Biota Neotropica 14(2): e20130010, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Epiphytic angiosperms in a mountain forest in southern Bahia, Brazil

Paula Leitman[1,5]*, André Amorim*[2,3]*, Luiz Menini Neto*[4] *& Rafaela C. Forzza*[1]

[1] *Jardim Botânico do Rio de Janeiro, Rua Pacheco Leão 915, Jardim Botânico, Rio de Janeiro, RJ, Brazil, CEP: 22460-030*

[2] *Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Salobrinho, Ilhéus, BA, Brazil, CEP: 45662900*

[3] *Centro de Pesquisas do Cacau - Herbário CEPEC, Caixa Postal 07, Itabuna, Bahia, Brazil, CEP: 45660970*

[4] *Centro de Ensino Superior de Juiz de Fora, Campus Arnaldo Janssen - Rua Luz Interior 345, Santa Luzia, Juiz de Fora, MG, Brazil, CEP: 36030-776*

[5] *Corresponding author: Paula Leitman, e-mail: paulaleitman@gmail.com*

LEITMAN, P., AMORIM, A., MENINI NETO, L., FORZZA, R.C. **Epiphytic angiosperms in a mountain forest in southern Bahia, Brazil.** Biota Neotropica. 14(2): e20130010. http://dx.doi.org/10.1590/S1676-06032014001013

Abstract: The Atlantic Forest in southern Bahia State, Brazil, has high levels of diversity and vascular plant endemism. There have been few floristic surveys of the mountain forests there, however, especially those focusing on herbs and canopy plants, with studies of Atlantic Forest epiphytes having been limited to the southern and southeastern region of that country. The present study therefore surveyed the epiphytic angiosperms in the Serra das Lontras National Park (SLNP), the distribution of their species among genera and families, and their biogeographical patterns. Fieldwork was performed between February 2011 and March 2012. Collections were made along roads and trails and phorophytes were occasionally climbed and fallen trees and branches examined in order to sample canopy species. The study site demonstrated high epiphyte richness (256 spp.), one of the highest recorded in the Atlantic Forest. The richest families are Orchidaceae, Bromeliaceae, and Araceae, reaffirming the patterns reported in previous major reviews on epiphytes. The species exhibit high degrees of endemism (45%) to the Atlantic Forest, especially among the Bromeliaceae and Orchidaceae. One new occurrence to Brazil, four to the Atlantic Forest and 30 to Bahia state are registered. The SLNP shares more species with areas of southern and southeastern Brazil than with other northeastern states.

Keywords: *Atlantic forest, Araceae, Bromeliaceae, Orchidaceae, biogeographical patterns.*

LEITMAN, P., AMORIM, A., MENINI NETO, L., FORZZA, R.C. **Angiospermas epífitas de uma floresta montana no sul da Bahia, Brasil.** Biota Neotropica. 14(2): e20130010. http://dx.doi.org/10.1590/S1676-06032014001013

Resumo: A Floresta Atlântica do sul da Bahia apresenta elevados níveis de diversidade e endemismo de plantas vasculares. No entanto, poucos levantamentos florísticos foram realizados em áreas de floresta montana, especialmente para ervas e plantas de dossel. Estudos com epífitas estão concentrados principalmente em áreas do Sul e Sudeste do Brasil. Desta forma, o presente estudo realizou o levantamento das angiospermas epífitas do Parque Nacional da Serra das Lontras (PNSL) e verificou a distribuição das espécies pelas famílias e gêneros e seus padrões biogeográficos. As coletas foram realizadas entre fevereiro de 2011 e março de 2012 nas trilhas e estradas de acesso. Alguns forófitos foram escalados e árvores e ramos caídos foram examinados com o intuito de coletar espécies restritas ao dossel. A área de estudo apresentou alta diversidade de epífitas (256 spp.), uma das maiores já registradas para a Floresta Atlântica. As famílias com maior riqueza são Orchidaceae, Bromeliaceae e Araceae, reafirmando os padrões encontrados anteriormente em revisões do tema. As espécies apresentam alto grau de endemismo (45%) à Floresta Atlântica, especialmente em Bromeliaceae e Orchidaceae. São registradas uma nova ocorrência para o Brasil, quatro para a Floresta Atlântica e 30 para a Bahia. O PNSL possui mais espécies em comum com o Sul e o Sudeste do que com a região Nordeste.

Palavras-chave: *Floresta Atlântica, Araceae, Bromeliaceae, Orchidaceae, padrões biogeográficos.*

Introduction

Epiphytes spend most or all of their life cycles growing on other plants (phorophytes), taking advantage of their mechanical support (Benzing 1990). Epiphytes account for approximately 10% of world's vascular flora and are found in 84 angiosperm families (Gentry & Dodson 1987, Kersten 2010). Araceae, Bromeliaceae, and Orchidaceae are the most successful epiphytic angiosperm families, and the latter is responsible for over 70% of total richness.

Bromeliaceae is a typically American family, while the largest genera of Araceae and Orchidaceae (*e.g.*, *Anthurium*, *Epidendrum*, *Lepanthes*, *Philodendron* and *Pleurothallis s.l.*) are likewise endemic to that continent. The Neotropical region therefore hosts the greater part of world's epiphytic flora (> 15.500 spp.), which are mainly concentrated in Central America, the Andes, northwestern Amazonia and the Atlantic Forest (Gentry & Dodson 1987, Nieder et al. 2001). Of the 14.500 vascular plants known to inhabit the Atlantic Forest, 3.000-4.000 are epiphytes (Stehmann et al. 2009, Kersten 2010). The Atlantic Forest has large latitudinal (from 3°S to 30°S) and altitudinal (from sea level up to 2.890 m) extensions and significant rainfall variations – resulting in high habitat heterogeneity and an extraordinary diversity of organisms (Oliveira-Filho & Fontes 2000).

Southern Bahia is considered an area of great biological importance, with elevated levels of richness and endemism in its arboreal component (Mori et al. 1983, Thomas et al. 1998, Martini et al. 2007, Thomas et al. 2009, Rocha & Amorim 2012), although surveys of humid montane forests have been scarce, especially those focusing on terrestrial and epiphytic herbs (Amorim et al. 2009, Matos et al. 2010). The recently created Serra das Lontras National Park comprises a vast remnant of montane Atlantic Forest in southern Bahia (Save Brasil et al. 2009).

A preliminary survey in the park, covering only a small area, recorded 709 angiosperm species, of which 158 (22.3%) were epiphytes (Amorim et al. 2009). These authors highlighted the fact that many of the species encountered, including many epiphytes (*e.g.*, *Fuchsia regia* [Vell.] Munz, *Nematanthus lanceolatus* [Poir.] Chautems, and *Vriesea longicaulis* Mez), were previously known only from mountainous areas in southern and southeastern Brazil.

For the preliminary survey there was no effort focused on this habit, which presents peculiarities that hinder their sampling, including the height they occur on the phorophyte and the small sizes of some groups (*e.g.*, *Peperomia* and *Pleurothallis s.l.*). We therefore sought to inventory the composition of epiphytic angiosperms in the Serra das Lontras National Park to investigate their distributions into genera and families and their biogeographical patterns to increase our knowledge of this group in the park and in northeastern Brazil.

Material and methods

Serra das Lontras National Park (SLNP) is located in southern Bahia State (Figure 1), Brazil, in the municipalities of Arataca, São José da Vitória, and Una (15°07′-15°15′S and 39°15′-39°25′W). The park comprises approximately 11.000 hectares at altitudes that vary from 400 to 1.000 m. Located 30 km from the coast, the mountains act as a first barrier to humid air masses moving inland from the ocean, resulting in mean annual precipitation rates of 1.300-1.600 mm, without a marked dry season, and a mean annual temperature of 24°C (classified as Af in the Koppen system) (Peel et al. 2007, Amorim et al. 2009, Nacif et al. 2009).

Situated in the Atlantic Forest domain, the SLNP comprises a vegetation mosaic of anthropogenic areas mixed with well-preserved submontane forests (with canopies >30 m) at lower altitudes and cloud forests above 800 m with smaller trees with twisted trunks bearing bryophytes (Stadtmüller 1987).

A total floristic inventory of the SLNP has been underway for the last eight years, and preliminary results have already been published (Amorim et al. 2009; Save Brasil et al. 2009). Visits to the area were made every two months, from February/2011 to March/2012 to survey the epiphytic angiosperms. Collections were made along roads and trails in order to cover the largest possible areas, and some living phorophytes were occasionally climbed and fallen trees examined to collect canopy species. Accidental epiphytes were not considered in this survey. Informations on the type of epiphytism (characteristic holoepiphyte, facultative holoepiphyte, hemiepiphyte) were obtained from local observations and complemented with informations from literature. This was done in order to have more accurate data, since many facultative species might have been seen only as epiphytes in the area or might occur as terrestrial or rupiculous in parts of the park that were not visited. All fertile material was deposited at the RB and CEPEC herbaria, while sterile specimens were incorporated into the *ex-situ* collection at the Rio de Janeiro Botanical Garden.

Specimens collected during the general floristic inventory, as well as those from the present survey, were identified to the species level, when possible, with the help of specialists and specific literature (*e.g.*, the Flora Neotropica). Nomenclature and species concepts follow the List of Species of the Brazilian Flora - LSBF (2013). Distribution and endemism data were obtained from the LSBF for taxa identified to the species level.

A Rapid Color Guide, published by The Field Museum, was prepared and images on most species can be seen at www.fm2.fieldmuseum.org/plantguides/guideimages.asp?ID=545.

Results

The Serra das Lontras National Park shows high epiphyte richness, with a total of 256 species identified, representing 87 genera and 18 families (Table 1) – making it one of the richest sites for epiphytic angiosperms in the Atlantic Forest. Of the published checklists, only Macaé de Cima in Rio de Janeiro State reported more epiphyte species (275 spp.) (Fontoura et al. 1997).

The most important families encountered were Orchidaceae (106 spp.), Bromeliaceae (64 spp.), Araceae (31 spp.), and Piperaceae (14 spp.). Together, these families encompassed more than 80% of the epiphyte flora at SLNP. The species distributions within the families were very unequal, however, with 11 families being represented by less than five species.

The richest genera were *Vriesea* (22 spp.), *Peperomia* and *Stelis* (14 spp. each), *Anthurium* (13 spp.), *Aechmea* and *Philodendron* (12 spp. each), *Epidendrum* (11 spp.), and *Hohenbergia* (10 spp.). The species distributions within the genera were very unequal, with half of them (43 genera) being represented by only a single species, and 82% by less than five species.

With many ornamental species, 10 epiphytes registered for the SLNP are cited on the Red Book of Brazilian Flora

Figure 1. Map showing the location of the studied area (Serra das Lontras National Park); in gray is the Atlantic Forest limits. N.P. - National Park; B.R. - Biological Reserve/Mapa de localização da área de estudo (Parque Nacional da Serra das Lontras); em cinza está demarcado o limite da Floresta Atlântica.

(Martinelli & Moraes 2013). Of this total, three are "Critically endangered", five are "Endangered", and two are "Vulnerable". Four are considered to be "Data Deficient" (Table 1).

Discussion

The high numbers of species observed in Araceae, Bromeliaceae, Orchidaceae, and Piperaceae were consonant with global patterns of epiphytic distribution among angiosperm families, as reported by Madison (1977) and Gentry & Dodson (1987). Similar results were reported for the Neotropical region (*e.g.*, Sudgen & Robins 1979, Gentry & Dodson 1987, Wolf & Flamenco-S 2003, Küper et al. 2004) and the tropical and subtropical Atlantic Forest (*e.g.*, Fontoura et al. 1997, Borgo & Silva 2003, Giongo & Waechter 2004, Kersten & Silva 2001, Buzatto et al. 2008, Martins et al. 2008, Menini Neto et al. 2009, Mania & Monteiro 2010).

Table 2 compares the SLNP and other Atlantic Forest areas with high epiphyte richness. The elevated numbers of species of Bromeliaceae, Araceae, and Gesneriaceae is notable, representing the highest epiphyte richness ever recorded for these families in the Atlantic Forest. *Vriesea*, *Stelis*, *Anthurium*,

Table 1. Epiphytic Angiosperms registered for Serra das Lontras National Park, Bahia, Brazil. [1] *New occurence to Bahia state; ** New occurence to the Atlantic Forest; *** New occurence to Brazil. [2] AA – André M. Amorim; AF – André P. Fontana; AJ – Alessandra B. Jardim; JJ – Jomar G. Jardim; JP – José Lima da Paixão; ML – Márdel M. Lopes; PF – Pedro Fiaschi; PL – Paula Leitman; RB – Rafael X. Borges; RP – Ricardo O. Perdiz; WT – Wm. Wayt Thomas. [3] Epi – Characteristic Holoepiphyte; Fac – Facultative Holoepiphyte; Hep – Hemiepiphyte. [4] CAF – Cerrado-Atlantic Forest; Di – Disjunct distribution Amazon-Atlantic Forest; En – Endemic to Atlantic Forest; WD – Wide distribution; O – Other; "-" – not applicable. [5] CR – Criticaly endangered; DD – Data deficient; EN – Endangered; VU – Vulnerable.

Family	Specie[1]	Voucher[2]	Habit[3]	Distribution[4]	Threat category[5]
Acanthaceae	*Clistax bahiensis* Profice & Leitman	AA 5301	Hep	En	
Araceae	*Anthurium boudetii* Nadruz *	AA 6399	Fac	En	
	Anthurium gladiifolium Schott	AA 5770	Epi	En	
	Anthurium gracile (Rudge) Lindl. **	PL 211	Epi	WD	
	Anthurium intermedium Kunth	PL 165	Fac	En	
	Anthurium jilekii Schott	PL 547	Hep	O	
	Anthurium pentaphyllum (Aubl.) G.Don	AA 5770a	Hep	WD	
	Anthurium scandens (Aubl.) Engl.	ML 1473	Hep	WD	
	Anthurium solitarium Schott	AA 6610	Fac	WD	
	Anthurium sp. 1	PL 417	Epi	-	
	Anthurium sp. 2	JJ 4919	Epi	-	
	Anthurium sp. 3	PL 324	Epi	-	
	Anthurium sp. 4	JJ 4389	Epi	-	
	Anthurium sp. 5	JJ 4337	Epi	-	
	Heteropsis oblongifolia H.B.K.	JJ 4886	Hep	WD	
	Monstera adansonii Schott	JP 956	Hep	WD	
	Philodendron cordatum Kunth	AA 6580	Hep	En	
	Philodendron edmundoi G.M.Barroso *	JJ 4898	Hep	En	
	Philodendron fragrantissimum (Hook.) G.Don	ML 1449	Hep	WD	
	Philodendron hederaceum (Jacq.) Schott	AA 5960	Hep	WD	
	Philodendron insigne Schott	JJ 4896	Fac	O	
	Philodendron ornatum Schott	AA 6727	Hep	WD	
	Philodendron pedatum (Hook.) H.B.K.	AA 6599	Hep	WD	
	Philodendron propinquum Schott	PL 202	Hep	En	
	Philodendron recurvifolium Schott	PL 287	Hep	En	
	Philodendron rudgeanum Schott	AA 5296	Hep	Di	
	Philodendron surinamense (Miq.) Engl.	PL 119	Hep	Di	
	Philodendron aff. *williamsii* Hook. f.	PL 561	Hep	-	
	Rhodospatha latifolia Poepp.	JJ 4842	Hep	WD	
	Rhodospatha oblongata Poepp.	PL 428	Hep	Di	
	Stenospermation spruceanum Schott	AA 5298	Epi	Di	
	Syngonium vellozianum Schott	AA 5960a	Hep	WD	
Araliaceae	*Oreopanax capitatus* (Jacq.) Decne. & Planch.	AA 6568	Hep	WD	
Begoniaceae	*Begonia convolvulacea* A.DC.	AA 5280	Hep	En	
	Begonia fruticosa (Klotzsch) A.DC.	AA 5265	Hep	En	
	Begonia aff. *itaguassuensis* Brade	PL 338	Hep	-	
	Begonia radicans Vell.	AA 5275	Hep	En	
	Begonia grisea A.DC. **	PL 424	Fac	O	
Bromeliaceae	*Aechmea burlemarxii* E. Pereira	PL 378	Fac	En	
	Aechmea conifera L.B.Sm. *	PL 309	Fac	En	
	Aechmea froesii (L.B.Sm.) Leme & J.A.Siqueira	AA 6594	Fac	En	
	Aechmea gustavoi J.A.Siqueira & Leme	PL 262	Fac	En	CR
	Aechmea multiflora L.B.Sm.	PL 395	Fac	En	
	Aechmea nudicaulis Griseb.	AA 7217	Fac	CAF	
	Aechmea patentissima (Mart. *ex* Schult. & Schult. f.) Baker	PL 129	Fac	Di	
	Aechmea subintegerrima (Philcox) Leme	ML 1484	Epi	En	
	Aechmea tentaculifera Leme *et al.*	ML 1491	Epi	En	
	Aechmea turbinocalyx Mez	PL 141	Epi	En	
	Aechmea viridostigma Leme & H.Luther	JJ 4680	Epi	En	
	Aechmea sp.	JJ 5431	Epi	-	

Continued on next page

Table 1. Continued.

Family	Specie[1]	Voucher[2]	Habit[3]	Distribution[4]	Threat category[5]
	Billbergia euphemiae E.Morren	AA 5752	Fac	En	
	Billbergia saundersii Bull	JP 976	Epi	En	
	Canistrum camacaense Martinelli & Leme	AA 5751	Fac	En	EN
	Canistrum montanum Leme	AA 5269	Epi	En	EN
	Guzmania lingulata (L.) Mez	RB 591	Fac	WD	
	Hohenbergia augusta (Vell.) E.Morren *	PL 149	Fac	En	
	Hohenbergia brachycephala L.B.Sm.	PL 439	Epi	En	
	Hohenbergia capitata Schult. & Schult.f.	AA 6602	Epi	En	
	Hohenbergia edmundoi L.B.Sm. & Read	JJ 4920	Epi	En	
	Hohenbergia minor L.B.Sm.	PL 158	Epi	En	
	Hohenbergia sp. 1	PL 398	Epi	-	
	Hohenbergia sp. 2	PL 134	Epi	-	
	Hohenbergia sp. 3	PL 307	Epi	-	
	Hohenbergia sp. 4	PL 391	Epi	-	
	Hohenbergia sp. 5	PL 305	Epi	-	
	Lymania azurea Leme	JJ 5316	Epi	En	EN
	Neoregelia azevedoi Leme	AA 6624	Epi	En	
	Neoregelia crispata Leme	AA 5991	Epi	En	
	Neoregelia kerryi Leme	AA 5807	Fac	En	
	Neoregelia pauciflora L.B.Sm.	AA 6590	Epi	En	
	Neoregelia wilsoniana M.B.Foster	PL 267	Epi	En	
	Nidularium innocentii Lem.	AA 6696	Fac	En	
	Nidularium procerum Lindm.	WT 14093b	Fac	En	
	Portea filifera L.B.Sm.	PL 435	Epi	En	
	Portea nana Leme	AA 6597	Epi	En	EN
	Quesnelia clavata Amorim & Leme	AA 5351	Fac	En	
	Racinaea spiculosa (Griseb.) M.A.Spencer & L.B.Sm.	AA 5820	Epi	WD	
	Tillandsia geminiflora Brong.	AA 6391	Epi	CAF	
	Tillandsia sprengeliana Klotzsch *ex* Mez	JJ 4895	Epi	CAF	
	Tillandsia stricta Sol.	AA 6086	Epi	CAF	
	Vriesea breviscapa (E.Pereira & I.A.Penna) Leme	PL 208	Epi	En	DD
	Vriesea dictyographa Leme	AA 5303	Epi	En	
	Vriesea drepanocarpa (Baker) Mez	PL 380	Epi	En	
	Vriesea duvaliana E.Morren	JP 965	Epi	En	
	Vriesea ensiformis (Vell.) Beer	JP 975	Epi	En	
	Vriesea flammea L.B.Sm.	RB 590	Epi	En	
	Vriesea guttata Linden & André *	PL 489	Epi	En	
	Vriesea longiscapa Ule	AA 5797	Epi	En	
	Vriesea longisepala A.F.Costa	AA 6758	Epi	En	
	Vriesea paratiensis E.Pereira	AA 6646	Epi	Di	
	Vriesea procera (Mart. *ex* Schult. & Schult.f.) Wittm.	PL 368	Epi	O	
	Vriesea regnelli Mez	AA 6759	Epi	En	
	Vriesea rhodostachys L.B.Sm.	PL 301	Epi	En	DD
	Vriesea rodigasiana E.Morren	PL 205	Epi	En	
	Vriesea ruschii L.B.Sm.	PL 150	Epi	En	
	Vriesea simplex (Vell.) Beer	PL 345	Epi	O	
	Vriesea tijucana E. Pereira	AA 6097	Epi	En	
	Vriesea vagans (L.B.Sm.) L.B.Sm. *	AA 6688	Epi	En	
	Vriesea sp. 1	PL 289	Epi	-	
	Vriesea sp. 2	PL 114	Epi	-	
	Vriesea sp. 3	PL 181	Epi	-	
	Vriesea sp. 4	PL 442	Epi	-	
Cactaceae	*Epiphyllum phyllanthus* (L.) Haw.	JJ 4401	Epi	WD	
	Lepismium cruciforme (Vell.) Miq.	PL 230	Epi	O	
	Rhipsalis floccosa Salm-Dyck *ex* Pfeiff.	PL 200	Epi	En	

Continued on next page

Table 1. Continued.

Family	Specie[1]	Voucher[2]	Habit[3]	Distribution[4]	Threat category[5]
	Rhipsalis hileiabaiana (N.P.Taylor & Barthlott) N. Korotkova & Barthlott	PL 521	Epi	CAF	DD
	Rhipsalis lindbergiana K.Schum	PL 367	Epi	O	
	Rhipsalis neves-armondii K.Schum	PL 513	Epi	En	
	Rhipsalis oblonga Loefgr.	ML 1019	Epi	En	
Clusiaceae	*Clusia panapanari* (Aubl.) Choisy	AA 7205	Hep	O	
Cyclanthaceae	*Asplundia gardneri* (Hook,) Harling	PL 213	Hep	WD	
	Asplundia maximiliani Harling	PL 506	Hep	En	
	Evodianthus funifer (Poit.) Lindm.	ML 1464	Hep	WD	
	Thoracocarpus bissectus (Vell.) Harling	PL 427	Hep	WD	
Gesneriaceae	*Codonanthe cordifolia* Chautems	JJ 4892	Epi	CAF	
	Codonanthe gracilis (Mart.) Hanst.	PL 411	Epi	En	
	Codonanthe uleana Fritsch	AA 7221	Epi	WD	
	Columnea sanguinea (Pers.) Hanst.	RB 622	Epi	WD	
	Nematanthus albus Chautems	JJ 4907	Epi	En	
	Nematanthus corticola Schrad.	JP 973	Epi	En	
	Nematanthus lanceolatus (Poir.) Chautems	AA 5276	Fac	CAF	
Lentibulariaceae	*Utricularia jamesoniana* Oliv. **	JJ 4908	Epi	O	
Marcgraviaceae	*Marcgravia coriacea* Vahl	AA 6679	Hep	WD	
	Marcgravia polyantha Delpino	JJ 4697	Hep	CAF	
Melastomataceae	*Bertolonia alternifolia* Baumgratz *et al.*	AJ 170	Epi	En	
	Bertolonia bullata Baumgratz *et al.*	AA 5979	Epi	En	
	Bertolonia ovata DC.	WT 14581	Epi	En	
	Pleiochiton blepharodes (DC.) Reginato & Goldenberg	JJ 4921	Epi	En	
Moraceae	*Ficus arpazusa* Casar.	WT 14112	Hep	WD	
	Ficus castellviana Dugand	PF 2811	Hep	WD	
	Ficus hirsuta Schott	FF 1447	Hep	O	
Onagraceae	*Fuchsia regia* (Vand. *ex* Vell.) Munz	AA 5806	Hep	CAF	
Orchidaceae	*Acianthera auriculata* (Lindl.) Pridgeon & M.W.Chase	PL 412	Epi	En	
	Acianthera capanemae (Barb.Rodr.) Pridgeon & M.W.Chase *	PL 361	Epi	En	
	Acianthera hygrophila (Barb.Rodr.) Pridgeon & M.W.Chase *	AF 2682	Epi	Di	
	Anathallis rubens (Lindl.) Pridgeon & M.W.Chase	PL 251	Fac	WD	
	Anathallis sclerophylla (Lindl.) Pridgeon & M.W.Chase	AA 5809	Epi	WD	
	Baptistonia gutfreundiana (Chiron & V.P.Castro) Chiron & V.P.Castro	PL 376	Epi	En	
	Baptistonia truncata (Pabst) Chiron & V.P.Castro *	RP 536	Epi	En	CR
	Brachionidium restrepioides Hoehne & Pabst	JJ 4677	Epi	En	VU
	Bulbophyllum micropetaliforme J.E.Leite	PL 225	Epi	En	
	Bulbophyllum napellii Lindl.	JJ 5383	Epi	CAF	
	Camaridium carinatum (Barb.Rodr.) Hoehne	AF 2666	Epi	O	
	Camaridium cf. *micranthum* M.A. Blanco	AF 2688	Epi	-	
	Catasetum cf. *hookeri* Lindl.	JJ 4385	Epi	-	
	Catasetum purum Nees & Sinnings	PL 244	Epi	En	
	Cirrhaea cf. *seidelii* Pabst	PL 355	Epi	-	
	Coppensia flexuosa (Sims) Campacci	JJ 4922	Epi	Di	
	Coppensia hookeri (Rolfe) F.Barros & L.Guimarães	AA 6626	Epi	En	
	Dichaea brevicaulis Cogn.	PL 354	Epi	En	
	Dichaea cogniauxiana Schltr.	AA 5816	Epi	CAF	

Continued on next page

Table 1. Continued.

Family	Specie[1]	Voucher[2]	Habit[3]	Distribution[4]	Threat category[5]
	Dichaea pendula (Aubl.) Cogn.	PL 353	Epi	WD	
	Elleanthus brasiliensis (Lindl.) Rchb.f.	PL 549	Epi	O	
	Elleanthus crinipes Rchb.f.	AF 2673	Epi	CAF	
	Elleanthus hymenophorus (Rchb.f.) Rchb.f. ***	AA 4960	Epi	WD	
	Elleanthus linifolius C.Presl	AA 4983	Epi	WD	
	Encyclia fimbriata A.C.Bastos *et al.*	WT 14604	Epi	En	
	Encyclia patens Hook.	PL 326	Fac	CAF	
	Encyclia unaensis Fowlie	AF 2659	Epi	En	
	Epidendrum armeniacum Lindl.	AA 6581	Epi	O	
	Epidendrum densiflorum Lindl.	PL 463	Fac	WD	
	Epidendrum latilabre Lindl. *	PL 432	Epi	Di	
	Epidendrum macrocarpum Rich.	AA 6413	Epi	O	
	Epidendrum nocturnum Jacq.	ML 539	Epi	WD	
	Epidendrum ochrochlorum Barb.Rodr.	JP 971	Epi	WD	
	Epidendrum paranaense Barb.Rodr.	AA 6412	Fac	WD	
	Epidendrum ramosum Jacq.	AA 5810	Epi	CAF	
	Epidendrum saximontanum Pabst	AF 2685	Epi	En	
	Epidendrum secundum Jacq.	JJ 4901	Epi	WD	
	Epidendrum sp.	JJ 4904	Epi	-	
	Gomesa recurva Barb.Rodr.	AA 4448	Fac	CAF	
	Grandiphyllum pohlianum (Cogn.) Docha Neto *	PL 413	Epi	En	
	Heterotaxis brasiliensis (Brieger & Illg) F.Barros	PL 191	Epi	Di	
	Houlletia brocklehurstiana Lindl.	WT 14594	Epi	En	EN
	Jacquiniella globosa (Jacq.) Schltr.	AF 2675	Epi	WD	
	Koellensteinia graminea Rchb.f.	PL 555	Epi	O	
	Lankesterella longicollis (Cogn.) Hoehne *	AF 2684	Epi	En	
	Lockhartia lunifera Rchb.f.	AF 2654	Epi	Di	
	Masdevallia infracta Lindl.	WT 14097	Epi	CAF	
	Maxillaria bradei Schltr. *ex* Hoehne *	JJ 4912	Epi	En	
	Maxilaria candida Lodd. *ex* Lindl. *	ML 1023	Epi	Di	
	Maxillaria leucaimata Barb.Rodr.	AA 5329	Epi	Di	
	Maxillaria ochroleuca Lodd. *ex* Lindl.	JJ 4379	Epi	WD	
	Maxilaria aff. *ringens* Rchb.f.	PL 154	Epi	-	
	Maxillaria spiritusanctensis Pabst	JJ 4681	Epi	En	
	Maxilaria aff. *splendens* Poepp. & Endl.	PL 374	Epi	-	
	Maxilaria sp.	PL 314	Epi	-	
	Maxillariella robusta (Barb. Rodr.) M.A.Blanco & Carnevali *	PL 316	Epi	En	
	Mormolyca rufescens (Lindl.) M.A.Blanco	JJ 4683	Epi	Di	
	Nitidobulbon nasutum (Rchb.f.) Ojeda & Carnevali	AA 4970	Epi	WD	
	Octomeria concolor Barb.Rodr. *	PL 464	Epi	O	
	Octomeria crassifolia Lindl.	AF 2657	Epi	O	
	Octomeria decumbens Cogn.	PL 400	Epi	En	DD
	Octomeria geraensis Barb.Rodr. *	PL 265	Epi	En	VU
	Octomeria grandiflora Lindl.	PL 226	Epi	WD	
	Octomeria tricolor Rchb.f.	JJ 4665	Epi	En	
	Octomeria sp.	PL 493	Epi	-	
	Ornithidium rigidum (Barb.Rodr.) M.A.Blanco & Ojeda *	RP 301	Epi	Di	
	Pabstiella bradei (Schltr.) Luer *	PL 377	Epi	En	
	Pabstiella ramphastorhyncha (Barb. Rodr.) L. Kollmann	PL 360	Epi	CAF	
	Pabstiella aff. *trifida* (Lindl.) Luer	AF 2658	Epi	-	
	Pleurothallis ruscifolia (Jacq.) R.Br.	PF 2821	Epi	WD	
	Pleurothallis sp.	PL 222	Epi	-	

Continued on next page

Table 1. Continued.

