiraceae Kützing 1844

Melosira C. Agardh 1824

Melosira muscigena Iwahashi. Journal of Japanese Botany, 12(2): 121-127, p.121, fig.17. 1936.

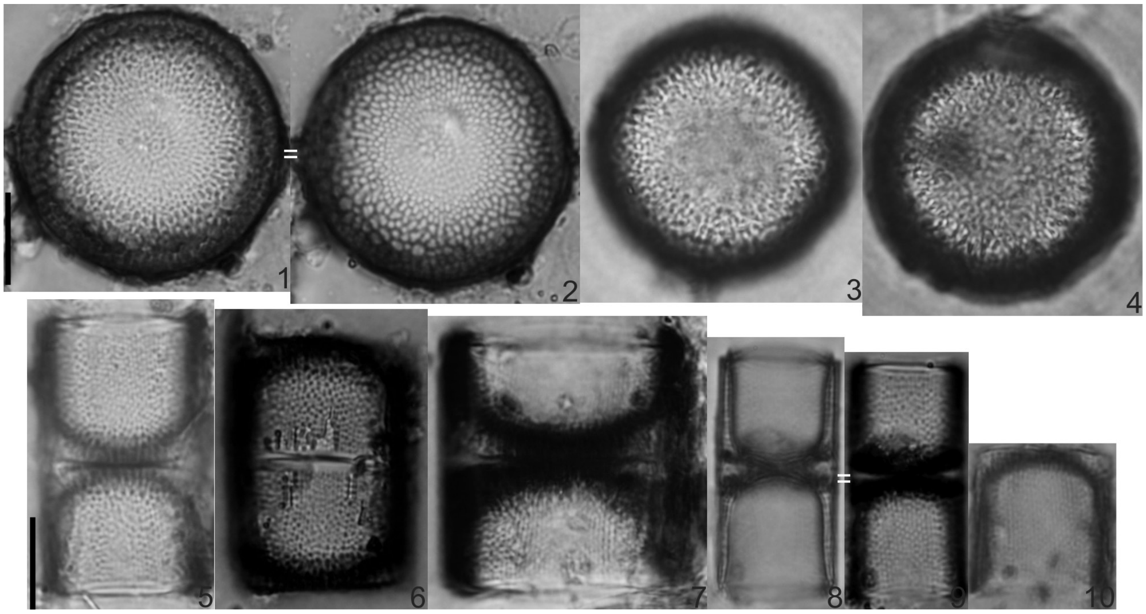
Synonym*: Melosira ruttneri* Hustedt. Archiv für Hydrobiologie 15: 140-141, pl. 9, fig. 11-16. 1937.

LM observations. Cylindrical frustules, with thick wall of uneven structure forming two layers, the external view cylindrical and the internal view more or less elliptical. Valve mantle formed with a reticulated pattern in polygonal chambers, decreasing toward collar. Circular valve view, reticulated striation pattern, composed of polygonal areolae decreasing in diameter toward the center, changing to radial rows of small pattern, scored lengthwise, hyaline central area. Cells solitary or joined by the valve face, forming pairs or short chains of three cells. Mantle height: 14.3–15.5 µm; diameter: 15.7–27.9 µm; 19–21 striae in 10 µm (Figures 1-10).