Family	Specie[1]	Voucher[2]	Habit[3]	Distribution[4]	Threat category[5]
	Polycycnis silvana F.Barros	AA 5805	Epi	En	
	Polystachya estrellensis Rchb.f.	RP 294	Fac	WD	
	Promenaea silvana F.Barros & Cath.	JJ 4815	Epi	En	
	Promenaea xanthina Lindl.	RP 330	Epi	En	
	Prosthechea bueraremensis (Campacci) Campacci	AF 2662	Epi	En	
	Prosthechea calamaria (Lindl.) W.E.Higgins *	AF 2674	Epi	En	
	Prosthechea fragans (Sw.) W.E.Higgins	AA 5361	Epi	WD	
	Prosthechea pachysepala (Klotzsch) Chiron & V.P.Castro	RP 335	Epi	CAF	
	Prosthechea pygmaea (Hook.) W.E.Higgins	WT 14101	Epi	WD	
	Prosthechea vespa (Vell.) W.E.Higgins *	ML 549	Fac	WD	
	Rhetinantha notylioglossa (Rchb.f.) M.A.Blanco	AA 5355	Epi	Di	
	Scaphyglottis fusiformis (Griseb.) Schultes *	PL 399	Epi	WD	
	Scaphyglottis modesta (Rchb.f.) Schltr.	AF 2672	Fac	WD	
	Scaphyglottis reflexa Lindl.	WT 14096	Epi	O	
	Sobralia cf. sessilis Lindl.	AF 2651	Epi	-	
	Specklinia grobyi Batem. *ex* Lindl.	PL 494	Epi	WD	
	Stelis aprica Lindl.	AA 6588	Epi	WD	
	Stelis caespitosa Lindl. **	PL 532	Epi	O	
	Stelis deregularis Barb.Rodr.	WT 14102	Epi	En	
	Stelis aff. *fraterna* Lindl.	PL 256	Epi	-	
	Stelis intermedia Poepp. & Endl. *	AA 5746	Epi	O	
	Stelis megantha Barb.Rodr. *	PL 135	Epi	En	
	Stelis papaquerensis Rchb.f. *	PL 430	Epi	Di	
	Stelis pauciflora Lindl. *	PL 175	Epi	Di	
	Stelis ruprechtiana Rchb.f. *	PL 359	Epi	En	
	Stelis sp. 1	PL 431	Epi	-	
	Stelis sp. 2	PL 519	Epi	-	
	Stelis sp. 3	JJ 4713	Epi	-	
	Stelis sp. 4	WT 14103	Epi	-	
	Stelis sp. 5	ML 1187	Epi	-	
	Trichopilia santoslimae Brade *	PL 221	Epi	En	CR
	Xylobium colleyi (Bateman *ex* Lindl.) Rolfe *	RP 69	Epi	WD	
	Xylobium variegatum (Ruiz & Pav.) Mansf. *	PL 310	Fac	WD	
	Zygopetalum crinitum Lodd. *	AA 7264	Epi	En	
	Zygopetalum cf. maxillare Lodd.	AF 2665	Epi	-	
Piperaceae	*Peperomia alata* Ruiz & Pav.	JJ 4346	Fac	WD	
	Peperomia corcovadensis Gardner *	PL 100	Fac	O	
	Peperomia elongata Kunth	AA 6649	Fac	WD	
	Peperomia emarginella (Sw.) C.DC.	WT 14541	Fac	O	
	Peperomia hernandiifolia (Vahl) A.Dietr.	ML 1020	Fac	WD	
	Peperomia macrostachya (Vahl) A.Dietr.	JJ 4798	Epi	WD	
	Peperomia magnoliifolia (Jacq.) A.Dietr.	AA 5952	Fac	WD	
	Peperomia obtusifolia (L.) A.Dietr.	AA 5946	Fac	WD	
	Peperomia pilicaulis C.DC.	MJ 840	Fac	WD	
	Peperomia pseudoestrelensis C.DC.	AA 6357	Fac	En	
	Peperomia serpens (Sw.) Loud	PL 548	Fac	WD	
	Peperomia tenella (Sw.) A.Dietr.	PL 421	Fac	CAF	
	Peperomia tetraphylla (G.Forst.) Hook. & Arn.	AA 6681	Fac	WD	
	Peperomia urocarpa Fisch. & C.A.Mey.	AA 5287	Fac	WD	
Rubiaceae	*Hillia parasitica* Jacq.	AA 5800	Epi	WD	
	Notopleura bahiensis C.M.Taylor	AA 5741	Epi	En	
	Schradera polycephala DC.	JJ 4851	Hep	Di	
Solanaceae	*Dyssochroma viridiflorum* (Sims) Miers	AA 4962	Hep	En	

Table 2. Comparison of species richness for the main families and genera with epiphytic habit between Serra das Lontras National Park and other surveys carried at the Atlantic Forest. [1] N.P. – National Park; S.P. – State Park; N.R. – Natural Reserve. "-" – Information not available.

Study area [1]	**Serra das Lontras N.P., BA**	**Macaé de Cima, RJ**	**Upper Iguaçu River Basin, PR**	**Prata Moutain Range, PR**	**Ibitipoca S.P., MG**	**Carlos Botelho S.P., SP**	**Ilha do Cardoso S.P., SP**	**Vale do Rio Doce N.R., ES**
Taxon	Present study	Fontoura *et al.* 1997; Costa & Wendt 2007	Kersten & Kunyioshi 2006	Blum *et al.* 2011	Menini Neto *et al.* 2009	Breier *et al.* 2005	Breier *et al.* 2005	Coelho 2010
Total area	11,000ha	7,000ha	-	6.3ha	1,923.5ha	10.24ha	10.24ha	22.000ha
Total epiphytic Angiosperms	256	275	254	204	181	121	136	-
Orchidaceae	103	184	147	103	66	42	72	-
Bromeliaceae	62	45	39	38	22	27	33	-
Araceae	29	5	9	14	9	13	11	22
Piperaceae	15	5	24	14	3	8	6	-
Cactaceae	7	7	12	9	7	11	1	-
Gesneriaceae	7	6	3	5	2	6	3	-
Vriesea	22	18	11	18	7	12	15	-
Peperomia	15	5	22	14	3	7	5	-
Stelis	14	4	6	7	5	1	1	-
Anthurium	13	-	2	6	5	3	3	4
Philodendron	12	10	7	6	4	8	7	12
Aechmea	11	4	9	5	1	5	3	-
Epidendrum	11	10	4	12	6	4	8	-
Hohenbergia	9	0	0	0	0	0	0	-

Aechmea, and *Hohenbergia* also exhibited their greatest epiphytic species diversity in the SLNP. It is interesting that *Hohenbergia* was among the richest genera in the study area, as this genus does not commonly figure among the most species rich taxa in epiphyte surveys. The greatest diversity of this genus is encountered in southern Bahia, where 21 of its 25 Atlantic Forest species occur (Martinelli et al. 2008, Forzza et al. 2013).

In addition to *H. brachycephala* and *H. minor*, both endemic to Bahia, *H. edmundoi*, a poorly-known species from Bahia for which no habitat information was available (Smith & Downs 1979, Forzza et al. 2013), was found in a submontane forest in the SLNP; *H. augusta*, previously considered to be restricted to southeastern Brazil, was also collected. These results reaffirm the importance of southern Bahia State in the distribution and taxonomy of this genus.

Vriesea (Tillandsioideae) and *Aechmea* (Bromelioideae) represent 12% and 7%, respectively, of the total number of species in the Atlantic Forest (Forzza et al. 2013). Fontoura et al. (2012) reported that Bromelioideae taxa were encountered 1.6 times more frequently in local surveys of epiphytic species in the Atlantic Forest than representatives of Tillandsioideae. This proportion was lower in the SLNP, where *Vriesea* is very diverse, with almost the same numbers of species being encountered in each subfamily (34 spp. Bromelioideae x 30 spp. Tillandsioideae).

Another family that demonstrated elevated richness in the SLNP was Araceae, with one third of the 65 species known to the Atlantic Forest being encountered there (Coelho et al. 2013). The most diversified genera of this family were likewise well represented in the park, with more than half of the species of *Anthurium* and *Philodendron* known from Bahia being encountered in the SLNP. Additionally, two new occurrence records for Bahia State (*A. boudetii* and *P. edmundoi*), one for the Atlantic Forest domain (*A. gracile*), and five morphotypes of *Anthurium* reinforce the importance of additional studies in mountainous areas there to improve our knowledge of the distribution of this family within the state. In contrast to the high endemism levels of Bromeliaceae and Orchidaceae, representatives of Araceae exhibit wide (and sometimes disjunct) distributions (Coelho et al. 2013).

Orchidaceae is responsible for approximately 70% of the global epiphytic flora, and is always among the top families in every floristic study of that habit (Benzing 1990, Kersten 2010, Zotz 2013). Most orchid diversity is found in the tropics, especially in mountainous areas (Dressler 1993). The majority of the orchid taxa encountered in the SLNP is relatively small (*e.g.*, *Acianthera*, *Anathallis*, *Brachionidium*, *Jacquiniella*, *Lankesterella*, *Octomeria*, *Pabstiella*, *Pleurothallis*, *Promenaea*, *Specklinia*, and *Stelis*) and commonly neglected in floristic surveys – and therefore poorly represented in scientific collections (Dressler 2005). As the present study focused on epiphytes (and *ex-situ* cultivation was undertaken), high numbers of species were included on the final list – with 22 new occurrences for Bahia State (Table 1).

Northeastern Brazil represents one of the 10 areas in the world considered most likely to have undescribed species, and where models predict a 30% increase in known diversity (Joppa et al. 2011). Since initiating preliminary studies of the flora of the SLNP (Amorim et al. 2009), six new epiphyte species have been described for the area: *Bertolonia alternifolia*, *B. bullata*, *Clistax bahiensis*, *Encyclia fimbriata*, *Quesnelia clavata*, and *Vriesea longisepala*, and one is about to be published. The present survey found other possible taxonomic novelties, and recent studies in neighboring areas encountered several new species with epiphytic habits (*e.g.*, Amorim & Leme 2009, Leme & Kollmann 2011, Costa et al. 2012, Reginato et al. 2013) – emphasizing the need of further investigations of this group in southern Bahia.

The present study expands the distribution of many taxa, with one new occurrence for Brazil (*Elleanthus hymenophorus* (Rchb.f.) Rchb.f.), four for the Atlantic Forest biome, and 30 for Bahia State (Table 1). *Utricularia jamsoniana* Oliv., a species previously known only from altitudinal regions of Central America and northern South America (Taylor 1989), was encountered in a cloud forest in the highest area of the park (Peito de Moça and Javi mountain ranges). Over half (16 spp.) of these new records were known only from collections in strictly southern and southeastern regions. The epiphytic flora of the SLNP shares more species with southern and southeastern Brazil (71 spp.) than with northeastern states (five species – four *Aechmea* and one *Hohenbergia*). This same pattern was found for ferns and lycophytes on a nearby mountainous area in the Serra Bonita Private Reserve, with almost a quarter of the surveyed species being previously restricted to southeastern Brazil (Matos et al. 2010).

Almost half of the 221 taxa identified to species level in the present study are endemic to the Atlantic Forest (100 spp. - 45%) (Table 1), and most of them belong to Bromeliaceae and Orchidaceae (44 and 32 species respectively). These two families exhibit high degrees of endemism in the Atlantic Forest, with 80% of Bromeliaceae and 63% of Orchidaceae being restricted to this domain (Martinelli et al. 2008, Stehmann et al. 2009). These high levels of endemism may be related to limited connections with the other major South American forest formation in the Amazon (Mori et al. 1981). These two forests are separated by an open area known as the "dry diagonal" (Prado & Gibbs 1993) that acts as a barrier to species dispersion, especially less drought-tolerant taxa.

On the other hand, 60 species showed broad distributions in Brazil or the Neotropical region, and 24 had disjunct distributions between the Atlantic and Amazon forests (Table 1); 19 species also occur in the "Cerrado" (Brazilian savanna) region, suggesting that dry formations do not act as barriers to all epiphyte taxa, especially those with broader ecophysiological tolerances (Oliveira-Filho & Ratter 1995, Ibisch et al. 1996). Deciduous and semi-deciduous seasonal forest patches and gallery forests that crisscross the Cerrado may offer dispersal pathways for many species and establish tenuous connections between these two major forest formations (Leitão Filho 1987, Oliveira-Filho & Ratter 1995).

All of the 10 species cited on the Red Book of Brazilian Flora (Martinelli & Moraes 2013) as threatened belong to Bromeliaceae and Orchidaceae, two very ornamental families. The five bromeliads are restricted to Northeast Brazil, and four of them are endemic to Bahia. On the other hand, the orchids indicated as threatened are new occurrences to the state. These results reinforce the importance of the park as a conservation unit and the relevance of floristic surveys, especially for often neglected groups such as epiphytes. Recent floristic studies in mountainous areas in southern Bahia have revealed large numbers of new species and new occurrences of epiphytes – pointing to the need for further investigations of this group.

Acknowledgments

We thank FAPESB, FAPERJ and CAPES for fieldwork financial support. Paula Leitman thank CNPq and CAPES for master's scholarship. Rafaela C. Forzza and André Amorim are CNPq research fellows. We also thank the specialists who helped identifying the species - Alain Chautems, Andrea Costa, Charlotte Taylor, Claudio Nicoletti Fraga, Daniela Zappi, Daniele Monteiro, Eliane de Lima Jacques, Elton Leme, Elsie Franklin Guimarães, João Renato Stehmann, Ludovic Kollmann, Marcus Nadruz, Nigel Taylor, Ricardo Perdiz, Sheila Profice & Simon Mayo – and fieldwork helpers – José Lima Paixão, Carlinhos, Lukas Daneu and Ricardo Perdiz.

References

AMORIM, A.M.A. & LEME, E.M.C. 2009. Two new species of *Quesnelia* (Bromeliaceae: Bromelioideae) from the Atlantic Rainforest of Bahia, Brazil. Brittonia 61(1): 14-21. doi: http://dx.doi.org/10.1007/s12228-008-9049-5

AMORIM, A.M.A., JARDIM, J.G., LOPES, M.M.M., FIASCHI, P., BORGES, R.A.X., PERDIZ, R.O. & THOMAS, W.W. 2009. Angiospermas em remanescentes de Floresta Montana no sul da Bahia, Brasil. Biota Neotrop. 9(3): 313-348 http://www.biotaneotropica.org.br/v9n3/en/abstract?inventory+bn02909032009 (accessed in 15/07/2013). doi: http://dx.doi.org/10.1590/S1676-06032009000300028

BENZING, D.H. 1990. Vascular epiphytes. Cambridge University Press, New York.

BLUM, C.T., RODERJAN, C.V. & GALVÃO, F. 2011. Composição florística e distribuição altitudinal de epífitas vasculares da Floresta Ombrófila Densa na Serra da Prata, Morretes, Paraná, Brasil. Biota Neotrop. 11(4): 1-19 http://www.biotaneotropica.org.br/v11n4/en/abstract?inventory+bn00811042011 (accessed in 15/07/2013). doi: http://dx.doi.org/10.1590/S1676-06032011000400015

BORGO, M. & SILVA, S.M. 2003. Epífitos vasculares em fragmentos de Floresta Ombrófila Mista, Curitiba, Paraná, Brasil. Rev. Bras. Bot. 26(3): 391–401. doi: http://dx.doi.org/10.1590/S0100-84042003000300012

BREIER T.B. 2005. O epifitismo vascular em florestas do Sudeste do Brasil. PhD Thesis, Universidade Estadual de Campinas, Campinas.

BUZATTO, C.R., SEVERO, B.M.A. & WAECHTER, J.L. 2008. Composição florística e distribuição ecológica de epífitos vasculares na Floresta Nacional de Passo Fundo, Rio Grande do Sul. Iheringia, Bot. 63(2): 231-239.

COELHO, M.A.N. 2010. A família Araceae na Reserva Natural Vale, Linhares, Espírito Santo, Brasil. Bol. Mus. Biol. Mello Leitão 28: 41-87.

COELHO, M.A.N., SAKURAGUI, C.M., MAYO, S., SOARES, M.L., TEMPONI, L.G., CALAZANS, L.S.B., GONçALVES, E.G., & ANDRADE, I.M. 2013. Araceae. In Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB51 (accessed in 15/05/2013).

COSTA, A. & WENDT, T. 2007. Bromeliaceae na região de Macaé de Cima, Nova Friburgo, Rio de Janeiro, Brasil. Rodriguésia 58(4): 905-939.

COSTA, A.F., FONTOURA, T. & AMORIM, A.M. 2012. Novelties in Bromeliaceae from the northeastern Brazilian Atlantic Rainforest. J. Torrey Bot. Soc. 139(1): 34-45. doi: http://dx.doi.org/10.3159/TORREY-D-11-00061.1

DRESSLER, R.L. 1993. Phylogeny and classification of the orchid family. Dioscorides Press, Portland.

DRESSLER, R.L. 2005. How many orchid species? Selbyana 26(1,2): 155-158.

FONTOURA, T., SYLVESTRE, L.S., VAZ, A.M.S.F. & VIEIRA, C.M. 1997. Epífitas vasculares, hemiepífitas e hemiparasitas da Reserva Ecológica de Macaé de Cima. In Serra de Macaé de Cima: Diversidade florística e conservação em Mata Atlântica (H.C. LIMA & R.R. GUEDES-BRUNI, EDS.). JARDIM BOTÂNICO DO RIO DE JANEIRO, RIO DE JANEIRO, P. 89-101.

FONTOURA, T., SCUDELLER, V.V. & COSTA, A.F. 2012. Floristics and environmental factors determining the geographic distribution of epiphytic bromeliads in the Brazilian Atlantic Rain Forest. Flora (Jena), 9(): 662-672. doi: http://dx.doi.org/10.1016/j.flora.2012.05.003

FORZZA, R.C., COSTA, A., SIQUEIRA FILHO, J.A., MARTINELLI, G., MONTEIRO, R.F., SANTOS-SILVA, F., SARAIVA, D. P. & PAIXÃO-SOUZA, B. 2013. Bromeliaceae. In Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB66 (accessed in 15/05/2013).

GENTRY, A.H. & DODSON, C.H. 1987. Diversity and biogeography of neotropical vascular epiphytes. Ann. Missouri Bot. Gard. 74: 205-233. doi: http://dx.doi.org/10.2307/2399395

GIONGO, C. & WAECHTER, J.L. 2004. Composição florística e estrutura comunitária de epífitos vasculares em uma floresta de galeria na Depressão Central do Rio Grande do Sul. Rev. Bras. Bot. 27(3): 563–572. doi: http://dx.doi.org/10.1590/S0100-84042004000300015

IBISCH, P.L., BOEGNER, A., NIEDER, J. & BARTHLOTT, W. 1996. How diverse are neotropical epiphytes? An analysis based on the "Catalogue of the flowering plants and gymnosperms of Peru". Ecotropica 2: 13-28.

JOPPA, L.N., ROBERTS, D.L., MYERS, N. & PIMM, S.L. 2011. Biodiversity hotspots house most undiscovered plant species. P. Natl. Acad. Sci. USA 108(32): 13171-13176. doi: http://dx.doi.org/10.1073/pnas.1109389108

KERSTEN, R.A. 2010. Epífitas vasculares: histórico, participação taxonômica e aspectos relevantes, com ênfase na Mata Atlântica. Hoehnea 37(1): 9-38. doi: http://dx.doi.org/10.1590/S2236-89062010000100001

KERSTEN, R.A. & SILVA, S.M. 2001. Composição florística e estrutura do componente epifítico vascular em floresta da planície litorânea na Ilha do Mel, Paraná, Brasil. Rev. Bras. Bot. 24(2): 213–226. doi: http://dx.doi.org/10.1590/S0100-84042001000200012

KÜPER, W., KREFT, H., NIEDER, J., KÖSTER, N. & BARTHLOTT, W. 2004. Large-scale diversity patterns of vascular epiphytes in Neotropical montane rain forests. J. biogeogr. 31: 1477-1487. doi: http://dx.doi.org/10.1111/j.1365-2699.2004.01093.x

LEITÃO FILHO, H.F. 1987. Considerações sobre a florística de florestas tropicais e subtropicais do Brasil. IPEF 35: 41-46.

LEME, E.M.C. & KOLLMANN, L.J.C. 2011. New species and a new combination of Brazilian Bromeliaceae. Phytotaxa 16: 1-36.

MADISON, M. 1977. Vascular epiphytes: their systematic occurrence and salient features. Selbyana 2: 1-13.

MANIA, L. & MONTEIRO, R. 2010. Florística e ecologia de epífitas vasculares em um fragmento de floresta de restinga, Ubatuba, SP, Brasil. Rodriguésia 61(4): 705-713.

MARTINELLI, G., VIEIRA, C.M., GONZALEZ, M., LEITMAN, P., PIRATININGA, A., COSTA, A.F. & FORZZA, R.C. 2008. Bromeliaceae da Mata Atlântica Brasileira: lista de espécies, distribuição e conservação. Rodriguésia 59(1): 209-258.

MARTINELLI, G. & MORAES, M.A. (orgs.) 2013. Livro vermelho da flora do Brasil. Andrea Jakobsson/Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro. 1100 p.

MARTINI, A.M.Z., FIASCHI, P., AMORIM, A.M. & PAIXÃO, J.L. 2007. A hot-point within a hot-spot: a high diversity site in Brazil's Atlantic Forest. Biodivers. Conserv. 16(11): 3111-3128. doi: http://dx.doi.org/10.1007/s10531-007-9166-6

MARTINS, S.E., ROSSI, L., SAMPAIO, P.S.P. & MAGENTA, M.A.G. 2008. Caracterização florística de comunidades vegetais de restinga em Bertioga, SP, Brasil. Acta bot. bras. 22(1): 249–274. doi: http://dx.doi.org/10.1590/S0102-33062008000100024

MATOS, F.B., AMORIM, A.M. & LABIAK, P.H. 2010. The ferns and lycophytes of a montane tropical forest in southern Bahia, Brazil. J. Bot. Res. Inst. Texas 4(1): 333-346.

MENINI NETO, L., FORZZA, R.C., & ZAPPI, D. 2009. Angiosperm epiphytes as conservation indicators in forest fragments: a case study from southeastern Minas Gerais, Brazil. Biodivers. Conserv. 18: 3785-3807. doi: http://dx.doi.org/10.1007/s10531-009-9679-2

MORI, S., BOOM, B.M. & PRANCE, G.T. 1981. Distribution patterns and conservation of eastern Brazilian coastal forest tree species. Brittonia 33(2): 233-245. doi: http://dx.doi.org/10.2307/2806330

MORI, S., BOOM, B.M., CARVALHO, A.M. & SANTOS, T.S. 1983. Southern Bahian moist forest. Bot. rev. 49(2): 155-232. doi: http://dx.doi.org/10.1007/BF02861011

NACIF, P.G.S., COSTA, O.V., ARAÚJO, M. & SANTOS, P.S. 2009. Geomorfodinâmica da Região do Complexo de Serras das Lontras. In Complexo de Serras das Lontras e Una, Bahia: Elementos naturais e aspectos de sua conservação (Save Brasil, IESB e Birdlife International, eds.). SAVE Brasil, São Paulo. p. 9-14.

NIEDER, J., PROSPERí, J. & MICHALOUD, G. 2001. Epiphytes and their contribution to canopy diversity. Plant ecol. 153: 51-63. doi: http://dx.doi.org/10.1023/A:1017517119305

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 1995. A study of the origin of central Brazilian forests by the analysis of plant species distribution patterns. Edinb. j. bot. 52(2): 141-194. doi: http://dx.doi.org/10.1017/S0960428600000949

OLIVEIRA-FILHO, A.T. & FONTES, M.A.L. 2000. Patterns of floristic differentiation among Atlantic forests in southeastern Brazil and the influence of climate. Biotropica 32(4b): 793-810. doi: http://dx.doi.org/10.1111/j.1744-7429.2000.tb00619.x

PEEL, M.C., FINLAYSON, B.L. & MCMAHON, T.A. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrol. Earth Syst. Sc. 11: 1633-1644. doi: http://dx.doi.org/10.5194/hess-11-1633-2007

PRADO, D. & GIBBS, P. 1993. Patterns of species distributions in the dry seasonal forests of South America. Ann. Missouri Bot. Gard. 80(4): 902-927. doi: http://dx.doi.org/10.2307/2399937

REGINATO, M., BAUMGRATZ, J.F.A. & GOLDENBERG, R. 2013. A taxonomic revision of *Pleiochiton* (Melastomataceae, Miconieae). Brittonia 65(1): 16-41. doi: http://dx.doi.org/10.1007/s12228-012-9258-9

ROCHA, D.S.B. & AMORIM, A.M.A. 2012. Heterogeneidade altitudinal na Floresta Atlântica setentrional: um estudo de caso no sul da Bahia, Brasil. Acta bot. bras. 26: 309-327.

SAVE Brasil, IESB & BirdLife International 2009. Complexo Serra das Lontras e Una, Bahia: Elementos naturais e aspectos de sua conservação. SAVE Brasil, São Paulo.

SMITH, L.B. & DOWNS, R.J. 1979. Bromelioideae (Bromeliaceae). Flora neotrop. 14(3): 1-649.

STADTMÜLLER, T. 1987. Cloud Forests in the Humid Tropics: A bibliographic review. http://archive.unu.edu/unupress/unupbooks/80670e/80670E00.htm#Contents (accessed in 08/2012).

STEHMANN, J.R., FORZZA, R.C., SOBRAL, M. & KAMINO, L.H.Y. 2009. Gimnospermas e Angiospermas. In Plantas da Floresta Atlântica (J.R. STEHMANN, R.C. FORZZA, A. SALINO, M. SOBRAL, D.P. COSTA & L.H.Y. KAMINO, EDS.). JARDIM BOTÂNICO DO RIO DE JANEIRO, RIO DE JANEIRO. P. 27-37.

SUDGEN, A. & ROBINS, R. 1979. Aspects of the Ecology of Vascular Epiphytes in Colombian Cloud Forests, I. The Distribution of the epiphytic flora. Biotropica 11(3): 173-188. doi: http://dx.doi.org/10.2307/2388037

TAYLOR, P. 1989. The genus Utricularia - a taxonomic monograph. Kew Bulletin, Additional Series XIV, London.

THOMAS, W.W., CARVALHO, A.M.V., AMORIM, A.M., GARRISON, J. & ARBELÁEZ, A.L. 1998. Plant endemism in two forests in southern Bahia, Brazil. Biodivers. Conserv. 7(3): 311-322. doi: http://dx.doi.org/10.1023/A:1008825627656

THOMAS, W.W., JARDIM, J.G., FIASCHI, P., MARIANO-NETO, E. & AMORIM, A.M. 2009. Composição florística e estrutura do componente arbóreo de uma área transicional de Floresta Atlântica no sul da Bahia, Brasil. Rev. Bras. Bot. 32(1): 65-78. doi: http://dx.doi.org/10.1590/S0100-84042009000100007

WOLF, J.H.D. & FLAMENCO-S, A. 2003. Patterns in species richness and distribution of vascular epiphytes in Chiapas, Mexico. J. biogeogr. 30: 1689-1707. doi: http://dx.doi.org/10.1046/j.1365-2699.2003.00902.x

ZOTZ, G. 2013. The systematic distribution of vascular epiphytes – a critical update. Bot. j. Linn. Soc. 171: 453-481. doi: http://dx.doi.org/10.1111/boj.12010

Received 01/08/2013
Accepted 14/02/2014

Biota Neotropica 14(2): e20130084, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Allometric equations for estimating tree biomass in restored mixed-species Atlantic Forest stands

Lauro Rodrigues Nogueira Junior[1,5], *Vera Lex Engel*[2], *John A. Parrotta*[3], *Antonio Carlos Galvão de Melo*[4] *& Danilo Scorzoni Ré*[2]

[1]*Empresa Brasileira de Pesquisa Agropecuária (Embrapa), Caixa Postal 44, CEP 49025-040, Aracaju, SE, Brasil. www.cpatc.embrapa.br*
[2]*Universidade Estadual Paulista "Julio de Mesquita Filho" (UNESP), Faculdade de Ciências Agronômicas, Departamento de Ciências Florestais, Caixa Postal 237, CEP 18610-307, Botucatu, SP, Brasil. www.fca.unesp.br*
[3]*USDA Forest Service, Research & Development, 1601 N. Kent Street, Arlington VA 22209, USA. www.fs.fed.us/research/*
[4]*Instituto Florestal de São Paulo (IF-SP), Floresta Estadual de Assis, Caixa Postal 104, CEP 19802-300, Assis, SP, Brasil. www.iflorestal.sp.gov.br*
[5]*Corresponding author: e-mail: lauro.nogueira@embrapa.br*

NOGUEIRA JUNIOR, L.R., ENGEL, V.L., PARROTTA, J.A., MELO, A.C.G., RÉ, D.S. **Allometric equations for estimating tree biomass in restored mixed-species Atlantic Forest stands.** Biota Neotropica. 14(2): e20130084. http://dx.doi.org/10.1590/1676-06032013008413

Abstract: Restoration of Atlantic Forests is receiving increasing attention because of its role in both biodiversity conservation and carbon sequestration for global climate change mitigation. This study was carried out in an Atlantic Forest restoration project in the south-central region of São Paulo State – Brazil to develop allometric equations to estimate tree biomass of indigenous tree species in mixed plantations. Above and below-ground biomass (AGB and BGB, respectively), stem diameter (DBH: diameter at 1.3 m height), tree height (H: total height) and specific wood density (WD) were measured for 60 trees of 19 species. Different biomass equations (linear and nonlinear-transformed) were adjusted to estimate AGB and BGB as a function of DBH, H and WD. For estimating AGB and BGB, the linear biomass equation models were the least accurate. The transformed nonlinear biomass equation that used log DBH^2, log H and log WD as predictor variables were the most accurate for AGB and the transformed nonlinear biomass equations that used log $DBH^{2}*WD$ as predictor variables were the most accurate for BGB. It is concluded that these adjusted equations can be used to estimate the AGB and BGB in areas of the studied project. The adjusted equations can be recommended for use elsewhere in the region for forest stands of similar age, tree size ranges, species composition and site characteristics.
Keywords: *Above-ground biomass, Below-ground biomass, Biomass equation, Tree allometry, Atlantic Forest, Restoration.*

NOGUEIRA JUNIOR, L.R., ENGEL, V.L., PARROTTA, J.A., MELO, A.C.G., RÉ, D.S. **Equações alométricas para estimativa da biomassa arbórea em plantios mistos com espécies nativas na restauração da Mata Atlântica.** Biota Neotropica. 14(2): e20130084. http://dx.doi.org/10.1590/1676-06032013008413

Resumo: A restauração da Mata Atlântica vem recebendo aumento na atenção por causa do papel na conservação da biodiversidade e sequestro de carbono para a mitigação da mudança global do clima. Este estudo foi conduzido em um projeto de restauração da Mata Atlântica na região centro-sul do Estado de São Paulo – Brasil e buscou desenvolver equações alométricas para estimar a biomassa arbórea de espécies nativas em plantios mistos. Em 60 árvores de 19 espécies foram medidas a biomassa acima e abaixo do solo, o diâmetro do tronco (DAP: diâmetro a 1,3 m de altura), altura (H) e densidade específica da madeira (Ds). Diferentes equações de biomassa (linear e não linear) foram ajustadas para estimar a biomassa acima e abaixo do solo, utilizando DAP, H e Ds como variáveis preditoras. As equações de biomassa lineares foram as menos acuradas para a estimativa da biomassa acima e abaixo do solo. As equações de biomassa não lineares que usaram log DAP^2, log H e log Ds como variáveis preditoras foram mais acuradas para a estimativa da biomassa acima do solo e as não lineares que usaram log $DBH^{2}*WD$ como variáveis preditoras foram as mais acuradas para a estimativa da biomassa abaixo do solo. Conclui-se que estas equações ajustadas podem ser usadas na estimativa da biomassa acima e abaixo do solo nas áreas do projeto estudado. Também pode ser considerado o uso destas equações ajustadas em outras áreas restauradas da Mata Atlântica com idade do povoamento, classes de tamanho das árvores, composição de espécies e características das áreas similares ao deste estudo, desde que árvores sejam avaliadas para verificar a eficácia da equação a ser usada.