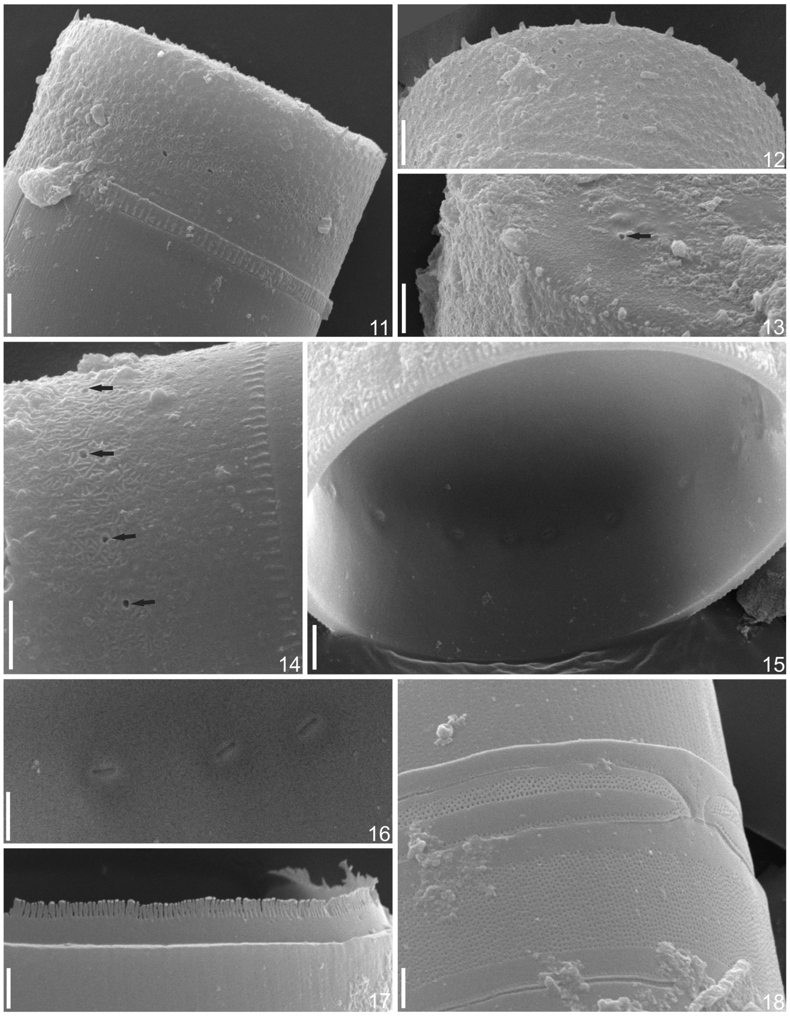
SEM observations. Flat valve face with short marginal spines. Rimoportulae scattered on the valve face and disposed in a ring around the mantle, not equidistant from each other. Rimoportula with external openings rounded or elongated, 0.5 µm in diameter, and internally sessile. Collar with short pervalvar wrinkles at the valve margin, and often oblique. Connective bands open, ornamented by delicate striae, 9-10 per 1 µm, composed by rounded pores, 10-11 per 1 µm. Prominent ligule and rounded antiligule. Fimbriate valvocopula and pleura thinner than the other bands (Figures 11-18).

Table 2. Herbarium data from plankton sampled in Station 1 (S1) and Station 2 (S2).

Collection date	**S1 UNOP-Algae**	**S2 UNOP-Algae**	**Collector(s)**
September 2010	3161	3156	M.S. Nardelli *n.*11, 12, N.C. Bueno *s.n.*
October 2010	3225	3213	M.S. Nardelli *n.*14, 18, N.C. Bueno *s.n.*
December 2010	3342	3338	M.S. Nardelli *n.* 21, 25, N.C.Bueno *s.n.*
January 2011	3412	3408	M.S. Nardelli *n.* 31, 35, N.C. Bueno *s.n.*
February 2011	3471	3467	M.S. Nardelli *n.* 38, 42, N.C. Bueno *s.n.*
March 2011	3536	3530	M.S. Nardelli *n.* 45, 51, N.C. Bueno *s.n.*
April 2011	3606	3601	M.S. Nardelli *n.* 55, 60, N.C. Bueno *s.n.*
May 2011	3680	3670	M.S. Nardelli *n.* 68, 74, N.C. Bueno *s.n.*
June 2011	3714	3709	M.S. Nardelli *n.* 80, 85, N.C. Bueno *s.n.*
July 2011	3758	3753	M.S. Nardelli *n.* 92, 97, N.C. Bueno *s.n.*
August 2011	3775	3770	M.S. Nardelli *n.*101, 106, N.C. Bueno *s.n.*
September 2011	3784	3779	M.S. Nardelli *n.*110, 115, N.C. Bueno *s.n.*



Figures 1–10. *Melosira muscigena*, LM. Figures 1–4. Valve view. Figures 5–10. Girdle view. Scales: 10 µm.