Palavras-chave: *Biomassa acima do solo, Biomassa abaixo do solo, Equação de biomassa, Alometria, Mata Atlântica, Restauração.*

Introduction

The restoration of Brazil's Atlantic Forest on degraded lands and riparian areas is receiving increasing attention in the development of public policies for biodiversity conservation and climate change mitigation purposes, with increasing funds available for this purpose through public and private programs and international cooperation (Rodrigues et al. 2009, Rodrigues et al. 2011, Calmon et al. 2011). An area of particular interest is the capacity of these restored forests to absorb atmospheric carbon dioxide and thereby enhance their role as a carbon sink. Accurate estimates of carbon sequestration in these restored forests require development of equations for accurately estimating tree biomass in mixed native species stands.

Tree biomass is an important characteristic of forest ecosystems, reflecting the accumulation of organic carbon and ecosystem productivity (Dixon et al. 1994, Clark et al. 2001, Masera et al. 2003, Grace 2004, Lal 2005) and it can be an important indicator for monitoring the developmentof restored ecosystems (Naeem et al. 2009). Moreover, accurate tree biomass estimates permit comparisons between restored and reference sites and estimates of nutrient stocks in tree compartments of the ecosystem.

There are several indirect methods for tree biomass estimates, such as allometric equations, most of which use a combination of predictor variables such as tree stem diameter, total height and wood density (Saldarriaga et al. 1988, Brown et al. 1989, Overman et al. 1994, Brown 1997, Nelson et al. 1999, Chave et al. 2005, Cole & Ewel 2006). According to Chave et al. (2005), the most important variables for predicting above-ground biomass are, in decreasing order of importance, tree stem diameter, woody specific density, tree height, and forest type. To select biomass equations models, the Akaike Information Criterion (AIC) provides a simple, effective and direct way to select the variables that will produce the best fitting model (Burnham & Anderson 2010).

Multi-species biomass equations are usually based on tree data from primary forests, which usually have different tree architectures than those found in planted (restoration) forests, and typically do not estimate root biomass (Brown et al. 1989, Brown 1997, Nelson et al. 1999, Chave et al. 2005). Miranda et al. (2011) developed and fitted allometric models to estimate dry biomass in trees (including both Cerrado and Atlantic forest species) planted in forest restoration areas ranging in age between 5 and 36 years. In their work, the best results were obtained by stepwise procedures with stratification of species by growth rates. However, equations models for estimating tree biomass in multispecies restoration projects are scarce; equations obtained from trees in natural mature forests are usually used for biomass and carbon estimations in restoration projects (Melo e Durigan 2006), in spite of the differences between tree structural patterns in these two different conditions. Here, we aimed at refining allometric equations for estimating biomass of trees planted in an Atlantic Forest restoration project in Brazil, to be used to assess the role of different plantations systems as carbon sinks.

Materials and Methods

The study sites were located at the São Paulo State University (UNESP) Experimental Farm, Botucatu, south-central region of São Paulo State, Brazil (22°52'32''S and 48°26'46''W). According to Köeppen's classification the climate is Cfa. Annual rainfall averages 1,494 mm with the rainy season lasting from October to March. Annual mean temperature is 20.5°C, with the minimum average occurring in July and maximum in February. The natural vegetation is a semi-deciduous tropical moist forest within the Atlantic Forest biome range.

The experiment was undertaken at two sites with Ultisol (22°49'39''S and 48°25'55''W) and Alfisol (22°48'54''S and 48°24'56''W) soils, respectively. At each site an experiment with 5 treatments and three replicates (random blocks design) was established from 1997 to1998, with each plot measuring 50 x 50 m. Treatments ranged from passive restoration (control plots) to a high-diversity native tree species mixture, and included a direct seeding system, an agroforestry system and a commercial species mixture (Engel & Parrotta 2001, Siddique et al. 2008, Nogueira Jr et al. 2011).

In 2009 we sampled 19 of the native tree species (Table 1) included in the experimental treatments (Control, Direct Seeding and High-Diversity Seedling Planting). These species represent more than 95% of the basal area in the restoration plots, based on previous inventories. They included two ecological groups (fast growing pioneer and slower growing secondary species. All selected individuals were located inside the restoration plots at least 10 m from the edge boundaries. Three individuals of each species, representing the range of tree sizes for each species, were sampled in the restoration treatments, by measuring diameter at breast height (DBH) and total height (H). Only for *Psidium guajava* six individuals were sampled, three in understory of Direct Seeding and High-Diversity Seedling Planting treatment and three in open area of Control treatment. For trees with more than one stem, we calculated the equivalent DBH:

$$equivalent\ DBH = \sqrt{dbh1^2 + dbh2^2 + dbh3^2 \ldots\ dbhn^2}$$

where, dbh = diameter at breast height of each stem

Among the trees sampled, tree heights ranged from 2.7 to 15.8 m and stem diameters ranged from 2 to 33 cm (Table 1). After being measured, each tree was felled and tree biomass was quantified by the direct method. For above-ground biomass (AGB) three compartments were considered: 1) *leaves* - leaves and twigs with diameters up to 1 cm; 2) *twigs/branches* - woody material of crown of the tree up to a minimum diameter of 1 cm; 3) *stem* - the main wooden axis of a tree, located between the base and the crown of the tree. For below-ground biomass (BGB) only roots with diameters >1 cm were considered. Roots were excavated manually for small trees and with the aid of a retro bulldozer for medium and large trees.

The fresh weight of each individual tree and its components was determined in the field using a dynamometer with capacity

Table 1. Diameter at breast height (DBH), height and specific wood density (WD) of each sampled tree (large (L), medium (M) and small (S)), for 19 native tree species (60 harvested trees) assessed by the direct method to quantify biomass.

Botanical Family	**Species**	**DBH**			**Height**			**WD**		
		L	**M**	**S**	**L**	**M**	**S**	**L**	**M**	**S**
			cm			m			g cm^{-3}	
Fab. Mimosoideae	*Piptadenia gonoacantha* J.F. Macbr.	33.3	14.0	4.0	13.6	9.1	5.0	0.54	0.51	0.46
Fab. Faboideae	*Schizolobium parahyba* S.F. Blake	26.1	19.3	13.1	15.8	12.1	11.7	0.29	0.29	0.25
Fab. Mimosoideae	*Parapiptadenia rigida* Brenan	25.8	13.1	7.0	7.1	7.2	5.9	0.60	0.43	0.61
Euphorbiaceae	*Croton floribundus* Spreng.	24.7	19.7	11.0	12.9	9.6	7.0	0.38	0.39	0.35
Anacardiaceae	*Schinus terebinthifolius* Raddi	22.9	17.4	11.5	7.1	7.2	5.9	0.49	0.51	0.47
Verbenaceae	*Citharexylum myrianthum* Cham.	21.7	15.0	11.4	10.7	11.0	8.7	0.40	0.35	0.38
Fab. Mimosoideae	*Enterolobium contorstisiliquum* Morong	19.7	12.8	6.7	10.1	5.2	4.9	0.31	0.28	0.23
Tiliaceae	*Luehea divaricata* Mart.	16.4	11.5	7.2	7.5	6.0	5.8	0.47	0.38	0.42
Boraginaceae	*Cordia superba* Cham.	14.9	9.7	4.9	7.2	6.8	5.5	0.35	0.33	0.29
Cecropiaceae	*Cecropiapachystachia* Trécul	14.4	12.5	9.7	13.0	10.0	8.1	0.41	0.39	0.35
Fab. Faboideae	**Lonchocarpus cultratus* Vell.	13.8	7.1	2.0	8.5	5.8	2.7	0.49	0.42	0.32
Fab. Faboideae	*Machaerium stipitatum* Vogel	11.2	7.3	4.4	9.8	6.9	4.8	0.35	0.36	0.31
Fab. Faboideae	*Centrolobium tomentosum* Guillemin ex Benth	10.9	8.6	6.4	9.9	9.5	9.7	0.54	0.52	0.39
Fab. Faboideae	*Pterogyne nitens* Tul.	9.9	6.9	3.2	8.9	5.9	4.3	0.54	0.52	0.37
Verbenaceae	**Aloysia virgata* Pers.	8.6	7.4	3.9	9.0	8.0	4.7	0.59	0.61	0.61
Fab. Caesalpinoideae	*Hymenea courbaril* Y.T. Lee&Langenh	8.0	5.7	2.6	8.0	5.4	3.3	0.54	0.53	0.54
Apocynaceae	**Peschiera fuchsiaefolia* Miers	6.8	5.0	3.1	7.0	4.6	4.1	0.38	0.39	0.35
Fab. Faboideae	*Dipteryx alata* Vogel	6.8	4.7	4.1	6.3	5.4	4.0	0.55	0.45	0.45
Myrtaceae	*[1]*Psidium guajava* L.	6.0	4.7	3.4	7.0	4.6	4.9	0.53	0.50	0.48
Myrtaceae	*[2]*Psidium guajava* L.	5.9	5.5	4.5	3.4	4.1	3.0	0.54	0.51	0.46

* Naturally regeneration (not planted) trees.
[1] Understory trees and [2] open area trees (for *P. guajava*).

for 200 kg and precision of 50 g. To determine the dry weight of each tree we first estimated the moisture content of each compartment by taking around 2 kg (fresh weight) of leaves, twigs/branches and roots, and five 3-5 cm thick disks (one near the base and the others at 25, 50, 75 and 95% of the stem height) for each stem. Two wedges were taken from each disk, one for determining the moisture content and the other for specific wood density (WD). In the laboratory the fresh samples of leaves, twigs/branches, stems and roots were weighed, oven-dried at 70°C to constant weight - approximately seven days. The dry weight of individual tree compartments were calculated using fresh weight ratios obtained from these samples. Wood density was analyzed by the Maximum Moisture Content method (Foelkel et al. 1971). The WD for each tree was computed as the arithmetic average of the five discs.

Above and belowground biomass (AGB and BGB) data were subjected to regression analyses, considering as predictor variables the DBH (cm), DBH^2 (cm^2), H (m) and WD (g cm^{-3}). For assessment of goodness of fit of biomass equations four indicators are reported: 1) standard error of parameter estimate of the predictor variables; 2) $P > |t|$, the probability that a t statistic would have a greater absolute value than observed one, given that the true parameter is zero; 3) coefficient of variation, computed percent ratio between the standard deviation of the error term divided by sample mean of the dependent variable; and 4) Akaike Information Criterion (AIC; Burnham & Anderson 2010), based on likelihood and complexity of equation models. Biomass equations having a t value probability > 0.05 for any predictor variable (DBH, DBH^2, H and WD) or intercept and biomass equations having coefficient of variation $> 70\%$ were rejected. The equations models were compared using AIC, choosing the best model the one with smaller AIC. AIC's differences less than 10 indicate similarity among models, and AIC's difference greater than 10 indicate difference among models. Graphical analysis of the error of estimated biomass in relation to the observed biomass was used. The correlation of the predictor variables DBH^2, WD and H with the dependent variables AGB and BGB were assessed. All analysis were conducted using SAS version 9.2 (SAS Institute 2009) except the AIC that was conducted using R (R Development Core Team 2011).

Results

The partitioning of dry biomass between the compartments of the 19 tree species evaluated was highly variable, did not show any pattern among species (Figure 1), and was probably due simply to different sizes of the trees (Table 1). From the aggregate data from the 60 trees measured, twigs/branches represented 38%, stems 33%, roots 20% and leaves only 8% of total tree biomass (4,260 kg). The average biomass per tree was 71 Kg (twigs/branches 27 Kg, stem 24 Kg, roots 14 Kg and leaves 6 Kg).

The correlation of the predictor variables DBH^2, WD and H with the dependent variables AGB and BGB (Figure 2) were higher in the logarithmic models (Figure 2g, 2h, 2i, 2j, 2k and 2l) than in the arithmetic ones (Figure 2a, 2b, 2c, 2d, 2e and 2f).

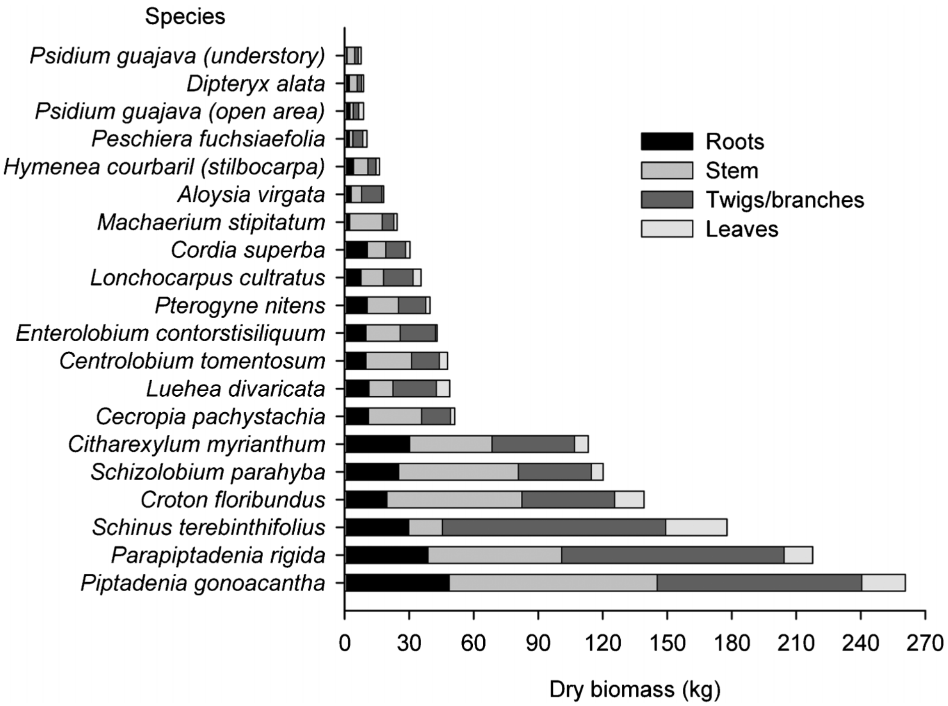


Figure 1. Average tree biomass (n = 3) by compartment in 19 species from an experimental area of Atlantic Forest restoration project.

Among the predictor variables (DBH^2, H and WD) the DBH^2 had the highest correlation with biomass (AGB and BGB). However, biomass equations using only DBH did not meet the required conditions to be accepted, regarding the arbitrated values of indicators.

For aboveground biomass (AGB) estimates, eight equations models (Table 2) were selected. Equations 4, 5 and 7 were the best fitted, with lower coefficient of variation and AIC. Equations 1 and 2 showed the lowest goodness of fit, with residues not uniformly distributed along the x-axis (Figure 3), mainly for trees $<$ 10 cm DBH. However, log-transformed equations showed a higher goodness of fit and lower error of estimated biomass. By AIC the best models to AGB were the models 5, 7 and 4, respectively.

For belowground biomass (BGB) estimates, six equation models were selected (Table 2). The log-transformed equations 11 and 13 were the best fitted regarding their lower coefficient of variation, lower error of estimated biomass and lower AIC. Similar to AGB, the untransformed equation (equation 9) led to the lowest goodness of fit, with higher coefficient of variation and AIC value (Table 2). By AIC the best models to BGB were the models 13 and 11, respectively.

Discussion

In general, most trees had a higher proportion of twigs/branch biomass than stem biomass, when compared to other studies undertaken in natural forests that involved a wider range of tree sizes (Chave et al. 2005). Only few species (*M. stipitatum, C. tomentosum, C. pachystachia, S. parahyba, C. floribundus, H. courbaril* and *D. alata*) had a higher proportion of biomass in stem than in other aboveground biomass components. In this experiment, trees were still young, around 11-12 years old, and therefore their architectural development was not completed yet, with poor stem development. Stem biomass will probably increase over time, when the tree individuals increase their DBH as well as WD. Furthermore, since the stands not yet completely stocked, higher availability of light stimulates greater branch development, in contrast to what occurs in more dense natural forests, where stronger light competition reduces branch formation and a higher investment in stem growth. This can be observed by the contrasting biomass allocation of *Psidum guajava* where trees growing in the understory had a higher proportion of stem than tress growing in full sunlight.

Since average root biomass was 20%, the BGB compartment represents an important component of total stand biomass. Fonseca et al. (2012) found a percentage of 22% of coarse roots in total tree biomass of native forest plantations in the humid tropical lowlands of Costa Rica. In a New Zealand beech (*Nothofagus*) forest ecosystem, roots represented 22% of total live tree biomass (Hart et al.2003). Root biomass or BGB is often expressed as a proportion to AGB, such as a root-shoot ratio (R/S ratio). The R/S ratio was 0.25, similar to forests in tropical zones (0.24, Cairns et al. 1997), montane moist forests (0.22, Sanford & Cuevas 1996) and New Zealand beech forest ecosystems (0.28, Hart et al. 2003). This indicates that studies focusing only in above ground biomass will be considerably underestimating the capacity of forest to stock carbon in projects that aim at climate change mitigation.

Tree height is well-known as an important indicator of site quality (Teshomea & Petty 2000) and together with DBH defines the main structural pattern of forest systems. While inclusion of both DBH and H in regression equations for biomass estimation is usually recommended (Silveira et al. 2008), in our analysis the use of only DBH^2 and H in equations 6 and 12 led to low goodness of fit, except when WD was included (in equations 5, 8 and 14), reducing the error of estimated biomass. However, the equations 6 and 12 that only use DBH^2 and H as predictor variables is not recommended to

http://dx.doi.org/10.1590/1676-06032013008413

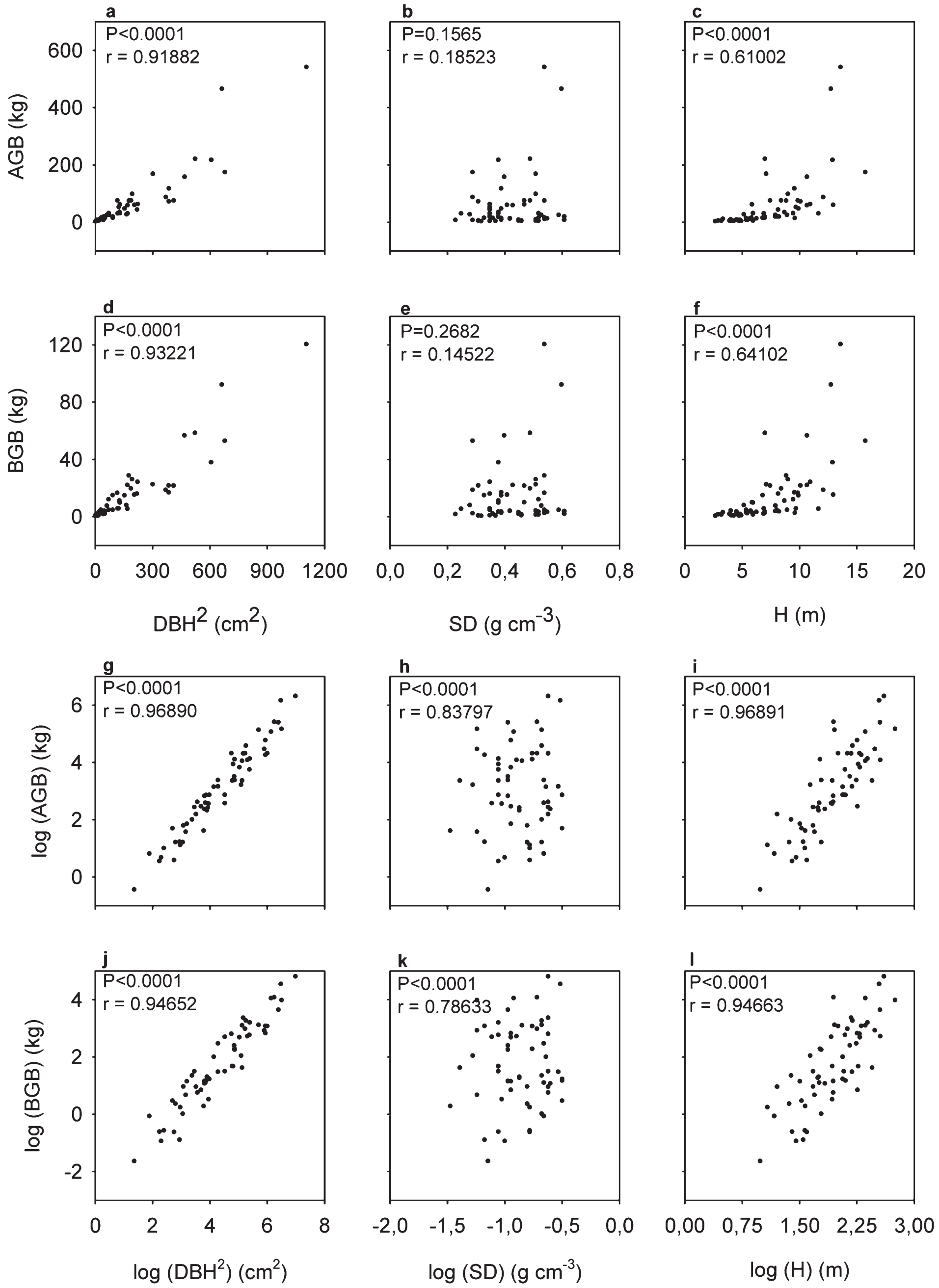


Figure 2. Pearson correlation between predictor variables (DBH, WD and H) and dry biomass (aboveground biomass – AGB and belowground biomass – BGB) for 60 trees of 19 Atlantic Forest species.

biomass estimate because of low goodness of fit.

Only WD correlated [?] with DBH^2 (equations 4 and 7 for AGB and equations 11 and 13 for BGB) provided good predictions of biomass. This may be attributed to the influence of WD in the variation of dry biomass between species and individuals of different sizes. For example, if only DBH^2 and H are used as predictor variables an underestimation of biomass for small trees having high WD such as *A virgata* and *P. guajava* and an overestimation of the biomass for large trees having low WD like *S. parahyba* are expected.

Estimates of forest biomass using different equations have led to very contrasting results. In the Brazilian Atlantic Forest, different models produced considerably different biomass estimates (Vieira et al. 2008, Lindner & Sattler 2012). However, for Vieira et al. 2008 pantropical models of biomass equations (c.f. Chave et al. 2005), using DBH^2, H and WD as predictor variables may be used to estimate above-ground tree biomass in the Atlantic Forest. Nevertheless, in the present study Chave et al. (2005)'s equation underestimated tree AGB, with an estimation of 1,885 Kg. This may be due to the fact that our study included trees with different DBH and H ranges (and different tree architectures), with many small individuals in these young forest stands in the early stage of reforestation (low average WD). It should be noted that equations used to estimate biomass, here or anywhere, first need to be based on the appropriate range of tree sizes, and secondarily to the range

Table 2. Regression analyses (N = 60) and Akaike Information Criterion (AIC) for equations models of above- and belowground biomass (AGB and BGB, respectively) of 19 native tree species used in the Atlantic Forest restoration project.

Biomass equation models	Parameter Estimate		Standard error	P > |t|	Coefficient of variation	AIC
	Symbol	Value				
AGB						
1) $AGB = \alpha + \beta(DBH^2)$	α	-13.127	6.4131	0.0452	68.76	614.3
	β	0.428	0.0242	<0.0001		
2) $AGB = \alpha + \beta_1(DBH^2) + \beta_2(WD)$	α	-100.353	20.1404	<0.0001	59.56	598.0
	β_1	0.430	0.0209	<0.0001		
	β_2	200.402	44.4777	<0.0001		
3) $\log(AGB) = \alpha + \beta\log(DBH^2)$	α	-1.890	0.1718	<0.0001	12.41	419.9
	β	1.127	0.0378	<0.0001		
4) $\log(AGB) = \alpha + \beta_1\log(DBH^2) + \beta_2\log(WD)$	α	-1.027	0.1710	<0.0001	8.97	382.4
	β_1	1.144	0.0274	<0.0001		
	β_2	1.085	0.1477	<0.0001		
5) $\log(AGB) = \alpha + \beta_1\log(DBH^2) + \beta_2\log(H) + \beta_3\log(WD)$	α	-1.305	0.2067	<0.0001	8.67	379.4
	β_1	1.055	0.0479	<0.0001		
	β_2	0.340	0.1519	0.0292		
	β_3	1.077	0.1428	<0.0001		
6) $\log(AGB) = \alpha + \beta\log(DBH^2 * H)$	α	-2.541	0.1987	<0.0001	12.76	422.9
	β	0.883	0.0305	<0.0001		
7) $\log(AGB) = \alpha + \beta\log(DBH^2 * WD)$	α	-0.970	0.1015	<0.0001	8.96	380.6
	β	1.142	0.0272	<0.0001		
8) $\log(AGB) = \alpha + \beta\log(DBH^2 * H * WD)$	α	-1.853	0.1312	<0.0001	9.66	389.5
	β	0.896	0.0231	<0.0001		
BGB						
9) $BGB = \alpha + \beta_1(DBH^2) + \beta_2\log(WD)$	α	-17.381	4.2857	0.0002	51.18	412.3
	β_1	0.097	0.0045	<0.0001		
	β_2	35.903	9.4645	0.0004		
10) $\log(BGB) = \alpha + \beta\log(DBH^2)$	α	-2.960	0.2177	<0.0001	27.78	290.9
	β	1.072	0.0479	<0.0001		
11) $\log(BGB) = \alpha + \beta_1\log(DBH^2) + \beta_2\log(WD)$	α	-2.134	0.2570	<0.0001	23.83	273.6
	β_1	1.088	0.0412	<0.0001		
	β_2	1.038	0.2221	<0.0001		
12) $\log(BGB) = \alpha + \beta\log(DBH^2 * H)$	α	-3.535	0.2655	<0.0001	30.12	300.5
	β	0.832	0.0408	<0.0001		
13) $\log(BGB) = \alpha + \beta\log(DBH^2 * WD)$	α	-2.086	0.1518	<0.0001	23.68	271.7
	β	1.086	0.0407	<0.0001		
14) $\log(BGB) = \alpha + \beta\log(DBH^2 * H * WD)$	α	-2.887	0.2051	<0.0001	26.65	285.9
	β	0.845	0.0361	<0.0001		

DBH = diameter at breast height (1.3 m) height; H = total height; WD = specific wood density.

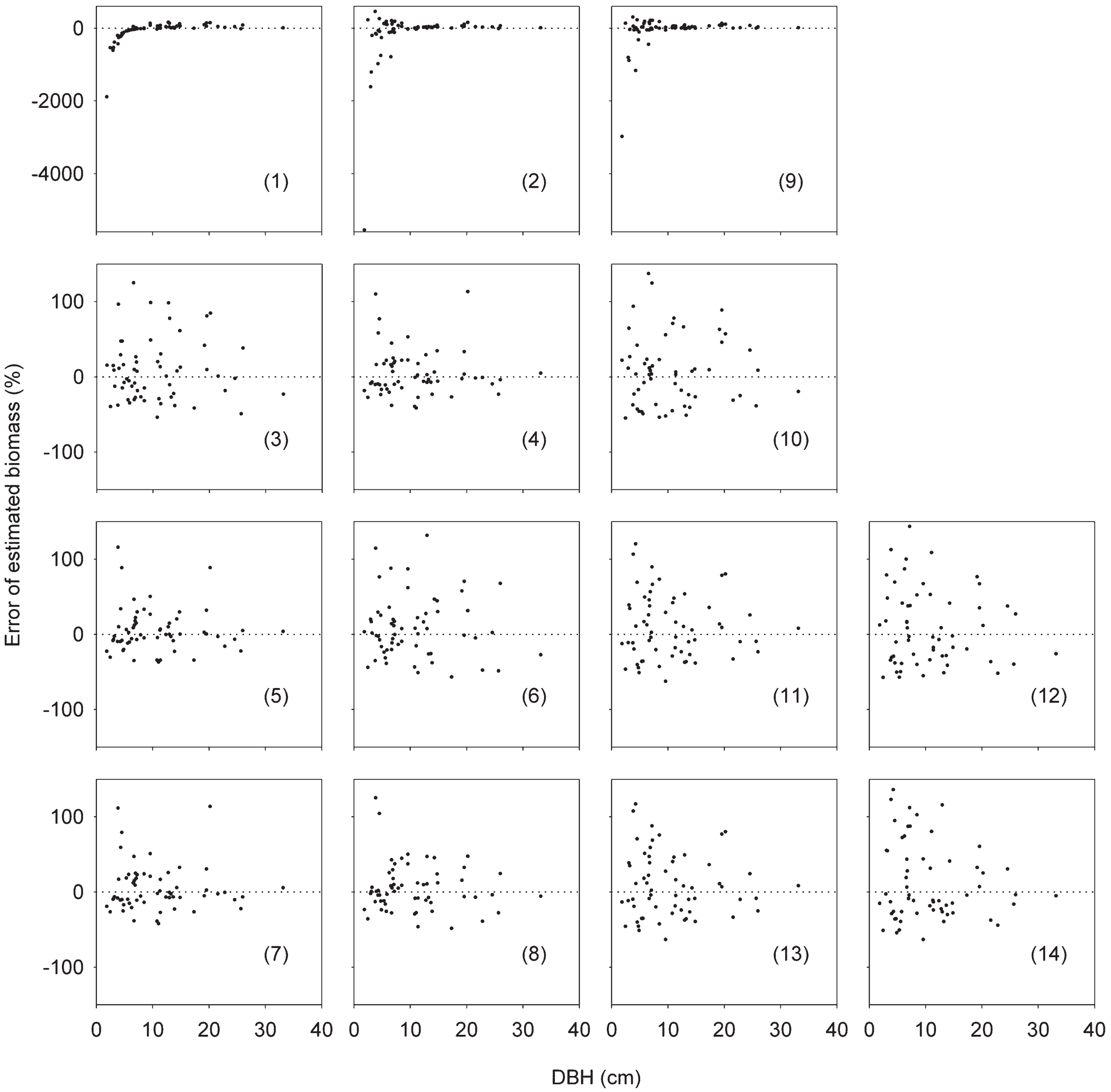


Figure 3. Residual analysis (error plots of estimated biomass (%) by the observed biomass) for14 equation models trees of 19 Atlantic Forest species. Biomass equation models for above- and belowground biomass (AGB and BGB):(1) $\mathrm{AGB}=\alpha+\beta(\mathrm{DBH}^2)$; (2) $\mathrm{AGB}=\alpha+\beta_1(\mathrm{DBH}^2)+\beta_2(\mathrm{WD})$; (3) $\log(\mathrm{AGB})=\alpha+\beta\log(\mathrm{DBH}^2)$; (4) $\log(\mathrm{AGB})=\alpha+\beta_1\log(\mathrm{DBH}^2)+\beta_2\log(\mathrm{WD})$; (5) $\log(\mathrm{AGB})=\alpha+\beta_1\log(\mathrm{DBH}^2)+\beta_2\log(\mathrm{H})+\beta_3\log(\mathrm{WD})$; (6) $\log(\mathrm{AGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{H})$; (7) $\log(\mathrm{AGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{WD})$; (8) $\log(\mathrm{AGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{H}*\mathrm{WD})$;(9) $\mathrm{BGB}=\alpha+\beta_1(\mathrm{DBH}^2)+\beta_2(\mathrm{WD})$; (10) $\log(\mathrm{BGB})=\alpha+\beta\log(\mathrm{DBH}^2)$; (11) $\log(\mathrm{BGB})=\alpha+\beta_1\log(\mathrm{DBH}^2)+\beta_2\log(\mathrm{WD})$; (12) $\log(\mathrm{BGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{H})$; (13) $\log(\mathrm{BGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{WD})$; (14) $\log(\mathrm{BGB})=\alpha+\beta\log(\mathrm{DBH}^2{*}\mathrm{H}*\mathrm{WD})$.

of tree architectural types found in the forest where such equations will be applied.