Figures 11–18. *Melosira muscigena*, SEM. Figure 11. Girdle view. Figure 12. Marginal spines located in the valve face/mantle junction. Figure 13. External rimoportula opening in the valve face (arrow). Figure 14. External rimoportula openings in the mantle (arrows). Figure 15. Internal rimoportula openings in the mantle. Figure 16. Detail of internal rimoportula openings. Figure 17. Fimbriate valvocopula. Figure 18. Detail of ligulate pleura and cingulum bands perforated by porous. Scales: 2 µm (Figs 11–15), 1 µm (Figs 16–18).

Comments. This is the first ultrastructure documentation of a brazilian population of *Melosira muscigena*. Analysis via SEM revealed unprecedented details of the ultrastructure, such as the shape and distribution of the rimoportulae at the valve mantle. The species was recorded by Koide (1987), as *M. ruttneri*, by Houk & Klee (2007) and Nardelli et al. (2014). Koide (1987) compared individuals identified as *M. ruttneri* from Japan (pl. 1, figures 1–7; diameter: 7–33 µm; mantle height: 5–25 µm) with the type material illustrations present by Iwahashi (1936) of *M. muscigena* (diameter: 16–33 µm; mantle height: 12–20 µm) and verified that it was the same taxon. The only difference found in the Hustedt (1937) and Iwahashi (1936) descriptions was regarding the presence or absence of thin spines on the rim of the valve face. The first describes the spines as not being well distinguished, and the latter makes no mention of them. As the *M. muscigena* name is older, it has priority over *M. ruttneri*.

We suggested the investigation of *Melosira muscigena* and *Melosira ruttneri* type materials since they were originally described based on optically limited characteristics. Also the original illustrations are uninformative. The two taxa are ambiguous, showing many similarities in their morphology. The frustule ultrastructure would properly ascertain other morphologically diagnostic features between the species.

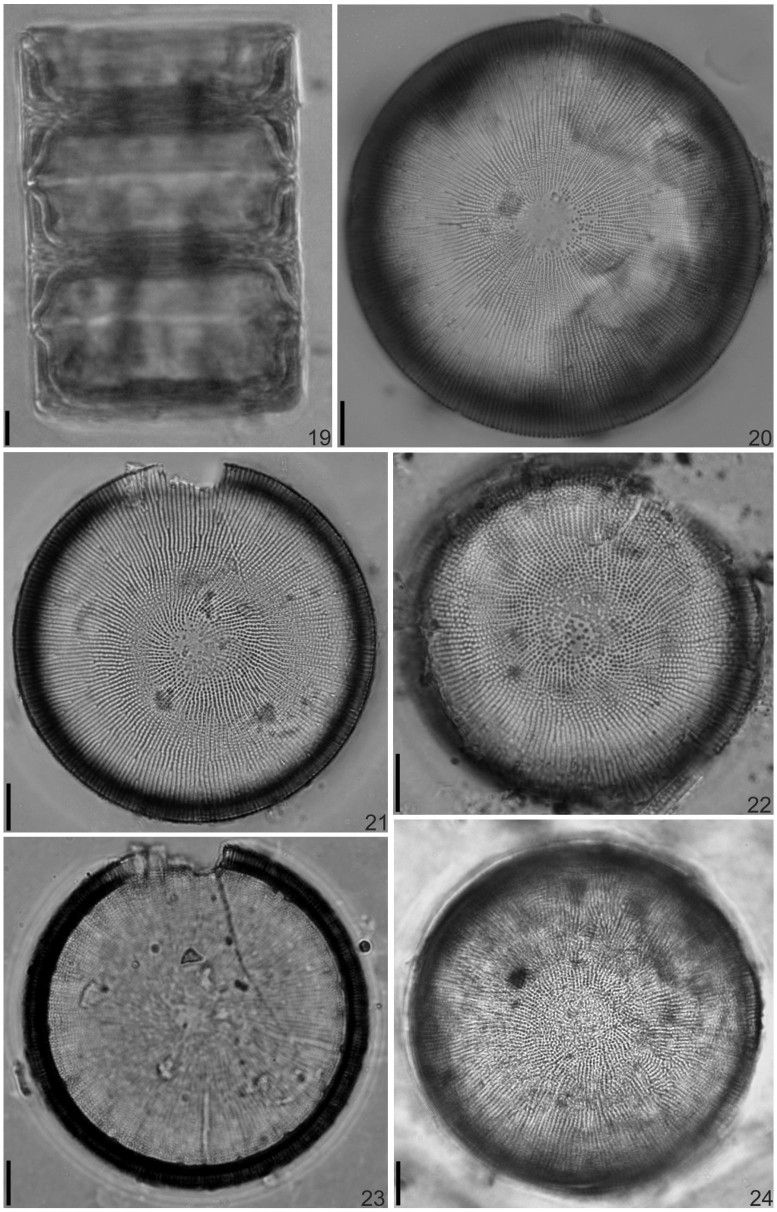
Melosira muscigena is morphologically similar to *M. anastomosans* Grunow in the reticulate pattern of the valve face but differs in the mantle outline, which is rounded and more similar to *M. undulata* (Houk & Klee 2007).

Houk & Klee (2007) describe *M. ruttneri* as rare in waterfalls, springs, and streams. It is frequently found in moss, and also a good indicator of alkaline waters (Koide 1987). However, in the present study, the species was found in the Iguaçu River, a place of flow and large water falls.

Occurrence in samples: (UNOP-Algae, Herbarium accession numbers) 3213, 3606, 3709, 3753, 3758, 3770, 3784.

Melosira undulata (Ehrenberg) Kützing **var**. ***undulata***. Bacillarien, p.54, 1844.

LM observations. Cylindrical frustules (Figure 19), usually solitary or united in pairs or short chains, valves wider than higher, internally



Figures 19–20. *Melosira undulata* var. *undulata*, LM. Figure 19. Frustules in girdle view showing undulate inner mantle surface. Figure 20. Valve view. **Figures 21–24**. Valve view of *Melosira undulata* var. *normanii*, LM. Figure 23. Note the position of rimoportulae in the internal valve margin. Scales: 10 µm.

constricted at the mantle midregion. Internal margin the of valve face with polygonal circumference and areolae disposed in radial rows which do not reach the valve center, forming a small hyaline central area (Figure 20). Mantle height: 21.5–32.0 µm; diameter: 93.5–94.0 µm; 10–11 striae in 10 µm on the valve face; 17–18 areolae in 10 µm on the valve face; 10 internal projections on the wall.

Comments. Krammer & Lange-Bertalot (1991) describe *M. undulata* var. *undulata* as presenting a rounded valve, with internal margin the of valve face with polygonal circumference different from the internal rounded shape of *M. undulata* var. *normanii* Arnott. Ferguson Wood et al. (1959) described individuals with polygonal morphology with six to twelve internal projections, however they did not illustrate specimens with these characteristics. Such internal projections are consistent with the sessile rimoportulae present in the valve mantle. Rimoportulae may also be found in the central region of the valve mantle (Bahls 2012).

The population here studied exhibit greater diameter than the one recorded by Houk (2003), 16–80 µm, and Bahls (2012), 30–81 µm. However, the other features of the taxon are coincident.