The sampling error in forest inventory estimates has two main components (Parresol 1999). The first is the component related to random selection of sample units and the second component is associated with the error of the regression model itself. In the present study, the 19 tree species sampled represent more than 95% of the restoration plots basal area, be in the Control, Direct Seeding and High-Diversity Seedling Plantings. The three harvested individuals of each species represent the range of sizes which were found in the planting sites. Regarding the regression errors they were high for equations 1, 2 (for aboveground biomass) and 9 (for belowground biomass), suggesting that the use of untransformed log equations is inadequate to estimate tree biomass in forest plantations.

To reduce the error of estimated biomass the use of log-transformed biomass equations was more appropriated, such as the equation 5 for AGB and the equation 13 to BGB which had a better goodness of fit. Finally, we concluded that in decrease order the better equations for above- and belowground biomass estimate in restored areas are:

$$\log(\mathrm{AGB}) = -1.305 + 1.055\log(\mathrm{DBH}^2) + 0.34\log(\mathrm{H}) + 1.077\log(\mathrm{WD})$$

$$\log(AGB) = -0.970 + 1.1421 \log(DBH^2 * WD)$$

$$\log(AGB) = -1.027 + 1.144 \log(DBH^2) + 1.085 \log(WD)$$

and

$$\log(BGB) = -2.086 + 1.086 \log(DBH^2 * WD)$$

$$\log(BGB) = -2.134 + 1.088 \log(DBH^2) + 1.038 \log(WD)$$

However, log-transformed biomass equations may be only applicable to mixed plantations with tree DBH, H and WD ranges similar to the ones showed in Table 1. Provided that there are similarities in species composition, the biomass equations presented here may be useful for application on a local and regional scale. Although these biomass equations may be applied in the context of the Atlantic Forest restoration, for projects focusing on environmental services like carbon sequestration, it is suggested that some tree individuals be evaluated by direct (destructive) method to verify whether the equation to be used overestimates or underestimates tree biomass (Brown 1997).

Conclusions

The logarithmically-transformed equation that use diameter at breast height, total height and specific wood density as predictor variables are the most accurate equation for estimating above-ground biomass. Furthermore, the logarithmically-transformed equations that use diameter at breast height and specific wood density as predictor variables showed good accuracy for estimating above- and below-ground biomass. These biomass equations may be recommended for estimating tree biomass in Atlantic Forest restoration projects, providing some similarity in species composition, age or structural development, and site characteristics.

Acknowledgements

The project received grants from São Paulo Research Foundation (FAPESP) and National Council of Research and Technology (CNPq). The first author received a Ph.D. Scholarship from FAPESP, Process 2006/06315-0. The second author thanks also to CNPq for the Research Productivity Fellowship. We thank all the students and staff members of the Laboratory of Ecology and Forest Restoration of São Paulo State University (LERF/UNESP) and employees of the Agronomic Sciences College (FCA/UNESP) for field assistance, and in particular Aparecido Agostinho Arruda and Elder Candido Mattos. We also thank A.V. Teodoro (Brazilian Agricultural Research Corporation – Embrapa) for comments on previous versions of the manuscript.

References

BROWN, S., GILLESPIE, A. & LUGO A. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science 35: 881-902.

BROWN, S. 1997. Estimating biomass and biomass change of tropical forest: a primer. FAO Forestry Paper - 134, Rome.

BURNHAM, K.P. & ANDERSON, D.R. 2010. Information and likelihood theory: A basis for model selection and inference.In Model selection and multimodel inference: A practical information-theoretic approach (K.P. Burnham & D.R. Anderson, eds). Springer Science, New York, 2nd ed, chap 2, pp 49-97.

CAIRNS, M.A., BROWN, S., HELMER, E.H. & BAUMGARDNER, G.A. 1997. Root biomass allocation in the world's upland forests. Oecologia 111: 1-11.

CALMON, M., BRANCALION, P., PAESE, A., ARONSON, J., CASTRO, P., DA SILVA, S & RODRIGUES, R. 2011. Emerging Threats and Opportunities for Large-Scale Ecological Restoration in the Atlantic Forest of Brazil. Restoration Ecology 19: 154-158.

CHAVE, J., ANDALO, C., BROWN, S., CAIRNS, M., CHAMBERS, J., EAMUS, D., FOLSTER, H., FROMARD, F., HIGUCHI, N., KIRA, T., LESCURE, J., NELSON, B., OGAWA, H., PUIG, H., RIERA, B. & YAMAKURA, T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99.

CLARK, D., BROWN, S., KICKLIGHTER, D., CHAMBERS, J., THOMLINSON, J. & NI, J. 2001. Measuring net primary production in forests: Concepts and field methods. Ecological Applications 11: 356-370.

COLE, T. & EWEL, J. 2006. Allometric equations for four valuable tropical tree species. Forest Ecology and Management 229: 351-360.

DIXON, R., BROWN, S., HOUGHTON, R., SOLOMON, A., TREXLER, M. & WISNIEWSKI, J. 1994. Carbon pools and flux of global forest ecosystems. Science 263: 185-190.

ENGEL, V. & PARROTTA, J. 2001. An evaluation of direct seeding for reforestation of degraded lands in central Sao Paulo state, Brazil. Forest Ecology and Management 152: 169-181.

FOELKEL, C., BRASIL, M. & BARRICHELO, L. 1971. Métodos para determinação da densidade básica de cavacos para coníferas e folhosas. IPEF 2/3:65-74.

FONSECA, W., ALICE, F.E. & REY-BENAYAS,J. 2012. Carbon accumulation in aboveground and belowground biomass and soil of different age native forest plantations in the humid tropical lowlands of Costa Rica. New Forests 43: 197-211.

GRACE, J. 2004. Understanding and managing the global carbon cycle. Journal of Ecology 92: 189-202.

HART, P., CLINTON, P., ALLEN, R., NORDMEYER, A. &, EVANS, G. 2003. Biomass and macro-nutrients (above- and below-ground) in a New Zealand beech (Nothofagus) forest ecosystem: implications for carbon storage and sustainable forest management. Forest Ecology and Management 174: 281-294.

LAL, R. 2005. Forest soils and carbon sequestration. Forest Ecology and Management 220: 242-258.

LINDNER, A. & SATTLER, D. 2012. Biomass estimations in forests of different disturbance history in the Atlantic Forest of Rio de Janeiro, Brazil. New Forests 43: 287-301.

MASERA, O., GARZA-CALIGARIS, J., KANNINEN, M., KARJALAINEN, T., LISKI, J., NABUURS, G., PUSSINEN, A., DE JONG, B & MOHREN, G. 2003. Modeling carbon sequestration in afforestation, agroforestry and forest management projects: the CO2FIX V.2 approach. Ecological Modelling 164: 177-199.

MELO, A. &DURIGAN, G. 2006. Fixação de carbono em reflorestamentos de matas ciliares no Vale do Paranapanema, SP, Brasil. Scientia Forestalis 71: 149-154.

MIRANDA, D.,MELO, A. &SANQUETTA, C. 2011. Equações alométricas para estimativa de biomassa e carbono em árvores de reflorestamentos de restauração. Revista Árvore 35: 679-689.

NAEEM, S., BUNKER, D., HECTOR, A., LOREAU, M. & PERRINGS, C. 2009. Biodiversity, ecosystem functioning and human wellbeing: An ecological and economic perspective. Oxford: Oxford University Press, 384p.

NELSON, B., MESQUITA, R., PEREIRA, J., DE SOUZA, S, BATISTA, G & COUTO, L. 1999. Allometric regressions for improved estimate of secondary forest biomass in the central Amazon. Forest Ecology and Management 117: 149-167.

NOGUEIRA JR, L, GONÇALVES, J, ENGEL, V & PARROTTA, J. 2011. Soil dynamics and carbon stocks 10 years after restoration of degraded land using Atlantic Forest tree species. Forest Systems 20: 536-545.

OVERMAN, J., WITTE, H. & SALDARRIAGA, J. 1994. Evaluation of regression models for above-ground biomass determination in Amazon rainforest. Journal of Tropical Ecology 10:207-218.

PARRESOL, B. 1999. Assessing tree and stand biomass: A review with examples and critical comparisons. Forest Science 45: 573-593.

RODRIGUES, R., GANDOLFI, S., NAVE, A., ARONSON, J., BARRETO, T., VIDAL, C. & BRANCALION, P. 2011. Large-scale ecological restoration of high-diversity tropical forests in SE Brazil. Forest Ecology and Management 261: 1605-1613.

RODRIGUES, R., LIMA, R., GANDOLFI, S. & NAVE, A. 2009. On the restoration of high diversity forests: 30 years of experience in the Brazilian Atlantic Forest. Biological Conservation 142: 1242-1251.

SALDARRIAGA, J., WEST, D., THARP, M. & UHL, C. 1988. Long-term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. Journal of Ecology 76: 938-958.

SANFORD JR, R & CUEVAS, E. 1996. Root growth and rhizosphere interactions in tropical forests.In Tropical forest plant ecophysiology(S. Mulkey, R. Chazdon & A. Smith, eds). Chapman and Hall, New York, pp 268-300.

SAS INSTITUTE. 2009. SAS® 9.2: qualification tools users guide. Cary.

SIDDIQUE, I., ENGEL, V., PARROTTA, J., LAMB, D., NARDOTO, G., OMETTO, J., MARTINELLI, L. & SCHMIDT, S. 2008. Dominance of legume trees alters nutrient relations in mixed species forest restoration plantings within seven years. Biogeochemistry 88: 89-101.

SILVEIRA, P., KOEHLER, H., SANQUETTA, C. & ARCE, J. 2008. O estado da arte na estimativa de biomassa e carbono em formações florestais. Floresta 38: 185-205.

TESHOMEA, T. & PETTY, J. 2000. Site index equation for Cupressus lusitanica stands in Munessa forest, Ethiopia. Forest Ecology and Management126: 339-347.

VIEIRA, S., ALVES, L., AIDAR, M., ARAÚJO, L., BAKER, T., BATISTA, J., CAMPOS, M., CAMARGO, P., CHAVE, J., DELITTI, W., HIGUCHI, N., HONÓRIO, E., JOLY, C., KELLER, M., MARTINELLI, L., MATTOS, E., METZKER, T., PHILLIPS, O., SANTOS, F., SHIMABUKURO, M., SILVEIRA, M., & TRUMBORE, S. 2008. Estimation of biomass and carbon stocks: the case of the Atlantic Forest. Biota Neotropica 8(2): 21-29.

Received 13/12/2013
Revised 18/03/2014
Accepted 30/03/2014

Biota Neotropica 14(2): e20130011, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

article

Benthic marine algae from the insular areas of Paraná, Brazil: new database to support the conservation of marine ecosystems

Franciane Pellizzari[1], Juliane Bernardi[2], Elzi Manoelle Silva[1], Michelle Cristine Silva[1] & Nair S. Yokoya[3]

[1]*Laboratório de Ficologia e Qualidade de Água do Mar, Universidade Estadual do Paraná (UNESPAR), Campus FAFIPAR, Comendador Correa Júnior 117, 82203-280 Paranaguá, PR, Brazil.*
[2]*Universidade Federal do Paraná, Centro de Estudos do Mar, Av. Beira Mar, s/no. Pontal do Sul, Pontal do Paraná, PR, Brazil.*
[3]*Núcleo de Pesquisa em Ficologia, Instituto de Botânica, Av. Miguel Estéfano, 3687, 04301-012, São Paulo, SP, Brazil.*
[4]*Corresponding author: Franciane Pellizzari, e-mail: franciane.pellizzari@unespar.edu.br*

PELLIZZARI, F., BERNARDI, J., SILVA, E.M., SILVA, M.C., YOKOYA, N.S. **Benthic marine algae from the insular areas of Paraná, Brazil: new database to support the conservation of marine ecosystems.** Biota Neotropica. 14(2): e20130011. http://dx.doi.org/10.1590/1676-060320140615183049

Abstract: This study describes the diversity of benthic marine algae from insular areas of the southern Brazilian coast. Algal samples were collected between 2006 and 2010 during the winter and the summer seasons at three sites in the coastal waters of Paraná, Brazil: Ilha do Mel, Currais Archipelago and Ilha do Farol. The samples were collected along parallel transects on the coast. In this survey, Paraná marine phycoflora comprised 139 taxa (90 Rhodophyta, 27 Chlorophyta and 22 Phaeophyceae). Fifty-two species represent new records for the state, and 14 taxa are present at all sampling sites and in both seasons. Higher diversities of rhodophytes and chlorophytes were observed at Ilha do Mel, while phaeophytes were more diverse at Currais Archipelago. Lower algal diversity was observed at Ilha do Farol, a sampling station which is near an urban area. Ceramiaceae, Rhodomelaceae and Corallinaceae were dominant among Rhodophyta, Cladophoraceae and Ulvaceae among Chlorophyta, and Dictyotaceae and Sargassaceae among Phaeophyceae. Seasonal and spatial differences in species composition could be explained by the availability of consolidated substrate, water transparency and proximity to an urban area. Seaweed biodiversity from the Paraná coast also presents low species richness compared to other Brazilian states as a result of the shorter coastline, lower availability of rocky shores, and the location between estuarine systems (Paranaguá and Guaratuba Bays). These bays input a large amount of continental water, resulting in decreased salinity, high concentrations of suspended particulate matter and low transparency in the water column. Knowledge of seaweed diversity is essential for conservation studies. In addition, environmental monitoring programs undertaken during medium- to long-term seasonal changes could be improved to reflect changes detected through new records, the introduction of alien species in the area of interest, or even dominance of opportunistic species over other taxa. Therefore, a database able to support the monitoring of biodiversity is a fundamental step in detecting environmental impacts that could change seaweed biogeography, mainly in urbanized and harbor areas.
Keywords: *Seaweeds, inventory, Paraná Coast, Southern Atlantic.*

PELLIZZARI, F., BERNARDI, J., SILVA, E.M., SILVA, M.C., YOKOYA, N.S. **Algas marinhas bentônicas de áreas insulares do Paraná, sul do Brasil: checklist, novas ocorrências para o Estado e implicações para a conservação.** Biota Neotropica. 14(2): e20130011. http://dx.doi.org/10.1590/1676-060320140615183049

Resumo: O presente estudo descreve a diversidade de algas marinhas bentônicas em áreas insulares da costa do Paraná, sul do Brasil. As amostras de algas foram coletadas entre 2006 e 2010 durante o inverno e o verão, em três locais: Ilha do Mel, Arquipélago de Currais e Ilha do Farol. A amostragem foi realizada ao longo de transectos paralelos à linha de costa e, na Ilha dos Currais, em diferentes profundidades. A ficoflora marinha paranaense é composta por 139 táxons (90 Rhodophyta, 27 Chlorophyta e 22 Phaeophyceae). Cinquenta e duas espécies são novas citações para o Estado do Paraná, e 14 táxons foram registrados em todos os locais estudados durante o verão e o inverno. Diferenças sazonais e espaciais na composição específica podem ser explicadas pela disponibilidade de substratos rochosos, transparência da água e proximidade com a área urbana. A maior diversidade de rodófitas e clorófitas foi observada na Ilha do Mel e a de feofíceas no Arquipélago de Currais. A menor diversidade de algas foi observada na Ilha do

Farol, ponto amostral mais próximo a uma área urbana. Ceramiaceae, Rhodomelaceae e Corallinaceae foram dominantes entre Rhodophyta, Cladophoraceae e Ulvaceae entre Chlorophyta, e Dictyotaceae e Sargassaceae entre Phaeophyceae. A diversidade de algas marinhas bentônicas na costa do Paraná é menor quando comparada a outros estados brasileiros e isto está associado à menor extensão de sua linha de costa, menor disponibilidade de substratos consolidados para recrutamento e localização entre dois sistemas estuarinos (baías de Paranaguá e de Guaratuba). Os estuários aumentam consideravelmente o aporte de água continental, diminuindo a salinidade, elevando as concentrações de material particulado em suspensão e reduzindo a transparência da água. O conhecimento da diversidade algácea é fundamental para estudos de conservação, sendo que câmbios sazonais em médio e longo prazo podem estar relacionados a alterações ambientais. O indicador destas mudanças pode ser a detecção de novas ocorrências, espécies novas ou ainda introdução de espécies exóticas na área em questão, ou mesmo pela dominância de táxons oportunistas. Portanto, uma base de dados que sustente um monitoramento da biodiversidade é relevante por detectar impactos que podem alterar padrões biogeográficos das comunidades de macroalgas, principalmente em regiões com influência de atividades antrópicas, como as zonas urbanas ou áreas portuárias.

Palavras-chave: *macroalgas marinhas, inventário, litoral do Paraná, Atlântico Sul.*

Introduction

The human population growth associated with intense socioeconomic activities are causing increasing impact on the coastal environments. Climate changes have also resulted in increased precipitation in different South American regions, leading to higher freshwater inputs into marine ecosystems and causing a decrease in salinity in coastal waters which, in turn, affects photosynthesis in primary producers (Santos et al. 2011; Scherner et al. 2012, 2013). Nonetheless, approaches designed to conserve marine ecosystems are still poorly supported by biological data, thus requiring actions focused on the biological characterization of marine communities.

Seaweeds are highly sensitive to environmental changes, and exposure to the long-term effects of pollutants, and eutrophication tend to modify the community structure, favoring opportunistic species, while excluding late successional and fragile species (Santos et al. 2011; Scherner et al. 2013). The ecological relevance of these bioindicators can extend beyond their fundamental role in the trophic chains as primary producers, and include sheltering for marine fauna, bioremediation due to fast uptake of water-born contaminants, and also economic importance.

Algal diversity is a key indicator, or proxy, for monitoring. Since 2006, cooperative conservation programs have been developed along the Paraná coast (Pellizzari & Kawaii, 2010) to establish a protocol for coastal long-term monitoring in this area, and seaweed diversity has been used as a monitoring tool. However, this sort of program has been limited by the lack of updated surveys focused on seaweed diversity. Although studies on benthic marine algae from the Paraná coast were published around two decades ago, they were concentrated on only a few coastal locations at intertidal zones that surround mangrove and estuarine areas.

Seaweed inventory on a spatiotemporal scale allows investigators to detect the disappearance of some taxa or identify new records. These data may predict potential changes in species composition and distribution patterns that could, in turn, suggest the nature of local impacts, allowing the opportunity to apply preventive or mitigative measures, as well as distinguish between native and alien species.

Several surveys have reported on seaweed diversity in the islands and other open water marine ecosystems of Brazil (Eston et al. 1986; Alves, 1989; Pedrini et al. 1989; Figueiredo, 2006; Horta et al. 2008; Burgos et al. 2009; Rocha-Jorge, 2010). Compared with the sampling areas of the present study, these works sampled more biogeographically isolated islands and/or rocky outcrops, such as "*Laje de Santos*". In addition, most of these study sites were concentrated along the southeastern and northeastern Brazilian coast.

Seaweed diversity from Paraná State, the second shortest coastline in Brazil, is poorly known. Some taxonomic studies were carried out in past decades, such as that of Ugadim (1973, 1974, 1976) who studied seaweeds from southern São Paulo to northern Paraná. Other studies reported a checklist of conspicuous seaweeds from Ilha do Farol, Caiobá (Shirata et al. 1991), as well as seaweeds from mangroves in Ilha do Mel and Guaraqueçaba Islands, both respectively located in the outer and inner sectors of Paranaguá Bay (Shirata 1993a, b).

More recent studies were performed with the aim of establishing a biological and technical database for cultivating the monostromatic green seaweeds *Gayralia oxysperm*a (Kützing) K.L.Vinogradova ex Scagel et al. and *G. brasiliensis* Pellizzari, M.C. Oliveira & N.S. Yokoya in Paranaguá Bay (Pellizzari et al. 2007, 2008, 2013). Pellizzari & Kawaii (2010) reported protocols for monitoring based on physical, chemical and biological indicators in the Paranaguá Bay Estuarine Complex, and, finally, Pellizzari & Reis (2011) published a compilation of seaweed resources with the potential for cultivation along the southern and southeastern Brazilian coast.

The Paraná coast embraces the largest cereal port in South America (Paranaguá Harbor). It is well known that harbor activities can affect the conservation state of coastal ecosystems by their physical and chemical impacts or geomorphological changes in coastal waters. Also, these activities can cause species introduction, as well disappearance of sensitive species and/or the predominance of opportunistic taxa. In general, natural system degradation occurs at a faster rate than the remediation of natural systems by the introduction of conservation initiatives (Amado-Filho et al. 2006). For these reasons, this study proposed a biological database focused on seaweed diversity in insular areas of Paraná, aiming to support future coastal monitoring and or conservation programs.

http://dx.doi.org/10.1590/1676-06032014061518304 9

Materials and Methods

1. *Study area*

Seaweeds from the Paraná coast were collected at three sampling stations: Ilha do Mel, Currais Archipelago and Ilha do Farol (Figure 1) during the summer and winter between 2006 and 2010. These islands are not considered to have a high degree of biogeographical isolation.

Ponta das Encantadas at Ilha do Mel (25°32'07''S and 48°19'52''W) is located 1.3 miles from the shore (Pontal do Paraná) at the mouth of Paranaguá Bay, showing an intermediate level of hydrodynamics. In general, this location shows a high concentration of suspended particulated matter and chlorophyll (Lana et al. 2001) among the sampled islands, resulting in a low water column. This continental island has a coastline that stretches 35 kilometers, and it is located on the northern boundary of our sampling area. The rocky boulders are composed of basalt, showing fractions of migmatite.

The Marine State Park of Currais Archipelago is a rocky basaltic outcropping formed by three oceanic islands and located about 10 miles from the coast (25°44'00''S and 48°22'00''W). The islands are orientated NW-SE, with the main island located on the eastern side of the archipelago (Borzone 1994). Ilha Grande was the sampling area, and it represents 81% of the immersed portion of the archipelago, showing real rocky shores with variable declivities, a short pebble beach, and mean depths lower than 15m. This island is preserved and shows the highest transparency and hydrodynamics among the sampled islands as a result of its exposure to open clear continental waters.

Ilha do Farol (25°51'9.01''S and 48°32'7.01''W) is the southern limit among our sampling stations, and it has a continental isthmus that allows transit only at ebbtide, being the nearest island from the coast and showing a sheltered side oriented to the mouth of Guaratuba Bay. The water transparency is variable following rainfall, and boulders along the shores show basaltic, gnaise and biolithic (*Phragmatopoma*) formations. Based on the evaluation of six water quality parameters (chlorophyll, Secchi depth, CO_2 saturation, dissolved inorganic nitrogen and phosphorus, and dissolved oxygen), Mizerkowski et al. (2012) suggested that Guaratuba Bay shows a low to medium trophic status, i.e., from meso- to oligotrophic, in turn indicating that the surrounding areas follow the same pattern. However, this island is located between two summer recreation areas in Paraná, Guaratuba and Caiobá Beaches, thus suffering from a huge input of organic matter from untreated sewage during the tourist season.

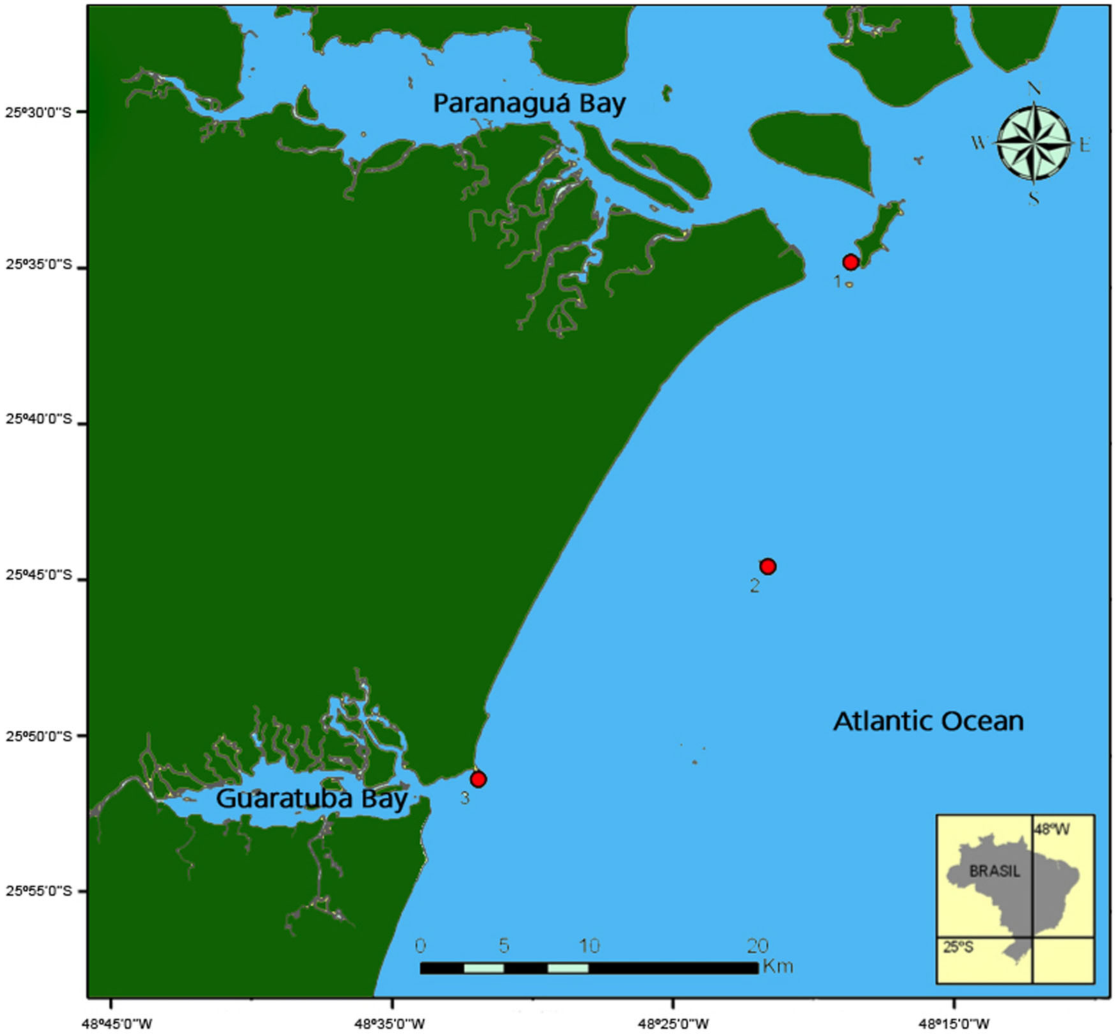


Figure 1. Sampling sites from the Paraná coast, southern Brazil. 1- Ponta das Encantadas, Ilha do Mel. 2- Ilha Grande, Currais Archipelago; 3- Ilha do Farol.

2. *Sampling method and data analysis*

Fertile specimens of each species (n=3) were collected by hand, using a spatula, inside replicated quadrats (1 m^2) randomly distributed in transects parallel to the coast (n=5 for each sampling zone: upper tidal, intertidal and subtidal). In the laboratory, the collected material was fixed in triplicate, using formalin 4% diluted with seawater. The taxonomic study was based on morphological and anatomical features observed in histological sections of vegetative and reproductive structures under stereomicroscopy and light microscopy (Olympus CX31 with image capturing). Species identification was based on specialized literature, and nomenclature updates were made following Wynne (2011) and Guiry & Guiry (2013). Some species were analyzed using molecular markers (SSU and ITS), after preserving algal material in SI GEL. Voucher specimens were deposited in the herbarium of the *Museu Botânico de Curitiba* (MBM). The seaweeds were grouped into morpho-functional categories, as proposed by Littler & Littler (1980) and Steneck & Dethier (1994).

In order to detect similarities among species and thus establish patterns of biodiversity, a cluster analysis was applied to compare sampling sites and seasons, using a presence-absence matrix of species and Bray-Curtis similarity index. The frequency of taxa was calculated using the constancy index (CI - Dajoz, 1973). According to this index, constant taxa were considered to be those that occurred in more than 50% of the samples. Accessory taxa were those occurring between 25% to 50% of the samples, and accidental (rare) taxa were those occurring in up to 25% of the samples. The proposed dendrograms were produced with the Primer-E statistics package (Plymouth Routines in Multivariate Ecological Research). Accidental (rare) species were deleted in the data matrix used to perform the CI in order to avoid generating noise in the results.

Results

A total of 139 taxa were identified, including 90 taxa of Rhodophyta, 27 species of Chlorophyta and 22 taxa of Phaeophyceae (Table 1), and 52 are new records for the Paraná coast (40 species of Rhodophyta, 7 of Phaeophyceae and 5 of Chlorophyta). Fourteen species were present for all sampling sites, including the green alga *Gayralia brasiliensis* Pellizzari, M.C.Oliveira & N. S. Yokoya, a recently described new species. Among red seaweeds, Rhodomelaceae (19 spp.), Ceramiaceae (12 spp.), and Corallinaceae (10 spp.) were the most representative families. Cladophoraceae (12 spp.) and Ulvaceae (5 spp.), as well as Dictyotaceae (8 taxa) and Sargassaceae (4 taxa), were the most representative families of green and brown algae, respectively. The most representative genus was *Ceramium* Roth (Rhodophyta), comprising seven species.

The highest seaweed diversity was observed at Ilha do Mel and Currais Archipelago (Figure 2). Currais showed the highest diversity during the summer, if compared with other islands, and most new records were reported for this island (Table 1).

The occurrence of 101 taxa was observed at Ilha do Mel, comprising 59 Rhodophyta, 27 Chlorophyta and 15 Phaeophyceae, and no seasonal differences in diversity were observed (Figure 2). The recently described species *Gayralia brasiliensis* occurred at all three sampling sites, and it was found on sheltered rocks or mangrove roots in areas with salinity around 30.