Melosira undulata var. *undulata* is an epilithic species occurring in circumneutral, oligohalobous (Foged 1976), and oligotrophic (Carter et al. 2006) environments. The species is frequently found in small arctic lakes and lagoons and with freshwater diatomites (Hustedt 1937, Mahood et al. 1984, McIntire et al. 1994, Stoermer & Julius 2003). It has also been detected in sediments, as well as in the plankton of tropical areas (Manguin 1949, Sovereign 1958, Ferguson Wood et al. 1959, Germain 1981, Huang, 1982, Krammer & Lange-Bertalot 1991, Li et al. 2010). In addition to those, Takano (1967) found *M. undulata* var. *undulata* in brackish water in Abashiri, Japan. This is the first record of *M. undulata* var. *undulata* in Brazilian rivers.

Occurrence in samples: (UNOP-Algae, Herbarium accession numbers) 3156.

Melosira undulata* var. *normanii Arnott. *In* Van Heurck, Synopsis, p. 90, f. 7. 1882.

LM observations. Cylindrical frustules, united in pairs or short chains. Rounded valve face with rounded internal wall, ornamented with areolate striae in radial rows, sometimes ramified and with a spiral arrangement in the central region. Diameter: 42.3–89.4 µm; 10–11 striae in 10 µm on the valve face; 12–14 areolae in 10 µm on the valve face (Figures 21-24).

Comments. *Melosira undulata* var. *normanii* differs from the typical variety by the spiral arrangement of central striae on the valve face as also the different internal margin the valve face described above (Krammer & Lange-Bertalot 1991, Brassac et al. 1999). Our study also found a smaller number of areolae (12–14 in 10 µm) in the var. *normanii* compared to the typical variety (17–18 in 10 µm).

Krammer & Lange-Bertalot (1991) comment that the species is taxonomically closer to the genus *Orthoseira* Thwaites due the structure of valve surface, requiring a more detailed taxonomic study. However, Garcia (2009) did a taxonomic comparison of *Melosira undulata* var. *normanii* with the genera *Orthoseira*, *Paralia* Heiberg, *Ellerbeckia* Crawford, *Podosira* Ehrenberg, and *Hyalodiscus* Ehrenberg and concluded that the species features are in accordance with the genus *Melosira*.

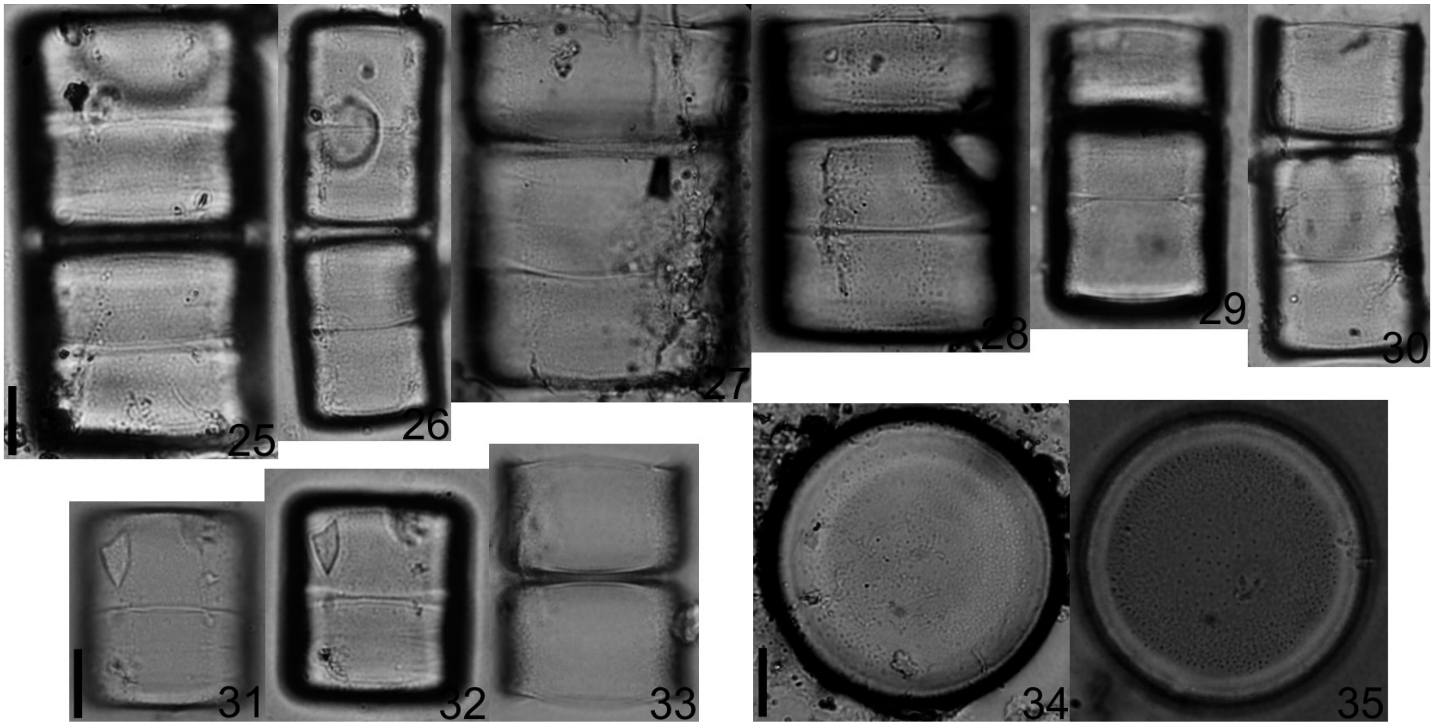
Records of *Melosira undulata* var. *normanii* from Brazil: in Rio Grande do Sul State, plankton from a brackish lagoon (Rosa et al. 1994), sand from Guaíba river, and plankton from Emboaba lagoon (Garcia 2009); in Paraná State, plankton from Iguaçu river (Brassac et al. 1999, Nardelli et al. 2014); and in Pernambuco State, estuarine plankton from Barra da Jangada (Branco 2007).