In Currais Archipelago, 101 taxa were found (64 taxa of Rhodophyta, 18 of Chlorophyta and 19 of Phaeophyceae), and the highest diversity occurred during the winter (Figure 2). The most representative families were Ceramiaceae, Corallinaceae and Rhodomelaceae (Table 1). Brown and green seaweeds mainly occurred down to depths of 3 m, and the predominant species were Dictyotales/Ectocarpales and Cladophoraceae, respectively. Until 6 m depth, the algal community was predominated by turf algae of articulated and non-articulated Corallinales, presenting Ceramiales as epiphytes. At greater depths, seaweed diversity was limited by the scarcity of consolidated substrate, fouling, and the presence of a high concentration of particulated organic material. The most representative taxa from this island were *Asparagopsis taxiformis* (Delile) Trevis, *Amphiroa* spp. and *Gelidium* spp. (Table 1).

At Ilha do Farol, 66 taxa were identified, including 37 Rhodophyta, 19 Chlorophyta and 10 Phaeophyceae, and the highest diversity was observed during the summer with biomass dominance of Ulvales opportunistic species (Figure 2, Table 1).

The most common species among the sampling sites were *Bryothamnion seaforthii* (Turner) Kutz., *Caulerpa fastigiata* Montagne, *Centroceras clavulatum* (C. Agardh in Kunth) Mont. in Durieu de Maisonneuve, *Chaetomorpha antennina* (Bory de Saint-Vincent) Kützing, *Cladophoropsis membranacea* (Hofman Bang ex C. Agardh) Børgesen, *Cladophora vagabunda* (Linnaeus) Hoek, *Codium decorticatum* (Woodward) M.A. Howe, *Gelidium pusillum* (Stackh.) Le Jolis, *Padina gymnospora* (Kützing) Sonder, *Pterocladiella capillacea* (S. G. Gmel.) Santel. & Hommers, *Rhizoclonium riparium* (Roth) Harvey, *Ulva lactuca* Linnaeus, *Sargassum cymosum* C. Agardh and *Pterosiphonia pennata* (C. Agardh) Falkenb.

Fourteen species (nine Chlorophyta, one Phaeophyceae and four Rhodophyta) occurred at all sampling sites and in both seasonal periods and could therefore be used as bioindicators for monitoring: *Caulerpa fastigiata, Codium decorticatum, Chaetomorpha anteninna, Cladophora vagabunda, Rhizoclonium riparium, Gayralia brasiliensis, Ulva fasciata* Delile, *U. flexuosa* Wulfen, *U. lactuca, Padina gymnospora, Centroceras clavulatum, Pterosiphonia pennata, Pterocladiella capillaceae* and *Hypnea musciformis* (Wulfen in Jacquin) J. V. Lamour (Table 1).

By constancy index (CI), it was shown that the seaweed taxa from insular areas of the Paraná coast are distributed as 44% accessory species and 33% accidental (rare) species, while only 23% of species are considered constant. Using full diversity, a dendrogram was produced and showed 62% similarity among samples collected during the summer at Ilha do Mel (IMV) and Ilha do Farol (IFV) and 61% between samples from the Currais Archipelago during summer and winter (CV and CI). CS and CI showed a cluster of only 45% with the other sites/seasons. When accidental (rare) species were disregarded, the dendrogram showed the same cluster pattern (Figure 3); however, the sampling sites showed higher similarity between IF and IM. IMV and IFV showed 71% of similarity, while CV and CI showed 69.4% similarity. Ilha do Mel during the winter (IMI) showed similarity of 63% between IMV and IFV. Ilha do Farol during the winter (IFI) clustered 56% with CV, and CI showed a cluster of only 52% with the other sites/seasons. To summarize, Currais Arquipelago showed a high similarity

Table 1. Composition of benthic marine algae species collected from islands of the Paraná coast sampled during summer (S) and winter (W) seasons.

TAXA	Ilha do Mel		Currais Archipelago		Ilha do Farol	
	S	W	S	W	S	W
CHLOROPHYTA						
Bryopsidales						
Bryopsidaceae						
Bryopsis pennata J.V. Lamouroux	+	-	+	-	+	-
Caulerpaceae						
Caulerpa fastigiata Montagne	+	+	+	+	+	+
Caulerpa sp.	+	-	-	-	+	-
Codiaceae						
Codium decorticatum (Woodward) M.A. Howe	+	+	+	+	+	+
Codium sp.	-	+	-	+	-	-
Codium taylorii P.C. Silva	+	-	-	-	+	+
Udoteaceae						
Boodleopsis pusilla (F.S. Collins) W.R. Taylor, A.B. Joly & Bernatowicz	+	+	+	-	+	+
Cladophorales						
Boodleaceae						
Cladophoropsis membranacea (Hofman Bang ex C. Agardh) Børgesen	-	+	+	-	-	+
Cladophoraceae						
Chaetomorpha aerea (Dillwyn) Kützing	+	-	-	-	-	-
Chaetomorpha antennina (Bory de Saint-Vincent) Kützing	+	+	+	+	+	+
Chaetomorpha brachygona Harvey	+	-	-	+	-	-
Cladophora albida (Nees) Kutzing	+	-	-	-	-	-
Cladophora montagneana Kützing	-	+	-	+	-	+
Cladophora prolifera (Roth) Kützing	-	+	+	-	-	+
Cladophora sp.	-	+	-	-	-	-
Cladophora vagabunda (Linnaeus) Hoek	+	+	+	+	+	+
Rhizoclonium africanum Kützing	-	+	+	-	-	+
Rhizoclonium riparium (Roth) Harvey	+	+	+	+	+	+
Rhizoclonium sp.	+	-	-	-	-	-
Rhizoclonium tortuosum (Dillwyn) Kützing	+	+	-	-	-	-
Ulotrichales						
Gayraliaceae						
Gayralia brasiliensis Pellizzari, M.C. Oliveira et N.S. Yokoya	+	+	+	+	+	+
Gayralia oxysperma (Kützing) K.L. Vinogradova ex Scagel et al.	+	+	-	-	-	-
Ulvales						
Ulvaceae						
Ulva clathrata (Roth) C. Agardh	+	+	+	+	+	-
Ulva fasciata Delile	+	+	+	+	+	+
Ulva flexuosa Wulfen	+	+	+	+	+	+
Ulva lactuca Linnaeus	+	+	+	+	+	+
Ulva linza Linnaeus	-	+	-	-	-	+
Total 27	20	20	15	13	14	16
OCHROPHYTA						
Dictyotales						
Dictyotaceae						
Canistrocarpus cervicornis (Kutzing) de Paula & de Clerck	+	+	-	+	-	-
Canistrocarpus cervicornis f. pseudohamatus (Cribb) M.J. Wynne	-	+	-	+	-	-
Dictyopteris delicatula J.V. Lamouroux	-	+	-	+	-	-
Dictyota menstrualis (Hoyt) Schnetter, Hörning & Weber-Peukert	+	+	-	+	-	-
Lobophora variegata (Lamouroux) Womersley ex Oliveira	-	-	+	-	+	-
Padina antillarum (Kutzing) Piccone	-	-	-	-	+	-
Padina gymnospora (Kützing) Sonder	+	+	+	+	+	+
Spatoglossum schroederi (C. Agardh) Kützing	-	+	-	+	-	-
Ectocarpales						
Acinetosporaceae						

Continued on next page

Table 1. Continued.

TAXA	Ilha do Mel		Currais Archipelago		Ilha do Farol	
Feldmannia irregularis (Kützing) G.Hamel	+	-	-	-	-	-
Feldmannia mitchelliae (Harvey) H.S. Kim	-	-	+	+	-	-
Chordariaceae						
Levringia brasiliensis (Montagne) A.B. Joly	+	-	+	-	-	-
Protectocarpus speciosus (Børgesen) Kornmann	-	-	-	+	-	-
Scytosiphonaceae						
Chnoospora minima (K. Hering) Papenfuss	-	-	-	+	+	-
Colpomenia sinuosa (Mertens ex Roth) Derbès & Solie	+	-	+	+	-	-
Petalonia fascia (O.F. Müller) Kuntze	+	-	-	+	-	+
Fucales						
Sargassaceae						
Sargassum cymosum C. Agardh	+	-	-	+	+	+
Sargassum cymosum var. nanum E. de Paula & E. C. Oliveira	-	-	+	+	+	-
Sargassum stenophyllum Martius	+	-	-	+	+	+
Sargassum vulgare C. Agardh	-	-	-	-	+	-
Ralfsiales						
Neoralfsiaceae						
Neoralfsia expansa (J.Agardh) P.-E.Lim & H.Kawai ex Cormaci & G.Furnari	-	+	+	+	-	-
Scytothamnales						
Bachelotiaceae						
Bachelotia antillarum (Grunow) Gerloff	+	-	+	+	-	+
Sphacelariales						
Sphacelariaceae						
Sphacelaria brachygona Montagne	+	-	+	-	-	-
Total 22	**11**	**7**	**9**	**16**	**8**	**5**
RHODOPHYTA						
Acrochaetiales						
Acrochaetiaceae						
Acrochaetium flexuosum Vickers	-	-	+	+	-	-
Acrochaetium microscopicum (Nägeli ex Kützing) Nägeli	-	-	-	+	-	-
Bangiales						
Bangiaceae						
Pyropia acanthophora (E.C.Oliveira & Coll) M.C.Oliveira, D.Milstein & E.C.Oliveira	+	+	+	-	+	-
Pyropia acanthophora var. *brasiliensis* (E.C.Oliveira & Coll) M.C. Oliveira, D. Milstein & E.C. Oliveira	-	+	-	-	-	+
Pyropia spiralis (E.C.Oliveira & Coll) M.C.Oliveira, D.Milstein & E.C.Oliveira	-	+	-	-	-	+
Pyropia suborbiculata (Kjellman) J.E.Sutherland, H.G.Choi, M.S. Hwang & W.A.Nelson	+	+	+	-	+	+
Bonnemaisoniales						
Bonnemaisoniaceae						
Asparagopsis taxiformis (Delile) Trevis.	+	+	+	+	-	-
Ceramiales						
Ceramiaceae						
Aglaothamnion felliponei (M. Howe) N. Aponte, D. L. Ballant. & J. N.Norris	+	+	-	-	+	-
Aglaothamnion uruguayense (W. R. Taylor) N. Aponte, D. L. Ballant	+	-	-	-	+	+
Centroceras clavulatum (C. Agardh in Kunth) Mont. in Durieu de Maisonneuve	+	+	+	+	+	+
Centrocerocolax ubatubensis A. B. Joly	-	+	-	+	-	-
Ceramium brasiliense A. B. Joly	-	+	+	-	+	-
Ceramium brevizonatum H.E. Petersen	+	-	+	-	-	-
Ceramium dawsonii A. B. Joly	+	-	+	+	+	-
Ceramium deslongchampsii Chauv. ex Duby	-	-	+	-	-	-

Continued on next page

Table 1. Continued.

TAXA	Ilha do Mel		Currais Archipelago		Ilha do Farol	
Ceramium diaphanum (Lightfoot) Roth	+	-	-	+	-	-
Ceramium sp.	+	-	-	-	+	-
Ceramium tenerrimum (G. Martens) Okamura	-	-	+	+	-	-
Gayliella flaccida (Harvey ex Kützing) T.O.Cho & L.J.McIvor	+	-	+	-	-	-
Dasyaceae						
Dasya rigidula (Kutzing) Ardissone	-	-	-	+	-	-
Delesseriaceae						
Acrosorium ciliolatum (Harvey) Kylin	-	-	+	-	-	-
Caloglossa leprieurii (Mont.) G. Martens	+	+	-	-	+	-
Hypoglossum hypoglossoides (Stackhouse) F.S. Collins & Hervey	-	+	-	+	-	+
Rhodomelaceae						
Acanthophora spicifera (Vahl) Børgesen	+	+	+	-	+	-
Bostrychia calliptera Montagne	+	+	-	-	-	-
Bostrychia montagnei Harvey	+	+	-	-	+	+
Bostrychia moritziana (Sonder ex Kutzing) J. Agardh	+	+	-	-	-	-
Bostrychia radicans (Mont.) Mont. In Orbigny	+	+	-	-	+	+
Bostrychia tenella (J. V. Lamour.) J. Agardh	+	+	-	-	-	-
Bryocladia thyrsigera (J. Agardh) F. Shmitz	-	-	+	-	+	-
*Bryothamnion seaforthii (*Turner) Kutz.	+	-	+	+	+	-
Chondria atropurpurea Harvey	-	+	-	+	-	-
Dawsoniocolax bostrychiae A.B. Joly e Yamaguishi-Tomita	-	+	-	-	-	-
Herposiphonia secunda f. tenella (C. Agardh) Ambronn	+	-	+	+	+	-
Neosiphonia ferulacea (Suhr ex J. Agardh) S. M. Guim. & M. T. Fujii	-	-	+	+	-	-
Neosiphonia tepida (Hollenb.) S. M. Guim. & M. T. Fujii	-	-	-	+	-	-
Palisada flagellifera (J.Agardh) K.W.Nam	+	+	-	+	-	-
Palisada perforata (Bory) K.W. Nam	-	-	+	-	+	-
Polysiphonia howei Hollenberg	-	+	-	-	-	+
Polysiphonia sp.	-	-	+	-	+	-
Pterosiphonia parasitica (Hudson) Falkenberg	-	+	-	-	-	-
Pterosiphonia pennata (C. Agardh) Falkenb.	+	+	+	+	+	+
Spyridiaceae						
Spyridia hypnoides (Bory in Belanger) Papenf.	+	-	+	+	-	-
Wrangeliaceae						
Pleonosporium sp.	-	-	+	+	-	-
Ptilothamnion speluncarum (Collins & Herv.) D. L. Ballant. & M. J. Wynne	-	-	-	+	-	-
Wrangelia argus (Mont.) Mont.	+	+	+	+	-	-
Colaconematales						
Colaconemataceae						
Colaconema codicola (Børgesen) H.Stegenga, J.J.Bolton, & R.J.Anderson	-	+	-	+	-	-
Corallinales						
Corallinaceae						
Amphiroa anastomosan Weber-van Bosse	-	-	+	-	-	-
Amphiroa beauvoisii J. V. Lamour.	+	+	+	+	-	-
Amphiroa fragilissima (L.) J. V. Lamour.	-	-	+	+	-	-
Amphiroa sp.	-	-	-	+	-	-
Arthrocardia flabellata (Kütz.) Manza	-	+	-	+	-	+
Corallina officinalis Linnaeus	-	+	-	-	-	-
Jania adhaerens J. V. Lamour.	-	-	+	+	-	-
Jania prolifera A. B. Joly	-	-	+	+	-	-
Jania rubens (Linnaeus) J.V. Lamouroux	+	-	+	-	-	-
Lithophyllum stictaeforme (J.E. Areschough) Hauck	-	-	+	+	-	-
Erythopeltidales						

Continued on next page

Table 1. Continued.

TAXA	Ilha do Mel		Currais Archipelago		Ilha do Farol	
Erythrotrichiaceae						
Sahlingia subintegra (Rosenv.) Kornmann	-	-	+	-	-	-
Gelidiales						
Gelidiaceae						
Gelidium crinale (Hare ex Turner) Gaillon	+	-	-	-	-	-
Gelidium floridanum W.R. Taylor	+	+	+	-	-	-
Gelidium pusillum (Stackh.) Le Jolis	+	+	+	-	+	+
Gelidium sp.1	+	-	-	-	-	-
Gelidium sp.2	-	-	-	-	+	-
Pterocladiaceae						
Pterocladiella capillacea (S. G. Gmel.) Santel. & Hommers.	+	+	+	+	+	+
Gigartinales						
Caulacanthaceae						
Catenella caespitosa (Withering) L.M. Irvine	+	-	-	-	-	-
Cystocloniaceae						
Craspedocarpus jolyi (E.C.Oliviera) Schneider	+	-	-	-	-	-
Hypnea musciformis (Wulfen in Jacquin) J. V. Lamour.	+	+	+	+	+	+
Hypnea spinella (C. Agardh) Ku?tz.	+	-	+	+	+	-
Gigartinaceae						
Chondracanthus acicularis (Roth) Fredericq	-	-	+	-	+	-
Chondracanthus elegans (Grev. in J. St. Hil.) Guiry	-	-	-	-	+	-
Chondracantus teedei (Mertens ex Roth) Kützing	-	+	-	+	-	-
Chondracanthus sp.	-	+	-	-	-	-
Phyllophoraceae						
Gymnogongrus griffithsiae (Tuner) Mart.	+	+	+	-	+	-
Gracilariales						
Gracilariaceae						
Gracilaria cervicornis (Turner) J. Agardh	+	-	+	-	-	-
Gracilaria domingensis (Kütz) Sond. Ex Dickie	+	+	-	-	+	-
Hydropuntia caudata (J. Agardh) Gurgel & Fredericq	-	+	-	-	+	+
Halymeniales						
Halymeniaceae						
Grateloupia dichotoma J. Agardh	-	-	-	-	+	+
Grateloupia doryphora (Montagne) M.A. Howe	+	+	+	-	+	-
Grateloupia filicina (J.V. Lamouroux) C. Agardh	-	+	-	+	-	-
Halymenia C. Agardh	-	-	+	+	-	-
Hildenbrandiales						
Hildenbrandiaceae						
Hildenbrandia rubra (Sommerf.) Menegh	-	-	+	-	+	-
Nemaliales						
Galaxauraceae						
Tricleocarpa cylindrica (J. Ellis & Sol.) J. V. Lamour.	-	-	+	-	+	-
Peyssonneliales						
Peyssoneliaceae						
Peyssonnelia armorica (P.L.Crouan & H.M.Crouan) Weber-van Bosse	-	-	+	-	-	-
Plocamiales						
Plocamiaceae						
Plocamium brasiliense (Greville) M.A. Howe & W.R. Taylor	+	-	+	-	-	-
Rhodymeniales						
Champiaceae						
Champia parvula (C. Agardh) Harvey	-	-	+	+	-	-
Lomentariaceae						
Ceratodictyon intricatum (C. Agardth) R.E. Noaris	-	+	-	+	-	-
Ceratodictyon variabile (J.Agardh) R.E.	-	-	+	-	-	-
Lomentaria corallicola Børgesen	+	-	-	-	-	-

Continued on next page

Table 1. Continued.

TAXA	Ilha do Mel		Currais Archipelago		Ilha do Farol	
Rhodymeniaceae						
Rhodymenia pseudopalmata (J. V. Lamour.) P. C. Silva	+	-	+	+	-	-
Sebdeniales						
Sebdeniaceae						
Sebdenia flabellata (J. Agardh) P.G. Parkinson	-	-	-	+	-	-
Total 90	42	40	47	38	32	16

index between summer and winter; however, this community is different when compared to that of Ilha do Farol or Ilha do Mel. On the other hand, seasonal diversity patterns between Ilha do Mel and Ilha do Farol are quite defined showing similarity during the summer but differences during the winter.

Considering the morphofunctional groups, the filamentous group comprised the majority of the taxa of Chlorophyta, Phaeophyceae, and Rhodophyta, followed by terete and corticated foliose groups. On the other hand, the less representative group was crustose calcareous (Figure 4).

Discussion

This study reports the occurrence of 139 taxa of seaweeds in insular areas from the Paraná coast, comprising 52 species as new records for that state. The diversity found in Paraná in this survey is 33% higher than data reported over the last decade (Oliveira et al. 2013). However, diversity of benthic marine algae from the Paraná coast and nearby islands is lower when compared to other Brazilian states, corresponding to 44% and 70% of phycoflora from the States of São Paulo and Santa Catarina, respectively (following Horta et al. 2001). This difference could be explained by the shorter coastline and lower availability of rocky shores in Paraná State. Furthermore, the Paraná coast is located between estuarine systems (Paranaguá and Guaratuba Bays), thus receiving runoff and a large input of continental water, resulting in high concentrations of suspended particulate matter and low seawater transparency.

The differences in diversity between Currais Archipelago and the other islands (Ilha do Mel and Ilha do Farol) are probably associated with the distance from the coast, resulting in changes of temperature, salinity, nutrient input, anthropic influence, and hydrodynamics.

Ten species previously reported to the Paraná coast in a literature compilation (Oliveira et al. 2013) were not found in the present study: *Ulvella (*formerly *Entocladia) viridis* Reinke, *Acrochaetium globosum* Borgensen, *Bangiopsis dumontioides* (P.L. Crouan & H.M. Crouan) V. Krishnmurthy, *Cryptopleura ramosa* (Hudson) Kylin ex L. Newton, *Gelidium spinosum* (S.G. Gmelin) P.C. Silva, *Heterosiphonia gibbesi* (Harvey) Falkenberg, *Hydrolithon farinosum* (J.V. Lamouroux) Penrose & Y.M. Chamb, *Leptofauchea brasiliensis* A.B. Joly, *Pneophyllum fragile* Kützing and *Stylonema alsidii* (J.V. Lamouroux) P.C. Silva.

Nutrient pulses are higher and more conspicuous in urban environments compared to less urbanized or pristine areas (Scherner et al. 2012). The seaweed community structure from Currais Archipelago, a Marine State Park, showed the greatest difference among the sampling sites, and it was also the location with the highest number of new records on seaweed diversity for the state. These results reinforce the need to maintain the conservation status of this park. The marine flora here was dominated by turf algae (Littler & Littler 1980;

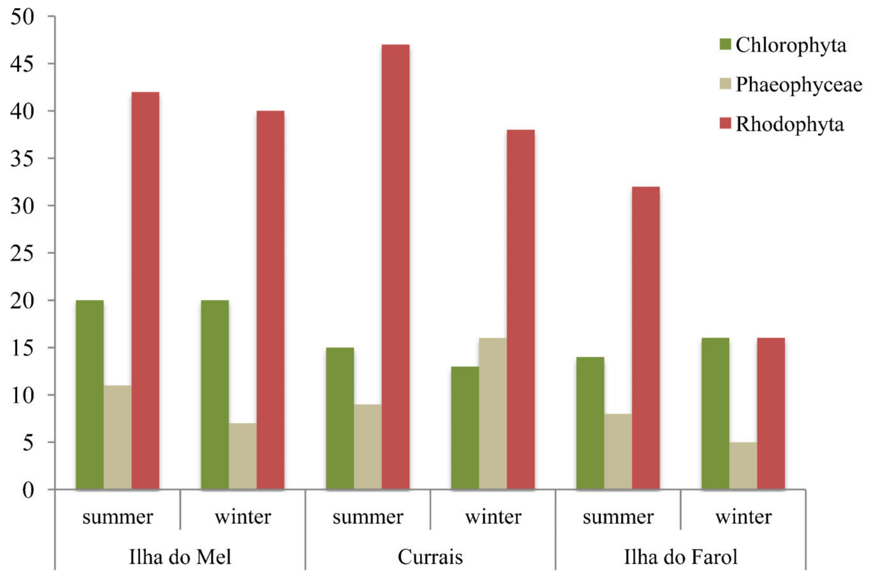


Figure 2. Variation in species number of Chlorophyta, Phaeophyceae and Rhodophyta during the summer and winter in the sampling sites (Ilha do Mel, Currais Archipelago and Ilha do Farol) along the Paraná coast, southern Brazil.

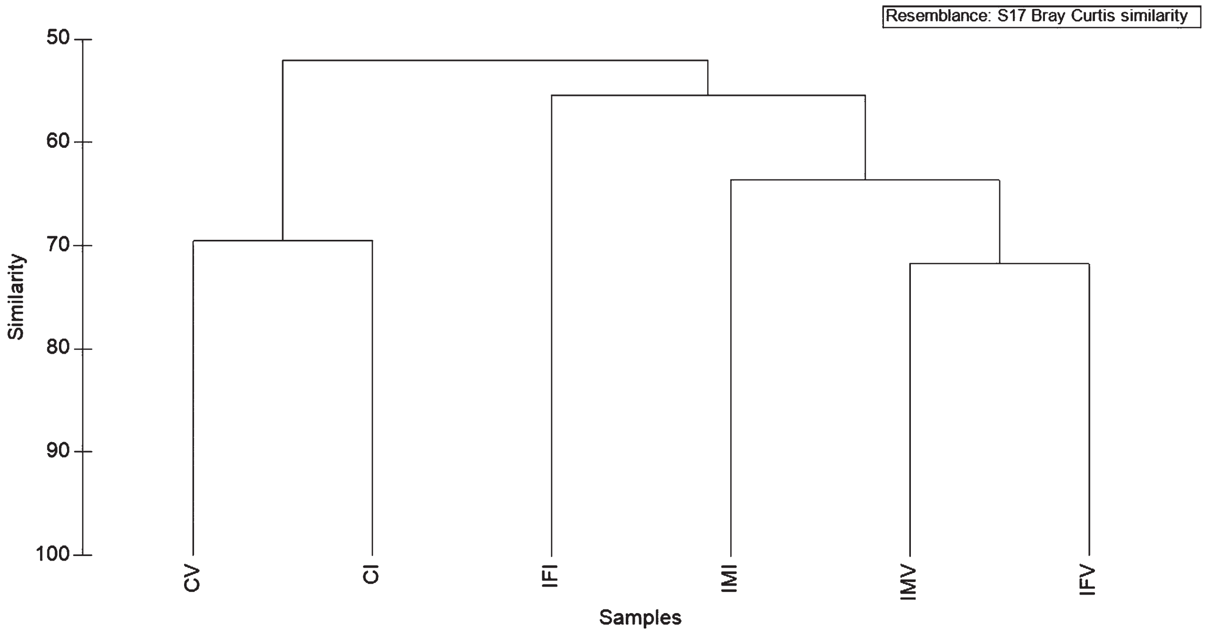


Figure 3. Similarity dendrogram of quadrants based on the Bray-Curtis similarity index among seaweed diversity data from samples collected at *Ilha do Mel* during the summer (IMV) and winter (IMI), *Ilha do Farol* during the summer (IFV) and winter (IFI), and *Currais* during the summer (CV) and winter (CI); islands along the Paraná coast, southern Brazil.

Steneck & Dethier 1994) composed of articulated Corallinaceae on the base and filamentous red algae as an epiphyte, in addition to crustose Corallinales found up to depths of 10m. Turfs are ecologically important in that they retain sand. Furthermore, geniculate coralline algae can act as 'anchor' taxa for other species, as well as maintain surface stability along exposed shores. Among sampling sites, infralittoral zone was sampled only at Currais Archipelago, and this area also showed the highest degree of hydrodynamics, been the farthest island from the coast. These could explain the peculiar phycoflora where seaweeds recruitment is limited by shortage of consolidated substrate and intensive fouling. Currais belongs to the Marine State Park category among Brazilian Conservation Units, and it is a target control site for coastal monitoring studies based on its high degree of conservation. On the other hand, Ilha do Mel and Ilha do Farol are located near estuarine mouths, Paranaguá and Guaratuba Bays, respectively, and also near urban and harbor areas, thus receiving different sediment and nutrient inputs compared to Currais Archipelago, what could explain the distinct patterns in diversity, biomass and distribution of macroalgae assemblages.

Estuarine systems flow into the open sea, adding continental sediments and nutrients. This nutrient input may favor seaweed growth. However, constant sediment input can also increase water turbidity, decrease light penetration, and impair photosynthetic rates, resulting in the dominance of a few

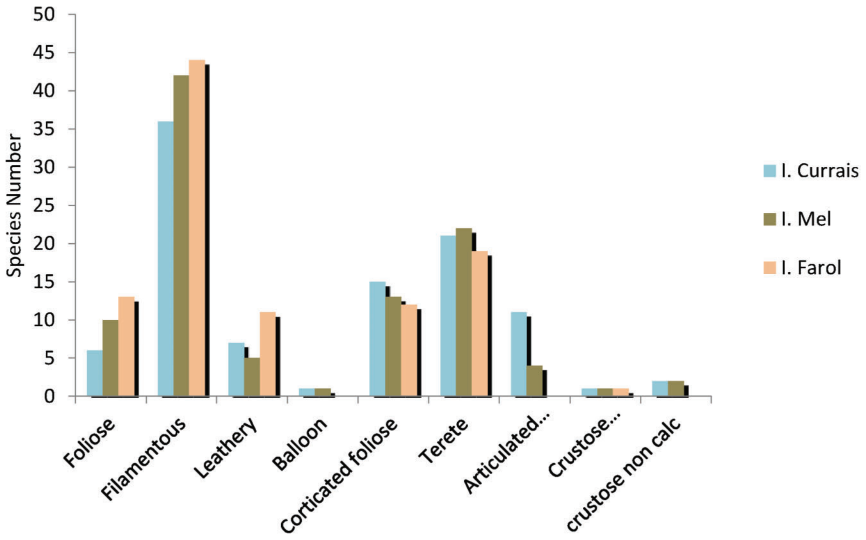


Figure 4. Variation in species number belonging to different morphofunctional groups in the sampling sites (Ilha do Mel, Currais Archipelago and Ilha do Farol) along the Paraná coast, southern Brazil.

opportunistic taxa adapted to high turbidity zones. The lowest diversity, which was observed at Ilha do Farol, could also be associated with anthropic influence on eutrophication in addition to lower salinity and higher water turbidity.

Ilha do Mel showed higher species similarity between seasons, while Ilha do Farol showed higher biomass (data not shown), mainly *Ulva fasciata* Delile during the summer and *Pyropia* spp. during the winter. Some green algae are cosmopolitan and show opportunistic behavior. In some cases, low diversity and/or high biomass of some opportunistic taxa suggests eutrophication, input of pollutants and/or high herbivory activity in the area, as reported by Yoneshigue-Valentin & Valentin (1992). Also, filamentous Ulvales and other orders of foliose seaweeds could dominate areas with high continental water discharge. Thus, algal blooms could be explained as a result of an impact that had already occurred. This fact corroborates the stress sensitivity of some species that suffer from the adverse effects of short- and long-term exposure to urban-derived contaminants. However, these same species, which respond quickly to organic pollution, may also be good bioindicators in coastal monitoring plans (Pellizzari & Kawaii 2010).

Green seaweed beds found at Ilha do Farol mainly during the summer could be associated with urbanization and eutrophication from the discharge of organic effluents from rivers or even sewage on the beaches during the summer tourist season. Eutrophication also probably results from the location of this island at the mouth of Guaratuba Bay. During the summer months, the precipitation is higher, increasing continental runoff and resulting in lower seaweed diversity and biomass dominated by opportunistic taxa. Several reports have described the ephemeral *Ulva* species as opportunistic taxa and as pollution-tolerant species (Scherner et al. 2013). These authors also report that the photosynthetic response of the perennial, canopy-forming seaweed *Sargassum stenophyllum* Martius declines after pollution stress. Studying the impact of coastal urbanization on the structure of phytobenthic communities in southern Brazil, Martins et al. (2012) suggest that pristine-like environments are characterized by an increase of Rhodophyta species and that urbanized environments are dominated by opportunistic algae, including such green algae as *Ulva* and *Cladophora*. Amado-Filho et al. (2006) studied the infralittoral seaweeds from Laje de Santos, São Paulo State, identifying *Cladophora vagabunda, Padina gymnospora, Hypnea spinella* (C. Agardh) Kütz., *Centroceras clavulatum* and *Amphiroa beauvoisii* J.V. Lamour as conspicuous species during the summer and winter. According to our study, these taxa were also found in all sampling sites in the Paraná islands and could be used as bioindicators or proxies of seasonal variation.