Occurrence in samples: (UNOP-Algae, Herbarium accession numbers) 3156, 3408, 3471, 3601, 3770.

Melosira varians C. Agardh. Flora oder Botanische Zeitung, 10:628. 1827.

LM observations. Cylindrical frustules forming straight chains connected to the valve face through small marginal spines (Figures 25-33). Circular valve face ornamented by delicate and inconspicuous areolae (Figures 34 and 35). Mantle height: 24.6–40.0 µm; diameter: 18.9–50.7 µm.

Comments. *Melosira varians* occurs mainly in alkaline conditions (pH 7–8.5), in oligotrophic to heterotrophic environments, with moderate



Figures 25–35. *Melosira varians*, LM. Figures 25–33. Girdle view. Figures 34–35. Valve view. Scales: 10 µm.

oxygen, and requires periodically high levels of nitrogen. Occurs mainly in water bodies, but it is also regularly found in humid environments (Soltanpour-Gargari et al. 2011).

Melosira varians is a very common species in freshwater, occurring in considerable abundance in streams and lakes, naturally eutrophic to polluted, throughout North America (Stoermer & Julius 2003). It is also very common in Brazilian waters, with more than 30 records from the Paraná (Tremarin et al. 2009) as opposed to *M. undulata* and *M. muscigena* Iwahashi, which have few taxonomic records around the world.

Occurrence in samples: (UNOP-Algae, Herbarium accession numbers) 3156, 3161, 3213, 3225, 3338, 3342, 3408, 3412, 3467, 3471, 3530, 3536, 3601, 3606, 3670, 3680, 3709, 3714, 3753, 3758, 3770, 3775, 3779, 3784.

Conclusion

This is an important study about the knowledge of *Melosira* diversity in Brazil and taxonomy of the genus as a whole. *Melosira undulata* var. *normanii* and *M. mucigena* are taxa with restricted distribution, which have few taxonomic records around the world. We did not find enough individuals in the samples to analyze in electron microscopy the taxon *M. undulata* var. *normanni* as also the typical variety, for highlighting the differences between both. There is a need for new studies under scanning electron microscopy, with a larger number of individuals, in order to discuss details of the ultrastructure.

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