Considering the advances in molecular analysis, seaweed diversity along the Brazilian coastline, including insular ecosystems, needs to be further investigated. Moreover, the subtidal regions remain a gap in phycoflora knowledge in some Brazilian states (Horta et al. 2001; Nunes 2005). Since the present study comprises subtidal samplings along the Paraná coast at Currais Archipelago, the survey, as detailed in Table 1, should serve to fill this gap. However, many places of the Paraná coast are still unexplored below depths of 15 m.

The knowledge of seaweed diversity through updated surveys is essential to conservation studies. Significant seasonal changes that affect diversity, both short and long term, can be detected through proxies as new occurrences. Changes in the ecosystem can also be indicated by the identification of new species, the invasion of alien species, and blooms of opportunistic taxa. Thus, the development of a database, such as that provided in the present study, can help in the identification of bioindicators for monitoring coastal waters, which is an essential component of conservation. This database serves to detect impacts that can affect the patterns of biogeographical distribution, suggesting, in turn, gradual or abrupt changes in coastal communities. Furthermore, the increase in algal utilization in many countries, including Brazil, may result in unsustainable seaweed resources and even depletion of natural beds, suggesting that diversity in association with water quality monitoring should be included as a mandatory tool for conservation initiatives.

Acknowledgments

The authors thank the Japanese International Cooperation Agency (JICA), Kobe University, NaGISA (inside CoML - Census of Marine Life), SARCE (South America Research Group in Coastal Ecosystems), Fundação Araucária; Dr. Juan Cruz, Dr. Patricia Miloslavich (USB – Venezuela) and Dr. Yara Tavares for reviewing the statistical analysis. NSY thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the research grant.

References

ALVES, R.J.V. 1998. Ilha da Trindade e Arquipélago Martin Vaz - Um Ensaio Geobotânico: Serviço de Documentação da Marinha do Brasil; Diretoria de Hidrografia e Navegação, Niterói (RJ). ISBN 85-7047-064-9.

AMADO-FILHO, G.M., HORTA, P.A., BRASILEIRO, P., BARROS-BARRETO, M.B. & FUJII, M.T. 2006. Subtidal benthic marine algae of the Marine State Park of Laje de Santos (Sao Paulo, Brazil.) Braz. J. Oceanog. 54(4):225-234.

BORZONE, C.A. 1994. Proposta para a categoria e o plano de manejo das ilhas oceânicas do litoral do Paraná. Pontal do Paraná, Pontal do Sul, Paraná, Brasil. Universidade Federal do Paraná. Relatório IAP - Centro de Estudos do Mar.

BURGOS, D.C., PEREIRA, S.M.B. & BANDEIRA-PEDROSA M.E. 2009. Levantamento florístico das Rodofíceas do Arquipélago de São Pedro e São Paulo (ASPSP) – Brasil. Acta Bot. Bras. 23(4):1110-1118, doi: http://dx.doi.org/10.1590/S0102-33062009000400020

DAJOZ, R. 1973. Ecologia geral. 3th ed. Vozes. Petrópolis, RJ.

ESTON, V.R., MIGOTTO, A.E., OLIVEIRA, E.C., RODRIGUES, S.A. & FREITAS, C. 1986. Vertical distribution of benthic marine organisms on rocky coasts of the Fernando de Noronha Archipelago (Brazil). Bol. Inst. Oceanogr. 34:37-53.

FIGUEIREDO, M.A.O. 2006. Diversity of macrophytes on the Abrolhos Bank, Brazil; p. 67-74 In: G.F. Dutra, G.R. Allen, T. Werner and S.A. McKenna (ed.). A Rapid Marine Biodiversity Assessment of the Abrolhos Bank, Bahia, Brazil. Washington: Conservation International.

GUIRY, M.D. & GUIRY, G.M. 2013. AlgaeBase. World-wide electronic publication. National University of Ireland, Galway. Retrieved from http://www.algaebase.org. Accessed on July 2013.

HORTA, P.A., AMANCIO, E., COIMBRA, C.S. & OLIVEIRA, E.C. 2001. Considerações sobre a distribuição e origem da flora de macroalgas marinhas brasileiras. Hoehnea. 28(3):243-265.

HORTA, P.A., SALLES, J.P., BOUZON, J., SCHERNER, F., CABRAL, D.Q. & BOUZON, Z.L. 2008. Composição e estrutura do fitobentos do infralitoral da Reserva Biológica Marinha do Arvoredo, Santa Catarina, Brasil – implicações para a conservação. Oecol. Brasil., 12(2):243-257.

LANA, P.C., MORONE, E., LOPES, R.M. & MACHADO, E.C. 2001. The Subtropical Estuarine Complex of Paranaguá Bay, Brazil, p. 131-145. In: U. SEELIGER & B. KJERFVE (Eds). Coastal Marine Ecosystems of Latin America. Berlin, Springer-Verlag.

LITTLER, M.M. & LITTLER, D.S. 1980. The evolution of thallus form and survival strategies in benthic marine macroalgae: field and laboratory tests of a functional form model. Am. Nat. 116:25-44, doi: http://dx.doi.org/10.1086/283610

MARTINS, C.L., ARANTES, N., FAVERI, C., BATISTA, M.B., OLIVEIRA, E.C., PAGLIOSA, P.R., FONSECA, A.L., NUNES, J.M.C., PEREIRA, S.B. & HORTA P.A. 2012. The impacts of coastal urbanization on the structure of phytobenthic communities in Southern Brazil. Mar. Poll. Bull. 64:772-778, doi: http://dx.doi.org/10.1016/j.marpolbul.2012.01.031

MIZERKOWSKI, B.D, MACHADO, E.C., BRANDINI, N., NAZARIO, M.G., & BONFIM, K.V. 2012. Environmental water quality assessment in Guaratuba Bay, state of Paraná, southern Brazil. Braz. J. Oceanog. 60(2):109-115, doi: http://dx.doi.org/10.1590/S1679-87592012000200001

NUNES, J.M.C. 2005. Rodofíceas marinhas bentônicas do Estado da Bahia, Brasil. Tese. Doutorado. Instituto de Biociências da Universidade de São Paulo.

OLIVEIRA, E.C., HORTA, P.H & SILVA, B.N.T. 2013. Algae Maris Brasilis. Algas Marinhas Bênticas do Brasil. Retrieved from http://www.algaemarisbrasilis.ccb.ufsc.br/. Accessed on July 2013.

PEDRINI, A.G., GONÇALVES, L.E.A., FONSECA, M.C.S., ZAÚ, A.S., LACORTE, C.C. 1989. A survey of the marine benthic algae of Trindade Island, Brazil. Bot. Mar. 32(2):97-99, doi: http://dx.doi.org/10.1515/botm.1989.32.2.97

PELLIZZARI, F.M., YOKOYA, N.S. & OLIVEIRA, E.C. 2007. Cultivation of the edible green seaweed *Gayralia* (Chlorophyta) in southern Brazil. J. App. Phycol. 19:63-69, doi: http://dx.doi.org/10.1007/s10811-006-9111-1

PELLIZZARI, F.M.; OLIVEIRA, E.C & YOKOYA, N.S. 2008. Life-history, thallus ontogeny, and the effects of temperature, irradiance and salinity on growth of the edible green seaweed *Gayralia* spp. (Chlorophyta) from Southern Brazil. J. Appl. Phycol. 20:75–82, doi: http://dx.doi.org/10.1007/s10811-007-9183-6

PELLIZZARI, F. & KAWAII, H. (Eds.). 2010. Manual of protocols for stablishment of a monitoring system and continual utilization of fishing ground in the Bays of Parana Coast, Brazil. Under JICA/HEAA Partnership Program.

PELLIZZARI, F. & REIS, R.P. 2011 Seaweed cultivation on the Southern and Southeastern Brazilian Coast. Braz. J. Pharmacog. 21(2):305-312.

PELLIZZARI, F., OLIVEIRA, M.C., MEDEIROS, A., YOKOYA, N.S. & OLIVEIRA E.C. 2013. Morphology, ontogeny, and phylogenetic position of *Gayralia brasiliensis* sp. nov. (Ulotrichales, Chlorophyta) from the southern coast of Brazil. Bot. Mar. 56(2):197–205, doi: http://dx.doi.org/10.1515/bot-2012-0197

ROCHA-JORGE, R. 2010. Diversidade de macroalgas do Parque Estadual Marinho da Laje de Santos, SP, Brasil. Dissertação. Instituto de Botânica da Secretaria do Meio Ambiente. São Paulo.

SANTOS, R., MARTINS, A.S., FARIAS, J.N., HORTA, P.A., PINHEIRO, H., TOREZANI, E., BAPTISTOTTE, C., SEMINOFF, J., BALAZS, G. & WORK, T. 2011. Coastal habitat degradation and green sea turttle diets in Southeastern Brazil. Mar. Poll. Bull. 62:1297-1302, doi: http://dx.doi.org/10.1016/j.marpolbul.2011.03.004

SCHERNER, F., BARUFI, J.B. & HORTA P.A. 2012. Photosynthetic response of two seaweeds species along an urban pollution gradient: Evidence of selection of pollution-tolerant species. Mar. Poll. Bull. 64:2380-2390, doi: http://dx.doi.org/10.1016/j.marpolbul.2012.08.012

SCHERNER, F., VENTURA, R., BARUFI, J.B. & HORTA P.A. 2013. Salinity critical threshold values for photosynthesis of two cosmopolitan seaweed species: providing baselines for potential shifts on seaweeds assemblages. Mar. Environ. Res. 91:14-25, doi: http://dx.doi.org/10.1016/j.marenvres.2012.05.007

SHIRATA, M.T. 1991. Algas marinhas da Ilha do Farol, Praia de Caiobá, município de Matinhos, Paraná, Brasil. Arq. Biol. Tecnol. 34(3/4):443-453.

SHIRATA, M.T. 1993a. Algas marinhas bentônicas da Porção Sul do Saco do Limoeiro (Ilha do Mel), município de Paranaguá, estado do Paraná, Brasil. Arq. Biol. Tecnol. 36(4):721-730.

SHIRATA, M.T. 1993b. Algas marinhas do manguezal de Guaraqueçaba, município de Guaraqueçaba, Estado do Paraná, Brasil. Publicação da Pontífica Universidade Católica do Paraná. Vol. 03. Curitiba, Paraná.

STENECK, R.S. & DETHIER, M.N. 1994. A functional group approach to the structure of algal – dominated communities. Oikos 69:476-498, doi: http://dx.doi.org/10.2307/3545860

UGADIM, Y. 1973. Algas marinhas bentônicas do litoral Sul do Estado de São Paulo e do litoral do Estado do Paraná (Brasil). I - Divisão Chlorophyta. Bol. Botânica, Universidade de São Paulo. 1:11-77.

UGADIM, Y. 1974. Algas marinhas bentônicas do litoral Sul do Estado de São Paulo e do litoral do Estado do Paraná (Brasil). III - Divisão Rhodophyta: Goniotrichales, Bangiales, Nemalionales e Gelidiales. Bol. Botânica, Universidade de São Paulo. 2:93-137.

UGADIM, Y. 1976. Ceramiales (Rhodophyta) do litoral Sul do Estado de São Paulo e do litoral do Estado do Paraná (Brasil). Bol. Botânica, Universidade de São Paulo. 4:133-172.

WYNNE, M.J. 2011. A checklist of benthic marine algae of the tropical and subtropical western Atlantic: third revision. Nova Hedwigia, Beiheft, Alemanha 140:1-166. ISBN 978-3-443-51062-6.

YONESHIGUE–VALENTIN, Y. & VALENTIN, J.L. 1992. Macroalgae of the Cabo Frio upwelling Region, Brazil: Ordination of Communities. p. 31-50. In: U. SEELIGER (ed). Coastal Plant Communities of Latin America. San Diego: Academic Press.

Received 02/08/2013
Revised 26/05/2014
Accepted 15/06/2014

Biota Neotropica 14(2): e20130029, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Characterization of the geographical distribution pattern of the family Limacinidae Gray, 1840 (Mollusca - Gastropoda) in the waters of Northeastern of Brazil

***Valdeni Soares de Oliveira Koblitz*[1] *& Maria Eduarda de L. Larrazábal*[2]**

[1,2] *Universidade Federal de Pernambuco, Centro de Ciências Biológicas - CCB, Departamento de Zoologia,*
Programa de Pós-Graduação em Biologia Animal. Av. Prof. Moraes Rêgo, 1235, CEP: 50640-420,
Recife-PE/Brasil. e-mail: vsokblitz@gmail.com; mells@ufpe.com

OLIVEIRA-KOBLITZ, V.S. & LARRAZÁBAL, M.E.L. **Characterization of the geographical distribution pattern of the family Limacinidae Gray, 1840 (Mollusca - Gastropoda) in the waters of Northeastern of Brazil.** Biota Neotropica. 14(2): e20130029. http://dx.doi.org/10.1590/1676-06032014002913

Abstract: The geographical distribution of the family Limacinidae in the Northeastern coast of Brazil was analyzed by taking into account the most relevant ecological aspects, aiming to increase the knowledge about the Family. The material was collected during the 4th Oceanographic Expedition of the REVIZEE program (Assessment of the Sustainable Potential of Living Resources in the Exclusive Economic Zone - *Avaliação do Potencial Sustentável de Recursos Vivos da Zona Econômica Exclusiva*), in the months from September to December 2000. The studied area is located between 00°46’45’’N and 13°53’45’’S and between 29°15’40’’W and 39°49’42’’W, where six trips were performed, totaling 123 stations. The samples were collected using a bongo net (300- and 500-µm mesh size and net mouths of 60 cm in diameter) coupled with a digital flowmeter in oblique hauls from a depth of 0 to 200 m. For this study, the organisms retained in the 300-µm mesh were considered. On board the ship, the samples were placed in plastic containers, labeled, and fixed in 4% formaldehyde buffered with sodium tetraborate. In the laboratory, the samples were analyzed on a “Bogorov” tray under a binocular stereomicroscope. A total of 5655 individuals of the family Limacinidae were examined and were distributed as follows: 3 genera and 5 species. Representatives of the family Limacinidae were observed at high temperatures and salinities and were thus characterized as tropical and euhaline. *Heliconoides inflatus* was the species with the greatest abundance and frequency. *Limacina lesueurii* proved to be a rare, infrequently observed species. *Limacina trochiformis* and *L. bulimoides* were not abundant or frequent. *Limacina lesueurii* and *L. bulimoides* were recorded in neritic waters for the first time; this was also the first record of *L. lesueurii* in the waters of Northeastern Brazil. *Limacina trochiformis* and *L. bulimoides* exhibited wide distributions, although they were neither very frequently observed nor abundant. The distribution of *Thielea helicoides* was restricted to oceanic waters. A correlation between *Limacina bulimoides*, *Heliconoides inflatus*, *Thielea helicoides,* and *L. lesueurii* was observed because they coexisted in the same niche.

Keywords: *holoplanktonic mollusks, REVIZEE, Northeastern Brazil.*

OLIVEIRA-KOBLITZ, V.S. & LARRAZÁBAL, M.E.L. **Caracterização do padrão de distribuição geográfica da família Limacinidae Gray, 1840 (Mollusca – Gastropoda) nas águas do Nordeste brasileiro.** Biota Neotropica. 14(2): e20130029. http://dx.doi.org/10.1590/1676-06032014002913

Resumo: A distribuição geográfica da família Limacinidae na costa do Nordeste brasileiro, foi analisada levando em consideração os aspectos ecológicos mais relevantes, objetivando a ampliação do conhecimento sobre a família. O material foi coletado durante a IV Expedição Oceanográfica do Programa REVIZEE (Avaliação do Potencial Sustentável de Recursos Vivos da Zona Econômica Exclusiva), nos meses de setembro a dezembro de 2000. A área estudada está localizada entre 00°46’45’’N a 13°53’45’’S - 29°15’40’’W a 39°49’42’’W, onde foram realizados seis cruzeiros, totalizando 123 estações. As amostras foram coletadas em rede tipo bongo (malhas coletoras de 300 e 500 µm, com aros de 60 cm de diâmetro) acopladas com fluxômetro digital, em arrastos oblíquos na profundidade de 0 a 200 m. Foram considerados os organismos retidos na malha de 300 µm. A bordo, as amostras foram acondicionadas em recipientes plásticos, etiquetadas e fixadas em formaldeído a 4%, tamponado com tetraborato de sódio. Em laboratório, as amostras foram analisadas em placa do tipo “Bogorov”, sob estereomicroscópio binocular. Foram examinados 5655 indivíduos da família Limacinidae, assim distribuídos: 03 gêneros e 05 espécies. Os representantes da família Limacinidae ocorreram em altas temperaturas e salinidades, caracterizando-se, assim, como tropicais e euhalinos. *Heliconoides inflatus* sobressaiu em abundância e frequência. *Limacina lesueurii* mostrou-se uma espécie rara e pouco frequente. *Limacina trochiformis* e *L. bulimoides* foram pouco abundantes e pouco frequentes. *Limacina lesueurii e L. bulimoides* foram registradas como primeira ocorrência em águas neríticas, sendo este o primeiro registro de *L. lesueurii* para as águas do Nordeste brasileiro. *Limacina trochiformis* e *L. bulimoides* tiveram ampla distribuição, apesar de pouco frequentes e pouco abundantes. A distribuição de *Thielea helicoides* restringiu-se às águas oceânicas. Foi observada uma correlação entre *Limacina bulimoides, Heliconoides inflatus*, *Thielea helicoides* e *L. lesueurii* por coexistirem no mesmo nicho.

Palavras-chave: *moluscos holoplanctônicos, REVIZEE, Nordeste do Brasil.*

Introduction

The family Limacinidae Gray, 1840 comprises holoplanktonic marine molusks found in all oceans, from the neritic to the oceanic zone (Bé & Gilmer 1977, Spoel & Dadon 1999). The family includes the Gastropoda belonging to clade Thecosomata Blainville, 1824 (Bouchet & Rocroi 2005). These molusks are characterized by conical and sinistral shells and exhibit a high or low spiral (Janssen 2003).

Spoel & Heyman (1983) list the following factors as being responsible for the geographical distribution and speciation of plankton: the geologic history of the oceans, continental barriers, current patterns, and the limit for individual survival of species and/or populations depending on the environmental conditions of abiotic and biotic factors. Changes in certain factors enable or preclude the presence of certain species, depending on the species tolerances to them. Thus, the distribution of species in nature can be wide or narrow (Hedling et al. 1994).

The patterns of the geographical distribution of holoplanktonic molusks have been studied by several researchers. Boas (1886 apud Spoel 1996) wrote the first monograph on the taxonomy, distribution, and variability of holoplanktonic molusks. This knowledge has been expanded in the nineteenth century as a result of large oceanographic expeditions that contributed to the knowledge of several planktonic species, including Limacinidae. The Challenger Expedition (1872-1874) was especially important for this zoological group, as it was during this expedition that Pelseneer (1888) described and recorded 42 species of Thecosomata among the various marine provinces. Meisenheimer (1905) published the first maps of the geographical distribution of Pteropoda (Thecosomata and Gymnosomata, members of the Valdivia Expedition collection), which is considered a pioneer study. Tesch (1913) produced a more recent monograph with new taxa. Bé & Gilmer (1977) described the geographical distribution of Euthecosomata. In the twentieth century, the works by Spoel (1967) and Lalli & Gilmer (1989) stand out due to their contributions to the taxonomy, ecology, and geographical distribution of the group.

For the South Atlantic, some reference studies are of significance for this zoological group. Scarabino (1967) described the occurrence of Heteropoda and Pteropoda at the Uruguayan continental shelf. Magaldi (1974, 1977 and 1981) conducted a systematic description of Pteropoda for the South Atlantic, adjacent to the coast of Argentina and Uruguay. Spoel & Boltovskoy (1981) devoted a chapter of a book on taxonomy, ecology, and the geographical distribution of Pteropoda in the South Atlantic. Dadon & Magaldi (1995) reported on the distribution of Thecosomata at the Brazil-Malvinas Confluence zone. Spoel & Dadon (1999) devoted a chapter to the systematics update, ecology, and geographical distribution of Pteropoda.

For the waters of Northeastern Brazil, the first occurrence of Pteropoda was described by Pelseneer (1888) using material from the Challenger Expedition. He described the species *Limacina inflata* (d'Orbigny, 1834), *Limacina lesueurii* (d'Orbigny, 1835), *L. trochiformis* (d'Orbigny, 1834), and *L. bulimoides* (d'Orbigny, 1834), based on shells deposited on the substrate between the states of Pernambuco and Bahia, which constituted the first records of the geographical distribution of the family Limacinidae. Barth & Oleiro (1968) contributed to the knowledge of the systematics, taxonomy, ecology and geographical distribuition of the planktonic molusks *Limacina inflata*, *L. helicoides,* and *Limacina lesueurii* in the region of Cabo Frio, Rio de Janeiro. Rios (1994) presented only a list of species with its illustrations for Brazil. Resgalla Júnior (1993) established the pattern of spatial and temporal distribution of Pteropoda, Cladocera, and Chaetognatha at the South Brazil shelf, stating that, for Pteropoda, the family Limacinidae is distinguished by the dominance of *Limacina retroversa* (Fleming, 1823) and *L. inflata.* Oliveira (2002) described the ecology and distribution of the group in relation to the waters of Northeastern Brazil, highlighting *Limacina inflata* as the dominant species; Oliveira & Larrazábal (2002) and Larrazábal & Oliveira (2003) described the ecology of Thecosomata and Gymnosomata at the waters of the São Pedro e São Paulo Arquipelago and the Fernando de Noronha chain.

Despite the widespread knowledge about the malacofauna of Brazil, with respect to Thecosomata, studies remain scarce. A study of the geographical distribution of Limacinidae proves to be significant due to the need to update the structural knowledge of the population relative to other planktonic organisms as well as the richness of malacofauna. This study thus aims to analyze the geographical distribution of the family Limacinidae in the waters of Northeastern Brazil.

Materials and Methods

The Exclusive Economic Zone (EEZ) in Northeast Brazil is located in the western region of the Atlantic from Salvador-BA to the mouth of the Parnaíba River, between 12 and 200 nautical miles from the coastline, from the surface to a depth varying from 500 m to, in specific cases, to 6, 000 m, which is equivalent to an area of approximately 1,100,000 km^2. This area does not include the 350,000 km^2 of the surroundings of the São Pedro and São Paulo Archipelago (Flores Montes et al. 2009).

The EEZ includes the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, and Ceará. Because it is an area of large oceanic extent and physiographic diversity, it was subdivided into sectors and sub-areas with higher degrees of homogeneity as follows: **Subarea I** - Continental Slope and Shelf of the EEZ, **Sector 1** – from the mouth of the Parnaíba River-PI to Cabo Calcanhar-RN and **Sector 2** – from Cabo Calcanhar-RN to Barra da Estância-BA; and **Subarea II** - Oceanic Zone of EEZ,

http://dx.doi.org/10.1590/1676-06032014002913

Sector 1 – from 35°W to the mouth of the Parnaíba River-PI, **Sector 2** - east of 35°W and north of 5°S, and **Sector 3** – from 5°S to Salvador-BA (Coordenação Geral do Programa REVIZEE [s.d.]).

With respect to hydrological and climatic aspects, the South Atlantic is characterized by its surface current dynamics associated with wind movement, which determines, in the southern hemisphere, anticyclonic rotation, known as the South Atlantic Gyre. The currents can reach varied depths in the regions close to the equator and the southern limit of the gyre (Pickard & Emery 1982, Assad et al. 2009).

The EEZ of the coast of Northeastern Brazil is part of the Equatorial System of Marine Currents. The trade winds from the southeast, which act on the equatorial region between the parallels 10° to 15°S, force the bifurcation of the South Equatorial Current (SEC), which flows westward toward the Northeastern Brazilian coast. The current that deviates to the north and crosses the equator toward the North Atlantic is the North Brazil Current (NBC), while the one that returns to the South becames the Brazil Current (BC), following southward the Brazilian coast. The latter is the main surface current in Brazil, which moves over the shelf or near the border region (Soares-Gomes & Figueiredo 2009; Assad et al. 2009).

In this region, water masses ranging from the surface to the bottom predominate: the Tropical Surface Water (TSW), the South Atlantic Central Water (SACW), and the Antarctic Intermediate Water (AIW), without significant influences from the continental contribution of low salinity waters (Medeiros et al. 2009).

According to Medeiros et al. (2009), the coast of Northeastern Brazil has a Tropical Atlantic climate with two clear seasons: dry and wet. The dry season occurs between the months from June to November, when the rainfall is reduced; the wet season occurs between the months from December to May, when rainfall totals are high.

The material was collected between the months of September to December 2000 by the oceanographic research ship Antares from the Office of Hydrography and Navigation of the Brazilian Navy (Diretoria de Hidrografia e Navegação-DHN/ Marinha do Brasil) as part of the project "Assessment of the Sustainable Potential of Living Resources in the Exclusive Economic Zone" (REVIZEE/SCORE- NS IV). This portion of the EEZ is located between the coordinates 00°46’45’’N and 13°53’45’’S - 29°15’40’’W and 39°49’42’’W. Six trips were conducted in the following areas: the Southern Oceanic, Eastern Oceanic, São Pedro and São Paulo Archipelago, North Chain/Rocas/Noronha, North Coast, and South Coast, totaling 123 stations. The water column was sampled using bongo nets with net mouths of 60 cm in diameter and a mesh size of 300 and 500 μm coupled with a digital flowmeter. For this study, the organisms retained on the 300-μm mesh collected in oblique hauls at depths of 0 to 200 m lasting 15 min until the net’s arrival at the surface were considered. The ship’s speed was constant (approximately 2 knots). On board, the samples were stored in plastic containers, labeled, and fixed in 4% formaldehyde buffered with sodium tetraborate for subsequent laboratory analysis.

Simultaneous with the collection of plankton, water samples were taken for the determination of abiotic data, such as salinity and temperature. These profiles were obtained using the CTD profiler (Conductivity Temperature Depth), used for the continuous measurement of conductivity, temperature, and depth, with readings in real time and using the computer software SEASOFT version 4.217 to monitor the termohaline profile. The hydrological samples were collected through a “Rosette” containing Niskin bottles.

The classification of the waters based on the temperature values is as follows: tropical (above 20°C); temperate-hot (13 to 20°C), temperate-cold (2 to 13°C), and cold (-2 to 2°C), as extracted from Melo-Filho & Melo (2001). The classification based on the values of water salinity according to the Venice Symposium of 1959 are as follows: hyperhaline (> 40); euhaline (30 to 40); mixohaline (0.5 to 30), which is divided into (mixo-) polyhaline (18 to 30), (mixo-) mesohaline (5 to 18), and (mixo-) oligohaline (0.5 to 5); and fresh <0.5, extracted from Semensatto Junior (2006).

In the laboratory, zooplankton samples were washed and placed on a “Bogorov” tray for observation under a binocular stereomicroscope. From each sample, all of the Thecosomata and Gymnosomata of the accompanying fauna were removed with the aid of a plastic Pasteur pipette and brush no. 00. Subsequently, the specimens were placed in glass vials and fixed in 70% alcohol and 10% glycerin. For the present study, the specimens of the family Limacinidae present in 111 stations (Table 1) were used. Figure 1 presents the geographical distribution of the stations in the waters of Northeastern Brazil. The collected material is stored at the Laboratory of Conservation Biology of the Department of Zoology of the Center of Biological Sciences of the Federal University of Pernambuco (Universidade Federal de Pernambuco – UFPE).

The identification followed the specialized bibliography, such as Pruvot-Fol (1942, 1954), Tesch (1904, 1946), Spoel (1964, 1967, 1972), Abbott (1974), Spoel & Boltovskoy (1981), and Spoel & Dadon (1999), among others. Recent publications by Janssen (2003, 2007, 2012) have raised controversy regarding the systematics of the family Limacinidae. Based on fossil records and reviewing the Family, Janssen established genus and type species in which *Heliconoides inflatus* (d’Orbigny, 1834) replaced *Limacina inflata*. *Thielea helicoides* (Jeffreys, 1877) also replaced *Limacina helicoides*. The proposed names were accepted in databases such as the CLEMAM (2011) and Global Species (2013). In the website Malacolog (Rosenberg 2009) considered the name *Limacina inflata* as valid in its database and, *Heliconoides inflata* a synonym. The website WoRMS considers *Heliconoides inflatus* as valid, although the author of the species, d’Orbigny (1834), considers named it *Atlanta inflata* because it was considered a Heteropoda at the time and later became *Limacina inflata*. This work follows the nomenclature established in the aforementioned review, extending this conversion to the reviewed works.

The Relative Abundance (*RA*) was calculated according to the recommendations of Lobo & Leighton (1986) using the following formula: $RA = N \times 100/Na$, where N is the total number of organisms from each taxon in the sample, and *Na* is the total number of organisms in the sample. The following criteria were adopted: $RA \geqslant 70\%$, dominant; $40\% \leq RA < 70$, abundant; $10\% < RA \leq 40\%$, not abundant; and $RA \leq 10\%$, rare.

The Frequency of Occurrence (*F*) of the species was calculated after taking into account the number of samples in which the species was found with respect to the total number of samples, modified by Matteucci & Colma (1982) using the following expression: $F = a \times 100/A$, where F = Frequency of Occurrence (%), a = the number of samples containing species,

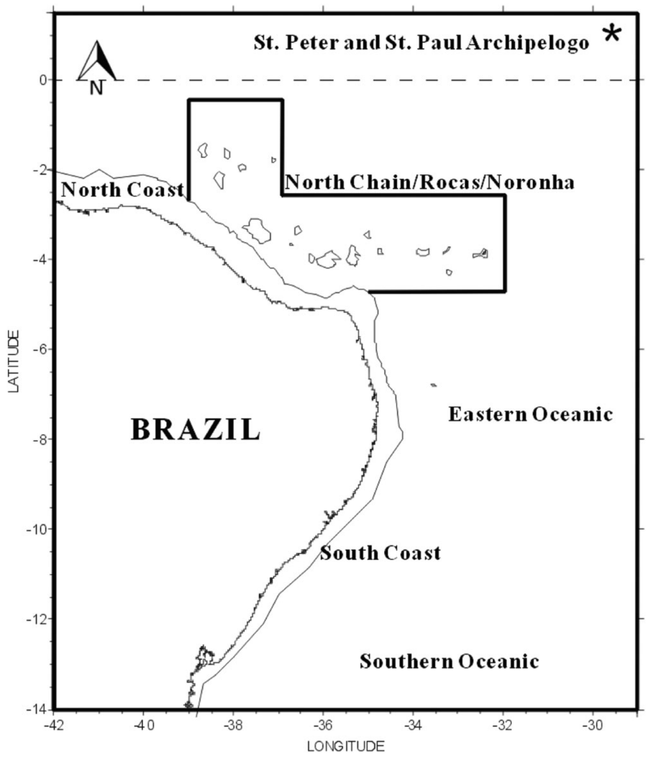
Table 1. Areas, stations, and coordinates of samplings performed in the 4th Campaign of REVIZEE-NE.

Southern Oceanic:											
E002,	13°17’44"S	-	37°39’59"W;	**E004**,	13°53’45"S	-	35°27’35"W;	**E005**,	13°30’58"S	-	35°59’14"W;
E006,	13°12’12"S	-	36°33’09"W;	**E007,**	12°50’03"S	-	37°21’28"W;	**E008,**	12°14’20"S	-	36°48’40"W;
E009,	12°35’53"S	-	36°13’42"W;	**E011,**	12°44’40"S	-	34°37’56"’W;	**E012**,	12°18’27"S	-	35°24’08"W;
E013,	11°41’18"S	-	36°25’30"W;	**E014**,	11°15’6"S	-	35°56’00"W;	**E015**,	11°39’08"S	-	35°19’18"W;
E016,	12°01’02"S	-	34°36’85"W;	**E017**,	11°33’25"S	-	33°46’06"W;	**E018**,	11°09’23"S	-	34°35’05"W;
E019,	10°51’39"S	-	35°46’50"W;	**E020**,	10°10’74"S	-	35°07’33"W;	**E021**,	10°38’59"S	-	34°54’25"W;
E022,	10°47’46"S	-	33°36’02"W;	**E023**,	10°41’46"S	-	32°86’12"W;	**E024**,	10°06’24"S	-	33°35’10"W;
E025,	09°38’17"S	-	34°21’38"W;	**E027**,	08°57’6"S	-	34°19’08"W;	**E028**,	09°43’31"S	-	33°12’81"W;
E029,	09°40’43"S	-	32°31’40"W;	**E030**,	08°50’04"S	-	31°44’47"W;	**E031**,	08°37’12"S	-	32°27’00"W;
E032,	08°29’57"S	-	33°02’56"W;	**E033**,	08°20’55"S	-	33°45’25"W;	**E034**,	08°09’43"S	-	34°29’14"W.
Eastern Oceanic:											
E036,	06°13’45"S	-	33°33’57"W;	**E037**,	05°33’09"S	-	33°42’17"W;	**E040**,	06°09’55"S	-	32°13’44"W;
E042,	07°47’45"S	-	31°57’44"W;	**E043**,	07°52’49"S	-	31°27’14"W;	**E044**,	07°02’05"S	-	31°25’10"W;
E045,	06°13’17"S	-	31°31’49"W;	**E046**,	05°32’04"S	-	31°39’38"W;	**E047**,	04°49’10"S	-	31°20’32"W;
E048,	04°07’06"S	-	31°29’42"W;	**E049**,	03°24’46"S	-	31°29’42"W;	**E050**,	02°51’42"S	-	31°16’20"W;
E051,	02°13’41"S	-	30°40’56"W;	**E052**,	01°37’42"S	-	30°04’57"W;	**E054**,	01°06’31"S	-	29°36’32"W;
E056,	04°04’18"S	-	29°30’10"W;	**E057**,	05°29’57"S	-	29°38’10"W;	**E059**,	05°30’49"S	-	31°59’08"W.
São Pedro and São Paulo Archipelago (ASPSP):											
E060,	04°01’22’S	-	34°20’39"W;	**E063**,	02°51’48"S	-	33°12’54"W;	**E065**,	02°01’03"S	-	32°14’12"W;
E069,	00°04’39"S	-	30°19’09"W;	**EA01**,	00°46’54"N	-	29°20’12"W;	**EA03**,	00°57’25"N	-	29°20’58"W;
EA04,	01°02’52"N	-	29°21’03"W;	**EA06**,	00°54’26"N	-	29°15’40"W;	**EA07**,	00°54’21"N	-	29°21’41"W;
EA08,	00°55’11"N	-	29°28’40"W;	**E085**,	01°45’05"W	-	33°47’53"W;	**E087**,	02°50’28"S	-	34°47’32"W.
North Chain/Rocas/Noronha (banks):											
E088,	03°56’19"S	-	36°18’34"W;	**E089**,	03°56’56"S	-	36°02’56"W;	**E090**,	04°02’44"S	-	35°50’37"W;
E091,	03°57’07"S	-	35°24’02"W;	**E092**,	03°58’08"S	-	35°13’02"W;	**E093**,	04°15’44"S	-	33°18’01"W;
E094,	04°15’50"S	-	33°12’00"W;	**E095**,	03°50’20"S	-	31°22’56"W;	**E098**,	03°51’16"S	-	32°29’10"W;
E099,	03°53’16"S	-	32°35’18"W;	**E101**,	03°45’50"S	-	33°08’40"W;	**E105**,	03°49’08"S	-	34°39’02"W;
E107,	03°29’52"S	-	35°03’08"W;	**E109**,	01°45’57"S	-	37°04’15"W;	**E111**,	01°55’38"S	-	37°48’19"W;
E112,	01°56’34"S	-	37°53’23"W;	**E113,**	01°39’57"S	-	38°06’05"W;	**E115**,	01°26’18"S	-	38°36’57"W;
E117,	02°05’59"S	-	38°25’18"W;	**E121**,	02°59’49"S	-	37°44’54"W;	**E125**,	03°37’42"S	-	36°42’44"W;
E126,	03°23’24"S	-	37°22’10"W;	**E130**,	03°21’14"S	-	38°07’29"W.				

Continued on next page

Table 1. Continued.

North Coast:											
E133,	02°09'88"S	-	39°49'42"W;	**E134**,	03°17'42"S	-	38°07'06"W;	**E136**,	04°31'54"S	-	36°41'54"W;
E139,	04°43'24"S	-	35°01'12"W;	**E140**,	04°48'06"S	-	35°06'12"W;	**E143**,	04°54'24"S	-	34°32'36"W;
E144,	04°46'24"S	-	34°03'48"W;	**E145**,	05°34'42"S	-	34°28'48"W;	**E146**,	05°38'08"S	-	34°54'24"W;
E151,	06°13'30"S	-	34°46'06"W;	**E152**,	06°16'48"S	-	34°16'30"W;	**E153**,	06°50'36"S	-	34°31'00"W;
E156,	07°05'00"S	-	34°29'00"W;	**E157**,	07°04'48"S	-	33°59'00"W;	**E158**,	07°04'42"S	-	33°29'18"W;
E159,	07°57'18"S	-	33°27'54"W;	**E160**,	07°54'00"S	-	33°57'36"W;	**E161**,	07°49'36"S	-	34°27'42"W;
E162,	07°33'06"S	-	34°18'00"W;	**E163**,	07°33'06"S	-	34°26'12"W.				
South Coast:											
E166,	08°08'48"S	-	34°08'21"W;	**E167**,	08°45'22"S	-	34°44'48"W;	**E170**,	09°28'14"S	-	35°03'24"W;
E171,	09°56'04"S	-	35°27'14"W;	**E174**,	10°24'54"S	-	35°58'34"W;	**E175**,	10°42'03"S	-	36°12'54"W;
E180,	11°57'25"S	-	37°57'20"W;	**E184**,	12°29'52"S	-	37°40'28"W.				



Source: Mafalda Júnior et al. (2009).

Figure 1. Areas of the 4th Campaign of REVIZEE-NE with the respective stations prospected in December 2000. N = indicates the geographical location of the stations.

and A = the total number of samples. Considering *F*, the following categories were distinguished: $F \geqslant 70\%$, very frequent; $40\% \leq F < 70\%$, frequent; $10\% < F < 40\%$, not very frequent; and $F \leq 10\%$, sporadic.

The relative density of the species was the result of dividing the number of individuals per species for each sample by the filtered volume of water in cubic meters. Subsequently, the calculated values were standardized by 10^{-3} as follows: $D = (n / V_f) \times 1000$, where D = density ($10^{-3}$ ind/m^3), n = number of individuals per species, and V_f = filtrate volume of water per cubic meter during hauling time.

The species were correlated by the density data and abiotic variables (temperature and salinity) through the non-parametric method of the Spearman coefficient (r_s).

In the taxonomic study, species were organized by synonymy, diagnosis, and geographical distribution of the material, including information on the oceanographic area, station, and coordinates.

The geographical distribution of the family Limacinidae was compiled for the Atlantic Ocean (north and south) at different times from the past to the present according to Pelseneer (1888), Meisenheimer (1905), Tesch (1946), Chen & Bé (1964), Furnestin (1964), Spoel (1967), Barth & Oleiro (1968), Lalli & Wells-Jr. (1973), Magaldi (1974, 1977 and 1981), Bé & Gilmer (1977), Haagensen (1976), Furnestin (1979), Wormuth (1981), Spoel & Boltovskoy (1981) Absalão (1989), Gasca & Suárez-Morales (1992), Resgalla Júnior (1993), Dadon & Magaldi (1995), Suárez-Morales & Gasca (1998), Spoel & Dadon (1999), Oliveira (2002), Oliveira & Larrazábal (2002), Larrazábal & Oliveira (2003), Parra-Flores & Gasca (2009), Larrazábal et al. (2009), and Suárez-Morales et al. (2009).

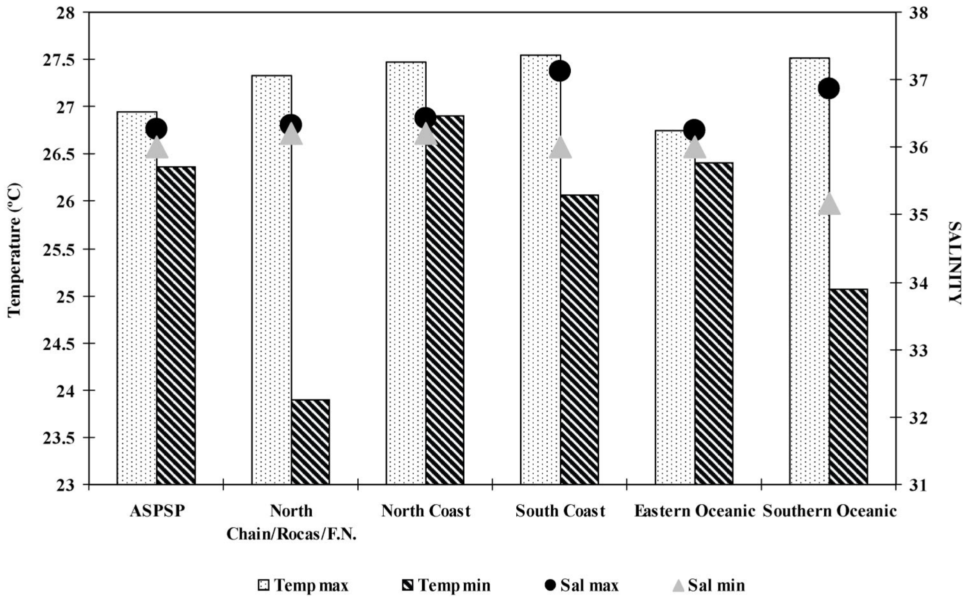


Figure 2. Minimum and maximum values of surface temperature and surface salinity in the areas of the Exclusive Economic Zone in Northeastern Brazil.

Results

The surface temperature of the water ranged from 23.90°C (station 88) to 27.54°C (station 166). The highest temperatures corresponded to the following areas: North Chain/Rocas/Fernando de Noronha, North Coast, South Coast, and Southern Oceanic, ranging from 27.33 to 27.54°C. The lowest temperatures were as follows: North Chain/Rocas/Fernando de Noronha, 23.90°C (station 88), and Southern Oceanic, 25.07°C (station 2). The surface salinity of the water ranged from 35.16 (station 22) to 37.12 (stations 174, 175 and 180). The highest value recorded for salinity was in the South Coast, with 37.53, and the lowest salinity recorded was in the Southern Oceanic, with 36.16 (Figure 2).

The Table 2 details the family Limacinidae occurrence according to surface temperature and salinity rates and its coefficient.

A total of 5663 individuals of Limacinidae, distributed in three genera and five species, were examined. *Heliconoides inflatus* was very abundant, whereas *Limacina bulimoides*, *L. trochiformis*, *L. lesueurii* and *Thielea helicoides* (Jeffreys, 1877) were rare, with *RAs* below 10% (Table 3).

Heliconoides inflatus was very frequent, with an *F* of 80.83%; *Limacina bulimoides* and *L. trochiformis* were frequent, with *F* of 51.66 and 50%, respectively. *L. lesueurii* was not very

Table 2. Variations of surface temperature and surface salinity in the samplings of species of the family Limacinidae during the 4th Campaign of REVIZEE NE, conducted in 2000.

Species	Surface Temperature ˚C Average	Min - Max	C.V (%)	Average	Surface Salinity Min - Max.	C.V (%)
H. inflatus	26.8	25.07 - 27.54	1.40	36.28	35.37 - 37.12	0.7
L. bulimoides	26.84	26.36 - 27.48	1.21	36.23	35.16 - 37.12	0.83
L. lesueurii	26.92	26.1 - 27.42	1.39	36.4	35.81 - 37.12	1.04
L. trochiformis	26.78	23.9 - 27.54	2.26	36.34	35.16 - 37.12	0.98
T. helicoides	26.68	26.4 - 27.15	1.53	36.03	35.81 - 36.2	0.56

Table 3: Species of the family Limacinidae identified in the 4th Campaign of REVIZEE NE, conducted in 2000, ranked according to Relative Abundance (*RA*).

GENUS	SPECIES	Number of individuals	*RA* (%)	*RA* Ranking
Heliconoides	*Heliconoides inflatus*	4 854	58.87	abundant
Limacina	*Limacina bulimoides*	297	3.51	rare
	Limacina lesueurii	31	0.37	rare
	Limacina trochiformis	477	3.79	rare
Thielea	*Thielea helicoides*	4	3.33	rare

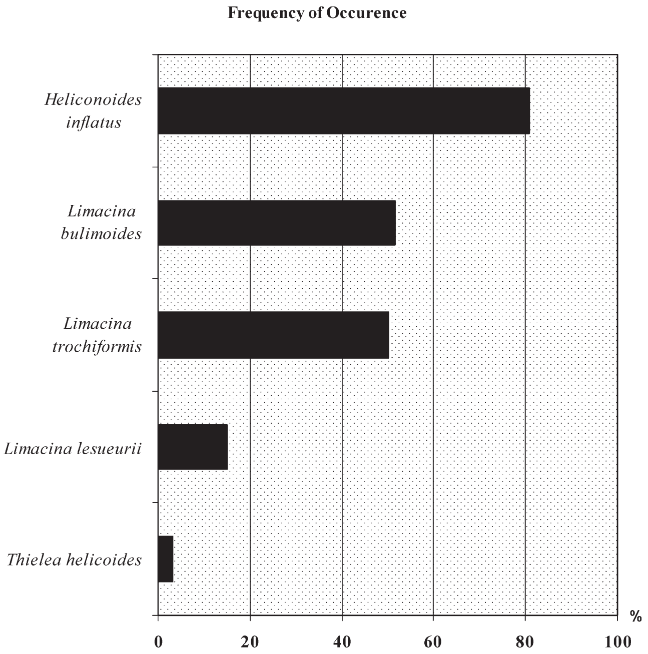


Figure 3. Frequency of the occurrence of species of the family Limacinidae collected during the 4th Campaign of REVIZEE-NE, conducted in 2000.

frequently observed, with an *F* 15%, and *Thielea helicoides* was sporadic, with an *F* of 3.33% (Figure 3).

The analysis of the Spearman coefficient indicates a positive and low correlation. *Limacina bulimoides* correlated positively with *T. helicoides*, *H. inflatus*, *L. lesueurii*, and surface salinity. *Thielea helicoides* correlated positively with *H. inflatus*. The species *H. inflatus* correlated positively with *L. lesueurii* and surface salinity. *Limacina lesueurii* correlated positively with *L. trochiformis* and was positively correlated with the abiotic parameters surface salinity and surface temperature. *Limacina trochiformis* was positively correlated with salinity (Table 4).

Taxonomic study and geographical distribution

Classe GASTROPODA Cuvier, 1795
Subclasse HETEROBRANCHIA Bursmeister, 1837
Infraclass OPISTHOBRANCHIA Milne-Edwards, 1846
Order THECOSOMATA Blainville, 1824
Family LIMACINIDAE Gray, 1840
Genus *Heliconoides* (d'Orbigny, 1835)
Heliconoides inflatus (d'Orbigny, 1834)
(Figure 9: a)

Synonymy

Atlanta inflata d'Orbigny, 1836: 174, pl. 12, figs. 16-19

Atlanta inflata d'Orbigny, 1836: 174, (1846), pl. 12, fig. 16-19.

Spirialis rostralis Eydoux & Souleyet, 1840: 236; Souleyet, 1855: 216, pl. 13, fig. 1 -10; Jeffreys, 1869:114; Bianco, 1903: 177.

Limacina inflata (d'Orbigny, 1836) Gray, 1850: 31; Boas, 1886: 48, 196, pl. 3, fig. 38; Pelseneer, 1888: 17; Carus, 1890: 439; Locard, 1897: 22; Tesch, 1904:11; Meisenheimer, 1905:4; Tesch, 1907: 182; Tesch, 1913:18, fig. 8; Vayssière, 1913: 183, pl. 20, fig. 10; Vayssière, 1915: 133, pl. 8, fig. 153-155; Stubbings, 1938: 16; Tesch, 1946:8, pl. 1, fig. 1a–c; Wormelle, 1962: 100.

Limacina scaphoidea Gould, 1852: 485 (1856), pl. 51, fig. 602 a-b.

Spirialis inflata Adams & Adams 1858: I, 59; Hubendick, 1951:3.

Helicinoides inflata Adams & Adams, 1858: II, 612; pl. 137, fig. 2, 2 a-b

Protomedea elata Costa, 1861:74, pl. 11, fig. 5; Dall, 1827:134.

Embolus rostralis (part) Jeffreys, 1870: 86.

Protomedea rostralis Fischer, 1883:430.

Spiratella inflata Pruvot-Fol, 1954:116 fig. 32f.

Limacina (*Thiele*) *inflata* (Orbigny) Spoel, 1967, p.50, figs. 17-18

Limacina inflata (d'Orbigny, 1836), Janssen: 1990, p. 14, pl, 2. figs. 5-7, pl. 3. fig. 11, pl. 10, fig. 2

Limacina (*Heliconoides*) *inflata* (d'Orbigny, 1834), Janssen: 1999. p. 14, pl. 2, figs. 10, 11

Heliconoides inflata (d'Orbigny, 1834), Janssen: 2003, p. 168

Heliconoides inflata (d'Orbigny, 1834), Janssen: 2004, p. 110, pl. 1, figs. 4-6

Limacina inflata (d'Orbigny, 1834) Rosenberg, 2009; Clemam, 2012

Heliconoides inflata (d'Orbigny, 1834) Janssen: 2012, p. 25, pl. 1, figs. 4-6

Heliconoides inflatus (d'Orbigny, 1834) WoRMS, 2013.

Diagnosis: Coiled shell in a single plane with 3 whorls on the same level. Opening at the left (sinistral). Presence of slightly deeper umbilicus.

Distribution. North Atlantic: Gulf of Guinea, Sargasso Sea, Gulf Stream, Cape Ghir (Ibero-Moroccan Bay), Adriatic Sea (north), Caribbean Sea (Barbados Island, Ascención Bay in the Sian Ka'an Reserve), and the Central Area of the North Atlantic. **South Atlantic:** South Equatorial Areas, South Transition Areas, Central Area of the South Atlantic, Brazil Current and Benguela Current, Argentinean coast (Brazil-Malvinas Confluence, Falkland), Uruguayan Coast, and Brazil (waters of Northeastern Brazil, Fernando de Noronha Chain,

Table 4. Spearman correlation test (n = 100, $p \leq 0.05$), where Sur. temp. = Surface temperature, Sur. Sal = Surface salinity, and n.s. = Not significant values.

	L. bulimoides	***T. helicoides***	***H. inflatus***	***L. lesueurii***	***L. trochiformis***	**Sur. temp.**
L. bulimoides						
T. helicoides	**0.26**					
H. inflatus	**0.61**	**0.19**				
L. lesueurii	**0.28**	n.s.	**0.29**			
L. trochiformis	n.s.	n.s.	n.s.	**0.23**		
Sur. temp.	n.s.	n.s.	n.s.	**0.14**	n.s.	
Sur. sal.	**0.15**	n.s.	**0.17**	**0.23**	**0.46**	**0.14**

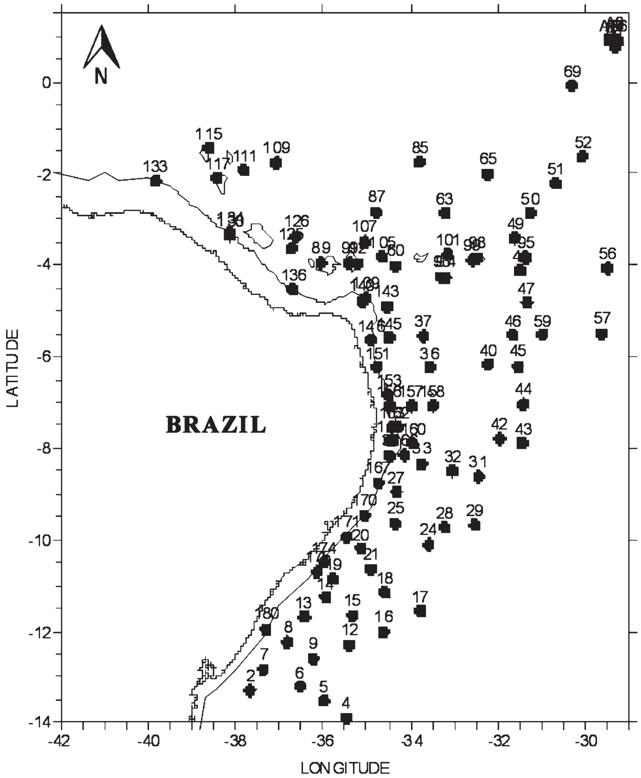


Figure 4. Geographical distribution of *Heliconoides inflatus* during the 4th Campaign of REVIZEE NE, conducted in 2000.

São Pedro and São Paulo Archipelago, continental shelf of Rio de Janeiro, Cabo Frio in Rio de Janeiro, Farol da Conceição to Chuí in Rio Grande do Sul).

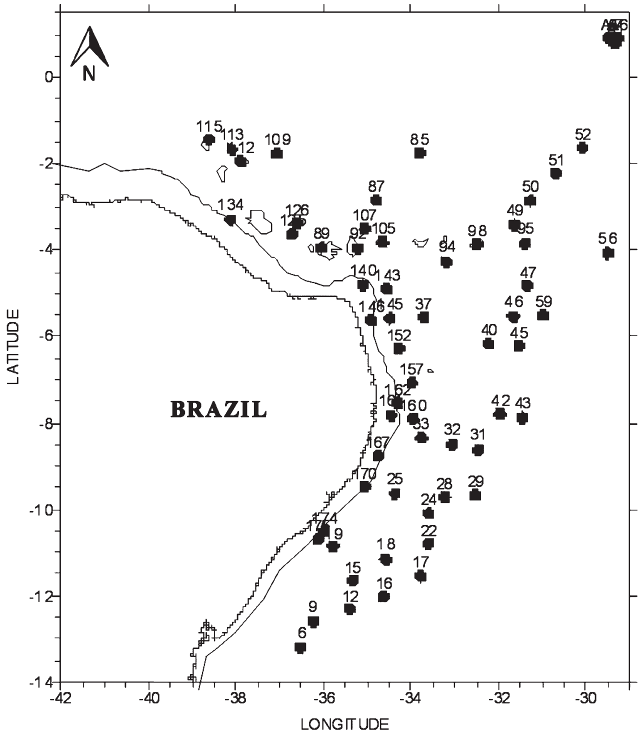


Figure 5. Geographical distribution and density of *Limacina bulimoides* during the 4th Campaign REVIZEE NE, conducted in 2000.

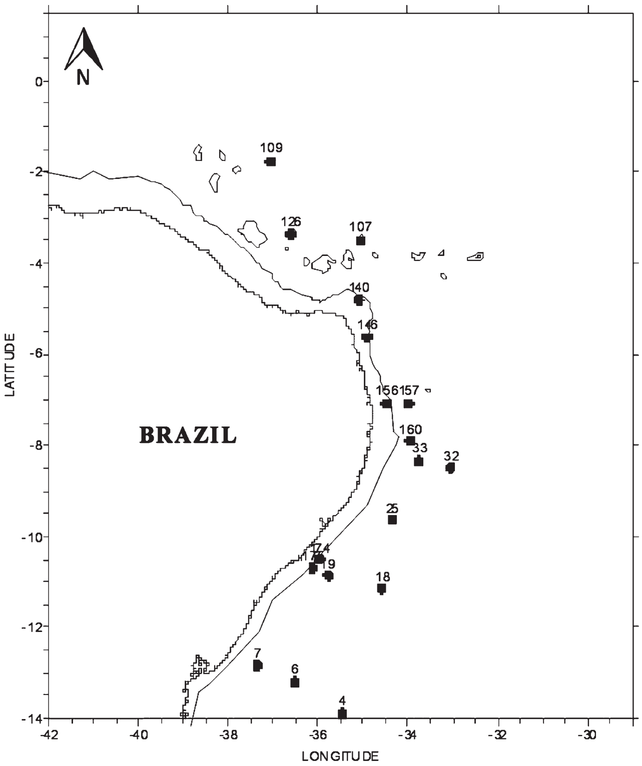


Figure 6. Geographical distribution of *Limacina lesueurii* during the 4th Campaign of REVIZEE NE, conducted in 2000.

Examined material. BRAZIL: EEZ/NE - Project REVIZEE SCORE NE-IV, Oceanographic Research Ship (ORS) "Antares". Oceanic South Area: **E002, E004, E005, E006, E007, E008, E009, E012, E013, E014, E015, E016, E017, E018, E019, E020, E021, E024, E025, E027, E028, E029, E031, E032, E033** and **E034** all in the stratum of 0 to 200 m. East Oceanic Area: **E036, E037, E040, E042, E043, E044, E045, E046, E047, E048, E049, E050, E051, E052, E056, E057** and **E059** all in the stratum of 0 to 200 m. São Pedro and São Paulo Archipelago Area: **E060, E063, E065, E069, EA01, EA03, EA04, EA06, EA07, EA08, E085** and **E087** all in the stratum of 0 to 200 m. North Chain/Rocas/Noronha Area: **E089, E091, E092, E093, E094, E095, E098, E099, E101, E105, E107, E109, E111, E115, E117, E125, E126** and **E130** all in the stratum of 0 to 200 m; North Coast Area: **E133, E134, E136, E139, E140, E143, E145, E146, E151, E153, E156, E157, E158, E160, E161, E162** and **E163** all in the stratum of 0 to 200 m. South Coast Area: **E166, E167, E170, E171, E174, E175** and **E180** all in the stratum of 0 to 200 m. 4845 specimens collected in 97 oceanographic stations (Figure 4).

Genus *Limacina* Bosc, 1817
Limacina bulimoides (d'Orbigny, 1834)
(Figure 9: b)

Synonymy

Atlanta bulimoides d'ORBIGNY, 1836: 179, (1846), pl. 12, fig. 36-38

Spirialis bulimoides EYDOUX & SOULEYET, 1840: 238; SOULEYET, 1855: 224, pl. 13, fig. 35-42; JEFFREYS, 1870:86

Limacina bulimoides (d'ORBIGNY, 1836) GRAY, 1850: 34; BOAS, 1886: 47, 196, pl. 3, fig. 36-37; PELSENEER, 1888: 30; CARUS, 1890: 440; LOCARD, 1897: 26; TESCH, 1904:13;

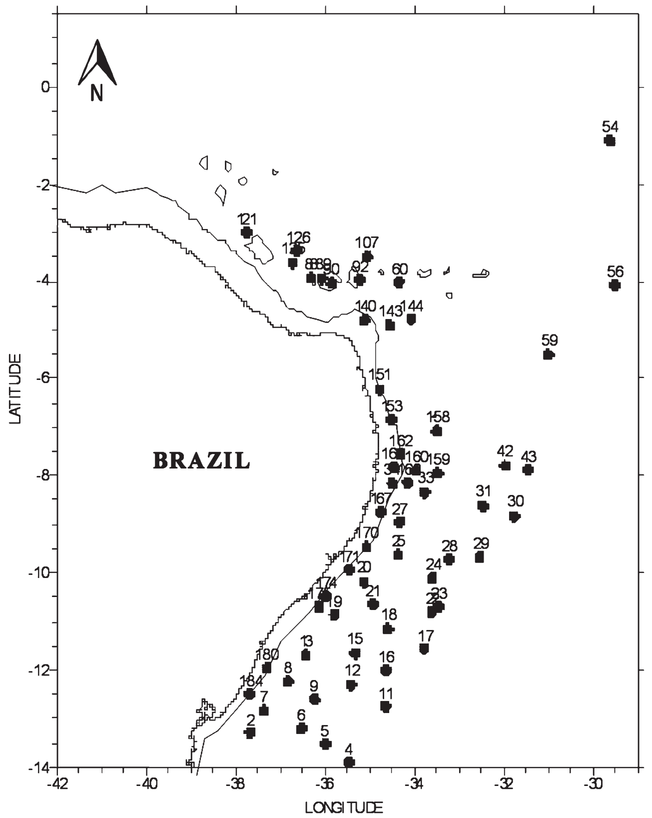


Figure 7. Geographical distribution of *Limacina trochiformis* during the 4th Campaign of REVIZEE NE, conducted in 2000.

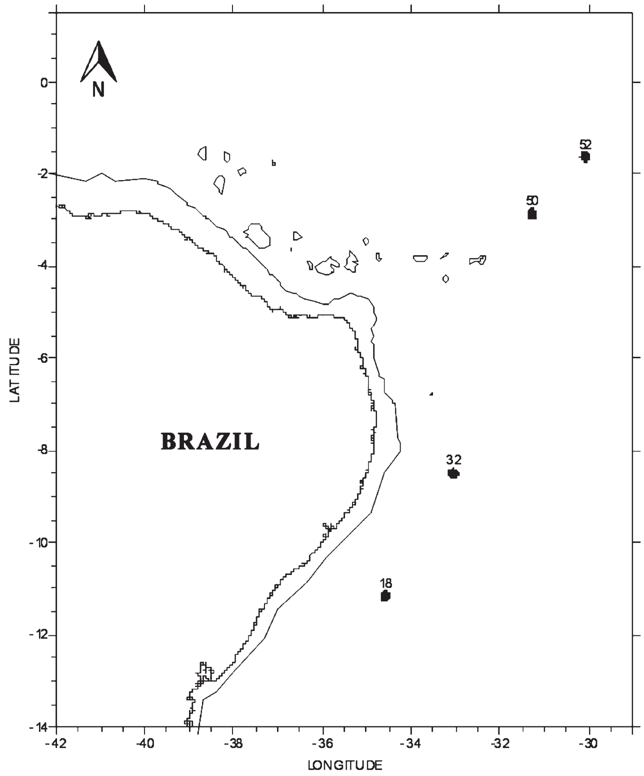


Figure 8. Geographical distribution of *Thielea helicoides* during the 4th Campaign of REVIZEE NE, conducted in 2000.

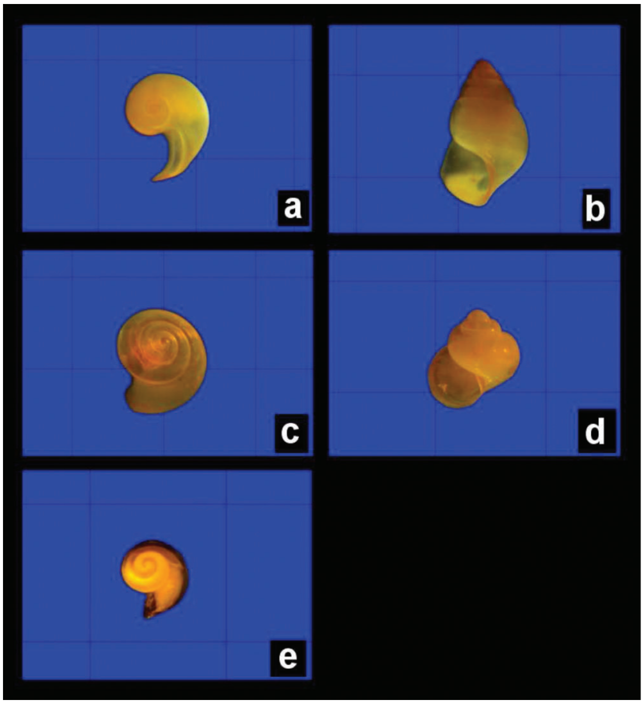


Figure 9. The species of the family Limacinidae: **a.** *Heliconoides inflatus* (**E3050**, 1 mm grade, 25X magnification); **b.** *Limacina bulimoides* (**E3050**, 1 mm grade, 35X magnification); **c.** *Limacina lesueurii* (**E3006**, 1 mm grade, 35X magnification); **d.** *Limacina trochiformis* (**E3125**, 1 mm grade, 35X magnification); **e.** *Thielea helicoides* (**E3032,** 1 mm grade, magnification 35X).

Meisenheimer, 1905:11; Tesch, 1907: 187; Tesch, 1913:21, fig. 14; Vayssière, 1913: 184, pl. 20, fig. 9; Vayssière, 1915: 141, pl. 8, fig. 165; Massy, 1932: 289; Tesch, 1946:9, pl. 5, fig. 4 a–d; Wormelle, 1962: 106

Heterofucus bulimoides (d'Orbigny) Adams & Adams, 1858: I, 60, pl. 7, fig. 5

Spiratella bulimoides (d'Orbigny, 1836) Hubendick, 1951: 3; Pruvot-Fol, 1954:117

Limacina (*Munthea*) *bulimoides* (d'Orbigny, 1836) Spoel, 1967: 53, pl. fig. 21

Limacina bulimoides (d'Orbigny, 1834), Janssen: 2004, p. 110, pl. 1, figs. 4-6; Rosenberg, 2009; Clemam, 2012; Janssen: 2012, p. 25, pl. 1, figs. 4-6; WoRMS, 2013

Diagnosis. Conical and high shell, hyaline, with 6 whorls, separated by a well-marked suture and showing brown coloration. Angular aperture on the left side (sinistral). Presence of umbilicus.

Distribution. North Atlantic: Canary Islands, Sombrero, Culebra, St. Thomas and Palma; Gulf of Guinea, Sargasso Sea, Gulf Stream, Labrador Current, Cape Ghir (Ibero-Moroccan Bay), and Caribbean Sea (Barbados Island, Yucatan Peninsula, Ascención Bay in the Sian Ka'na Reserve and near the coast of Mexico). **South Atlantic:** Ascension Island, Tristan da Cunha Island, Argentinean coast (Brazil-Malvinas Confluence, Falkland), and Brazil (waters of the Northeastern Brazil, Fernando de Noronha Chain, São Pedro and São Paulo Archipelago, between the states of Pernambuco and Bahia, Cabo Frio in Rio de Janeiro, Farol da Conceição to Chuí in Rio Grande do Sul, Brazil and Benguela Currents.

Examined material. BRAZIL: EEZ/NE - Project REVIZEE SCORE NE-IV, Oceanographic Research Ship (ORS)

"Antares". Oceanic South Area: **E006, E009, E012**, **E015**, **E016**, **E017**, **E018**, **E019**, **E022**, **E024**, **E025**, **E028**, **E029**, **E031**, **E032** and **E033** all in the stratum of 0 to 200 m. East Oceanic Area: **E037**, **E040**, **E042**, **E043**, **E045**, **E046**, **E047**, **E049**, **E050**, **E051**, **E052**, **E056** and **E059** all in the stratum of 0 to 200 m. São Pedro and São Paulo Archipelago Area: **EA01**, **EA06, EA07**, **EA08**, **E085** and **E087** all in the stratum of 0 to 200 m. North Chain/Rocas/Noronha Area: **E089**, **E092**, **E094**, **E095, E098**, **E105**, **E107**, **E109**, **E112**, **E113, E115**, **E125** and **E126** all in the stratum of 0 to 200 m; North Coast Area: **E134**, **E140**, **E143**, **E145**, **E146**, **E152**, **E157**, **E158**, **E160**, **E161** and **E162** all in the stratum of 0 to 200 m. South Coast Area: **E167**, **E170**, **E174** and **E175** all in the stratum of 0 to 200 m. 298 specimens collected in 62 oceanographic stations (Figure 5).

Limacina lesueurii (d'Orbigny, 1835)
(Figure 9: c)

Synonymy

Atlanta lesueurii Orbigny, 1836: 117 (1846) pl. 20, fig. 12-15

Spiriale ventrue (d'Orbigny) Souleyet, 1855: 218, pl. 13, fig 11-16

Limacina lesueurii (d'Orbigny, 1836) Boas, 1886: 46, 196, pl. 3, fig. 33-34; Gray, 1850; Tesch, 1904:12; Tesch, 1913: 18, fig. 9; Wormelle, 1962:102

Limacina lesueuri (d'Orbigny) Pelseneer, 1888: 24; Meisenheimer, 1905: 9; Tesch, 1946:8, fig. 4, pl. 1, fig. 2 a-d; Vayssière, 1915: 146, pl. 8. fig. 161-164

Limacina lesueuri var *minor* (*nomen nudum*) Locard, 1897:23

Limacina lesueuri var *alta* (*nomen nudum*) ? Locard, 1897:23

Limacina lesueuri var *depressa* (*nomen nudum*) Locard, 1897:23

Spiratella lesueuri (d'Orbigny, 1836) Pruvot-Fol, 1954:116, fig. 32 d-e

Limacina (*Thilea*) *lesueurii* (Orbigny, 1836), Spoel, 1967: 52, fig. 20

Limacina lesueuri (d'Orbigny) Bé & Gilmer, 1977: p.761, pl.3, fig.5a-d; fig. 9.

Limacina lesueurii (d'Orbigny, 1835) Rosenberg, 2009; WoRMS, 2013; Clemam, 2011.

Diagnosis. Flat and hyaline conical shell consisting of 4.5 whorls. Opening at the left side (sinistral), rounded. Presence of umbilicus with spiral lines.

Distribution. North Atlantic: Cape Verde Islands, Azores Island, Sargasso Sea, Gulf Stream, Canary Current, Subarctic Waters, and Caribbean Sea (Barbados Island, Yucatan Peninsula, Ascención Bay in the Sian Ka'na Reserve). **South Atlantic:** Transition Area of the South Atlantic, Benguela Current, Argentinean coast and Brazil (Cabo Frio in Rio de Janeiro, Farol da Conceição to Chuí in Rio Grande do Sul).

Examined material. BRAZIL: EEZ/NE - Project REVIZEE SCORE NE-IV, Oceanographic Research Ship (ORS) "Antares". Oceanic South Area: **E004**, **E006**, **E007**, **E018**, **E019**, **E025**, **E032** and **E033** all in the stratum of 0 to 200 m. North Chain/Rocas/Noronha Area: **E107**, **E109** and **E126** all in the stratum of 0 to 200 m. North Coast Area: **E140**, **E146**, **E156**, **E157** and **E160** all in the stratum of 0 to 200 m. South Coast Area: **E174** and **E175**, all in the stratum of 0 to 200 m. 31 specimens collected in 18 oceanographic stations (Figure 6).

Limacina trochiformis (d'Orbigny, 1834)
(Figure 9: d)

Synonymy

Atlanta trochiformis d'Orbigny, 1836: 117, (1846), pl. 12, fig. 29-31.

Spirialis trochiformis Eydoux & Souleyet, 1840: 237; Souleyet, 1855: 223, pl. 13, fig. 27-34

Limacina trochiformis (d'Orbigny, 1836) Gray, 1850: 33; Pelseneer, 1888: 29; Carus, 1890: 439; Tesch, 1904:13; Meisenheimer, 1905:10; Tesch, 1913:21, fig. 13; Vayssière, 1913: 183, pl. 21, fig. 2-3; Stubbings, 1938: 17; Tesch, 1946:8, pl. 1, fig. 3 a–d; Wormelle, 1962: 102

Heterofusus trochiformis Adams & Adams, 1858: I, 60

Limacina contorta Sykes, 1905: 327 + fig.

Spiratella trochiformis d'Orbigny, 1836 Pruvot-Fol, 1954:115

Limacina (*Munthea*) *trochiformis* (d'Orbigny, 1834) Spoel, 1967:53

Limacina trochiformis (d'Orbigny, 1834) Janssen: 2004, p. 110, pl. 1, figs. 4-6; Rosenberg, 2009; Clemam, 2012; Janssen: 2012, p. 25, pl. 1, figs. 4-6; WoRMS, 2013.

Diagnosis. Spiral and conical shell with 5 whorls, hyaline. Oval opening on the left side (sinistral). Presence of deep umbilicus.

Distribution. North Atlantic: Sargasso Sea, Gulf Stream, Labrador Current, Subarctic Waters, and Caribbean Sea (Barbados Island, Yucatan Peninsula, Ascención Bay in the Sian Ka'na Reserve). **South Atlantic:** Island of Tristan da Cunha, South Equatorial Area, Transition Area of the South Atlantic, Argentinean coast (Brazil-Malvinas Confluence, Falkland), and Brazil (waters of Northeastern Brazil, Fernando de Noronha Chain, São Pedro and São Paulo Archipelago, between the states of Pernambuco to Bahia, Cabo Frio in Rio de Janeiro, Farol da Conceição to Chuí in Rio Grande do Sul.

Examined material. BRAZIL: EEZ/NE - Project REVIZEE SCORE NE-IV, Oceanographic Research Ship (ORS) "Antares". Oceanic South Area: **E002**, **E004**, **E005**, **E006, E007, E008, E009, E011, E012**, **E013**, **E014**, **E015**, **E016**, **E017**, **E018**, **E019**, **E020**, **E021**, **E023**, **E024**, **E025**, **E027**, **E028**, **E029**, **E030, E031**, **E033** and **E034** all in the stratum of 0 to 200 m. East Oceanic Area: **E042**, **E043**, **E054**, **E056** and **E059** all in the stratum of 0 to 200 m. São Pedro and São Paulo Archipelago Area: **E060** all in the stratum of 0 to 200 m. North Chain/Rocas/Noronha Area: **E088, E089**, **E090, E092**, **E107**, **E121**, **E125**, **E126** and **E130** all in the stratum of 0 to 200 m; North Coast Area: **E140**, **E143**, **E144, E151**, **E153**, **E158**, **E159, E160**, **E161** and **E162** all in the stratum of 0 to 200 m. South Coast Area: **E166**, **E167**, **E170**, **E171**, **E174**, **E175**, **E180** and **E184** all in the stratum from 0 to 200 m. 477 specimens collected in 60 oceanographic stations (Figure 7).

Genus *Thielea* Strebel, 1908
Thielea helicoides (Jeffreys, 1877)
(Figure 9: e)

Synonymy

Limacina helicoides, Jeffreys, 1877:338; Pelseneer, 1888:23, pl. 1, fig. 5; Meisenheimer, 1905:8; Tesch, 1913:18, fig. 7; Vayssière, 1915:136, pl. 8, fig. 166; Massy, 1932:284; Tesch, 1946:9, fig. 6-7, pl. 6, fig. 32a-k; Rosenberg, 2009; Clemam, 2011.

Thilea procera Strebel, 1908, p. 85, pl. 1, fig. 14 a-c; Tesch, 1913:22, fig. 15a

Thielea procera (corr.) Tesch, 1913:142

Spiratella heliconoides Jeffreys, 1877; Pruvot-Fol, 1954:117, fig. 32a-c

Limacina (*Thilea*) *heliconoides* JEFFREYS, 1877 SPOEL, 1967:48, pl. figs.14-16

Thielea helicoides (JEFFREYS, 1877) WoRMS website, 2013

Diagnosis. Depressed shell of 3 to 4 whorls with a dark brown color and oval opening. Exhibits transverse growth lines found on the last whorl.

Distribution. North Atlantic: Sargasso Sea and Azores Island; **South Atlantic:** Tristan da Cunha, the mouth of the Congo and Gabon Rivers (700 m), between south and Cape Town and South Georgia Islands (2000-3000 m) and Brazil (Cabo Frio in Rio de Janeiro).

Examined material. BRAZIL: EEZ/NE - Project REVIZEE SCORE NE-IV, ORS "Antares". South Oceanic Area: **E018** and **E032**, all in the stratum from 0 to 200 m. East Oceanic Area: **E050** and **E052**, all in the stratum from 0 to 200 m. Four specimens sampled at four oceanographic stations (Figure 8).

Discussion

The geographical distribution of the family Limacinidae corresponded to the entire coastal and oceanic area of Northeastern Brazil. The richness and diversity of this family in this oceanographic region are considered high compared with other studies. Of the five species found in this study, *Heliconoides inflatus* exhibited the highest frequency in the samples. These data corroborate those reported by Oliveira (2002) for this same area in samples collected in 1996. Barth & Oleiro (1968) described the taxonomy, ecology, and geographical distribution of Pteropoda in the region of Cabo Frio-RJ and registered *H. inflatus* as an abundant species. Magaldi (1977) reported this species as the Pteropoda with the highest frequency in Brazilian and Uruguayan waters off the South American Atlantic coast.

Heliconoides inflatus exhibited an extensive distribution in the waters of Northeastern Brazil, being characterized as abundant and frequent. The data corroborate those cited by Bé & Gilmer (1977) as being a cosmopolitan species of warm waters, distributed in tropical and subtropical areas. The reproductive strategy of *Heliconoides inflatus*, conferring protection to offspring inside the palial cavity until the larval stage, may play a key role in its adaptive success. The study of the distribution and zoogeographical pattern of molusks on the continental shelf of Rio de Janeiro by Absalão (1989) recorded this species among the 175 identified taxa. In the same study, the author found that 70% of the local malacofauna exhibited thermophilic distribution patterns, thus characterizing it as a region heavily influenced by the warm waters of the Brazil Current. In a study conducted on the south coast of Brazil, from Farol da Conceição to Chuí, Resgalla Júnior (1993) identified *H. inflatus* as the second most abundant species, with an irregular distribution in waters with temperatures between 11.2 and 18.4°C and salinity between 33.75 and 35.75. Comparing such data with those obtained in the present study, in which *H. inflatus* was predominant in waters with temperatures ranging from 25.07 to 27.54°C and salinity from 35.37 to 37.12, it is evident that this species is well adapted to temperate-cold to tropical waters, which helps to explain its wide distribution in oceans. Oliveira & Larrazábal (2002) and Larrazábal & Oliveira (2003), in studies conducted in 1996 with material of REVIZEE NE-I, considered *H. inflatus* to be a very abundant and frequent species in waters surrounding the São Pedro and São Paulo Archipelago, being dominant and very frequent in the region of Fernando de Noronha. The results by the authors regarding the abundance and frequency of *H. inflatus* were similar to the results for REVIZEE NE-IV. Larrazábal et al. (2009), in a study on the macrozooplankton of the Exclusive Economic Zone of Northeastern Brazil (campaigns of REVIZEE NE-II in 1997, and REVIZEE NE-III in 1998), considered the species to be dominant and frequent, unlike the results obtained in the waters of Northeastern Brazil for REVIZEE NE-IV in 2000.

The data indicated that *Limacina trochiformis* is a rare but frequent species. The specimens present in the waters of Northeastern Brazil stood out due to the amplitude of the surface temperature values (23.9 and 27.54°C) and the surface salinity (35.16 and 37.12). Pelseneer (1888) described the geographical distribution of *L. trochiformis* in waters of Northeastern Brazil between Pernambuco and Bahia based on the shell deposits of this species. Spoel (1967) described the presence of *L. trochiformis* in the Equatorial South Area and South Transition Area. Spoel (1967) considered *L. trochiformis* to exhibit a discontinuous distribution, bisubtropical, occurring in the temperature range between 13.8 and 27.9°C and in the salinity range from 35.5 to 36.8. With respect to temperature and salinity, the results approached the ones obtained in the waters of Northeastern Brazil. Resgalla Júnior (1993) recorded *L. trochiformis* in the waters of Southern Brazil, considering the species to be epiplanktonic, with higher concentrations of individuals in the surface layers at night, common in tropical waters with temperatures ranging from 19.3 to 23.7°C and salinity between 35.7 and 36.4. Oliveira & Larrazábal (2002), studying the frequency of occurrence of Pteropoda from the São Pedro and São Paulo Archipelago and the surrounding areas, considered the species to be sporadic and rare. For the oceanic region of the Fernando de Noronha Island, Larrazábal & Oliveira (2003) described *L. trochiformis* as being a not very frequent and not very abundant species, corroborating the results for waters of Northeastern Brazil, which are the object of this study. Larrazábal et al. (2009) recorded this species in the study on the macrozooplankton of the Exclusive Zone of Northeastern Brazil in the campaigns REVIZEE NE-II and NE-III as abundant and frequent.

Limacina bulimoides was considered rare and frequent and was characterized as a tropical species; our study represents the first record of its existence in the neritic province in Northeastern Brazil. Pelseneer (1888) reported its distribution in South America between the states of Pernambuco and Bahia, stating that shell deposits were found in the substrate. On the distribution of *L. bulimoides*, the author stated that the living form of the species is unknown in the Mediterranean Sea and the North Atlantic (39°N); however, deposits of shells were found in deep areas of these seas. Regarding the vertical distribution, Pelseneer (1888) theorized that the deposits of shells on the substrate correspond to the real distribution of live specimens on the surface of the water column in the same area. Resgalla Júnior (1993) recorded low densities of *L. bulimoides* in the waters of the southern region of Brazil, extending into the Subtropical Waters. The species was described as sporadic and rare in the vicinity of the São Pedro and São Paulo Archipelago by Oliveira & Larrazábal (2002) and not very frequent and not very abundant in the oceanic region of the Fernando de Noronha Island by Larrazábal & Oliveira (2003). Larrazábal et al. (2009) recorded *L. bulimoides* as not very frequent and not very abundant in the campaigns of REVIZEE NE-II in 1997 and REVIZE NE-III in 1998, corresponding to the dry and wet seasons of the EEZ of Northeastern Brazil, respectively. As for the geographical distribution of this species in Northeastern Brazil, the records obtained here are supported by the studies cited above. Regarding the frequency of occurrence, the results of the present study indicate this species as being frequent in the São Pedro and São Paulo Archipelago and in the oceanic region of the Fernando de Noronha Island, in contrast to the data of the authors mentioned above.

Suarez-Morales & Gasca (1998) recorded the occurrence of *L. bulimoides* in neritic areas of the Caribbean Sea, a result also observed in waters of Northeastern Brazil, with material from REVIZEE NE-IV.

Limacina lesueurii was first recorded in the neritic province in waters of Northeastern Brazil, where it was not very frequent and rare. The high temperatures and salinities of the waters characterize it as a tropical species. Pelseneer (1888) recorded deposits of shells of *L. lesueurii* in two sampling stations in oceanic waters off the coast between the states of Bahia and Pernambuco. This species was recorded and classified by Barth & Oleiro (1968) as not very abundant in studies on the taxonomy and ecology of planktonic molusks in the region of Cabo Frio-RJ. Resgalla Júnior (1993) recorded *L. lesueurii* in waters in Southern Brazil, considering it rare, and the species exhibited a strong preference for surface waters, regardless of the sampling time. The data obtained in this study confirm that this is also a rare species in the waters of Northeastern Brazil. According to Bé & Gilmer (1977), *L. lesueurii* is considered subtropical, predominant in oligotrophic environments, and characteristic of central oceanic water masses and is easily displaced in warm waters. In these cases, the species is characterized by low abundance, as indicated by Spoel & Heyman (1983) and Gasca & Suarez-Morales (1992).

In the present study, *Thielea helicoides* was the species with the lowest distribution in the waters of Northeastern Brazil, with a low number of specimens, and was classified as rare and sporadic. Unlike this study, *T. helicoides* was classified as abundant in the oceanic area of Cabo Frio (Rio de Janeiro) in a study conducted by Barth & Oleiro (1968), who also described the shell morphology, ecology, and distribution of *T. helicoides* in Brazilian waters. Spoel & Boltovskoy (1981) diagnosed ontogenetic vertical migrations for this species, where juveniles are found in the more superficial layers, whereas adults are observed in deeper areas. This fact explains why only juveniles were found in the present study, given that the methodology used in the project REVIZEE included planktonic sampling in the stratum from 0 to 200 m in oceanic areas with depths ranging from 4394 to 4951 m.

Studies of the abiotic data were suitable for the oceanographic features of the area. Most species that comprise the family Limacinidae prevailed in an extensive ocean area off the coast of Northeastern Brazil and were found in broad or narrow temperature ranges, characterizing the species as tropical and euhaline species.

The Spearman correlation analysis demonstrated a positive correlation between the species and the abiotic parameters, and our analysis results indicate a low correlation coefficient. The correlation among the species *Limacina bulimoides*, *Heliconoides inflatus,* and *Limacina lesueurii* exhibited a positive correlation in the waters of Northeastern Brazil. The association among *Limacina bulimoides*, *Heliconoides inflatus,* and *L. lesueurii* can be explained because the species were observed in areas with oceanic salinity values between 35.81 and 37.12 and temperatures between 26 and 27°C, where the species coexist in the same layer of the water mass, characterized as epipelagic (Boltovskoy 1971, Spoel & Dadon 1999). Tesch (1946) recorded *L. bulimoides* in the Sargasso Sea and considered it to be a common species, paying attention to its association with the species *H. inflatus* and *Limacina lesueurii*. Although it was not the study objective, Boltovskoy (1971) associated the presence of *L. bulimoides* with *H. inflatus* in Mar Del Plata by simple observation, and this corroborates the results of the present study. *Thielea helicoides* correlated positively with *H. inflatus*, a fact that can be explained by the migration of juvenile fish to the surface layers of the water column for food, sharing space with *H. inflatus* (Spoel & Boltovskoy 1981).

Heliconoides inflatus exhibited a positive correlation between *L. lesueurii* and surface salinity. These species were observed in oceanic areas of very similar salinities and temperature ranges, thus characterizing these species as euhaline and tropical species that coexist in the same layer of water mass. Lalli & Wells-Jr. (1973) recorded *H. inflatus* as a species that covered a large geographical area in the sea of Barbados, occurring predominantly in tropical and subtropical areas. The authors also reported the coexistence of *H. inflatus* with other epipelagic species, *Limacina bulimoides*, *L. lesueurii,* and *L. trochiformis,* in the same niche, a fact that resembles the results obtained in this study. The epithet *inflatus* was first acknowledged by Dall (1908), being used for the species *Embolus inflatus* d'Orbigny (1834). However, it must also be considered as valid name for *Heliconoides inflatus*, wich according to the new combinations made for the species, the epithet must agree with the genus variation, Article 31 the ICZN (International Commission on Zoological Nomenclature 1999).

Limacina trochiformis exhibited a positive correlation with very low salinity. The species was observed at a range of salinity equal to or higher than 35 in the waters of Northeastern Brazil, characterizing it as a euhaline species. Historically, *L. trochiformis* has been observed at temperature ranges from 14.4 to 27.7°C and salinities from 35.5 to 36.7 in the North Atlantic (Chen & Bé 1964). For *L. trochiformis,* Spoel (1967) generalized the optimal conditions to be a temperature range from 13.8 to 27°C and a salinity from 33.5 to 36.8. For the Caribbean Sea, adult individuals of *L. trochiformis* were observed in the temperature range between 26.5 and 28°C and salinity between 34.25 and 36 at night, and juveniles were observed in the temperature range from 25.5 to 28°C and salinity from 35.75 to 36.3 (Haagensen 1976). This author described *L. trochiformis* in Tropical Surface Waters in the Caribbean Sea; the result is explained by the limits of the temperature and salinity ranges at which the species were found. Resgalla Júnior (1993) obtained a similar result on the southern shelf of Brazil, with *L. trochiformis* exhibiting a preference for Tropical Waters, where its detection was concentrated between 19.3 and 23.7°C in salinities from 35.7 to 36.4. The obtained results of the various cited authors with respect to the observation of *L. trochiformis* under specific conditions of temperature and salinity are corroborated by the data obtained in this study. The observation of *L. trochiformis* correlated significantly with *L. lesueurii*, which may point to a similarity between the abiotic parameter salinity in both species in the waters of Northeastern Brazil.

Final Considerations

Representatives of the family Limacinidae were observed at high temperatures and salinities and were characterized as tropical and euhaline species. *Heliconoides inflatus* was the most abundant and frequent species in the region of the Tropical Atlantic, exhibiting tolerance to variations in temperature and salinity.

Limacina bulimoides and *L. lesueurii*, despite the low values of abundance and frequency, stood out in this study because it is the first time that the species have been recorded in neritic waters. *Limacina bulimoides* exhibited a positive association with *Heliconoides inflatus*, *Thielea helicoides* and *L. lesueurii*. *Limacina lesueurii* exhibited a positive association with *L. trochiformis*. The first record of *Limacina lesueurii*, collected alive, was obtained in the waters of Northeastern Brazil.

Limacina trochiformis was positively correlated with surface salinity and *Limacina lesueurii*.

The distribution of *Thielea helicoides* was restricted to oceanic areas, where the species was characterized as rare and sporadic in the waters of Northeastern Brazil, correlating positively with *Heliconoides inflatus*.

The variation of the surface temperature of the water in the Southwest Atlantic was not indicated as a limiting environmental factor in the geographical distribution of species of Limacinidae.

Acknowledgments

To Doctors Silvio Macedo and Manuel Monte Flores from the Laboratory of Chemical Oceanography, Federal University of Pernambuco (UFPE) for providing data regarding Abiotic Oceanography (temperature and salinity) to complement this research.

References

ABBOTT, R.T. 1974. American Seashells: the marine mollusca of the Atlantic and Pacific coast of North America. 2th ed. Van Nostrand Reinhold, New York.

ABSALÃO, R.S. 1989. Padrões distributivos e zoogeográficos dos moluscos da plataforma continental brasileira. Parte II. Comissão Oceanográfica Espírito Santo I. Mem. Inst. Oswaldo Cruz. 84(4):1-6, doi: http://dx.doi.org/10.1590/S0074-02761989000800006

ADAMS, H. & ADAMS, A. 1858. The genera of recent Mollusca. J. v. Voorst, London, 1:1-256, 3.pl.. 1-32. http://www.biodiversitylibrary.org/item/23923#page/11/mode/1up. (último acesso em 10/07/2013).

ASSAD, L.P.F., MANO, M.F., DECCO, H.T., TORRES JUNIOR A.R & LANDAU, L. 2009. Noções básicas de modelagem hidrodinâmica computacional e de dispersão de poluentes, 1.ed. COPPE/UFRJ, Rio de Janeiro.

BARTH, R. & OLEIRO, T.A.P. 1968. Contribuição ao estudo dos moluscos planctônicos da região de Cabo Frio-RJ. MM/IPqM. 29,1-17.

BÉ, A.W.H. & GILMER, R.W.A. 1977. 6. Aô zoogeographic and taxonomic review of Euthecosomatous Pteropoda. In Oceanic Micropaleontology, 1 (A.T.S. Ramsay, ed.). Academic Press, London, p.733-808.

BIANCO, S.L. 1903. Le pesche abissali eseguite da F. A. Krupp col yacht Pusitan nelle adiacenze di Capri ed in altri localita del Mediterrâneo. Mitt. Zool. Station Neapel. 16(1/2):109-280.

BLAINVILLE, H.M.D. 1824. Mollusques, Mollusca (Malacoz.). Dictionnaire des Sciences naturelles. 32:1-392.

BOAS, J.E.V. 1886. Spolia Atlantica. Bildrag til Pteropodernes. Morfologi og systematic samt til kundsbaben om geografiske udbredelse. Vidensk. Selsk. Skr., 6. Reakk, naturvidensk. Mathemat. Afd. IV. I:1-123 apud SPOEL, S.van der 1996. Pteropoda In Introducción al estudio del zooplancton marino. (R. Gasca & E. Suárez, eds.). El Colegio de la Fronteira Sur (ECOSUR)/CONACYT, México, p.459-528.

BOLTOVSKOY, D. 1971. Pteropodos Thecosomados del Atlantico Sudoccidental. Malacologia. 11(1):121-140.

BOUCHET, P. & ROCROI, J.P. 2005. Classification and nomenclator of gastropod families. Malacologia. 47(1-2): 1-397.

CARUS, J.V. 1890. Mollusca Cephalopoda Tunicata. 2(2). Prodromus fauna Mediterrânea sive descriotio animalum maris Mediterranei incolarium. (1889-1893). E. Schweizerbartsche Verl. Stuttgart: 273-439. http://www.biodiversitylibrary.org/page/11977829#page/9/mode/1up. (último acesso em 10/07/2013).

CHEN, C. & BÉ, A.W.H. 1964. Seasonal distributions of Euthecosomatous Pteropod in the surface waters of five stations in the western north Atlantic. Bull. mar. sci. 14(2):185-220.

CLEMAM. 2011. Checklist of European Marine Mollusca.www.somali.asso.fr/clemam/index.php. (último acesso em 10/07/2013).

COORDENAÇÃO GERAL DO PROGRAMA REVIZEE [s.d.]. Ministério do Meio Ambiente dos Recursos Hídricosô eô da Amazônia Legal. [s.c.p.], Brasília.

COSTA, O.G. 1861. Microdoride mediterrânea o descrizione del poco bem conosciuti od affato ignoti viventi minuti e microscopici del Mediterrâneo. Dalla Stamperia dell Iride. Napoli. p.74, pl.XI. http://www.biodiversitylibrary.org/item/47094#page/97/mode/1up. (último acesso em: 10/12/2013).

CUVIER, G. 1795. Segundo Mérmoire sur l'organização et les rapports des animaux à cantou blanc, lequel dans em Traité de la estrutura dês Mollusques et de leur divisão em ordre lu à la société d'Histoire Naturelle de Paris, lê 11 prairial um troisième [30 de maio de 1795]. Magazin encyclopédique, UO Journal dês Sciences, dês Lettres et des Arts, 1795 [1. année]2:433-449. http://www.biodiversitylibrary.org/page/6736775#page/455/mode/1up. (último acesso em 20/07/2013).

DADON, J.R. & MAGALDI, N.H. 1995. Mesoscale distribution of Thecosomata (Gastropoda) in Brazil-Malvinas Confluence compared with simultaneous satellite images of surface temperature. Iheringia, Zool. 78:157-160.

DALL, W.H. 1908. The Mollusca and the Brachiopoda. Bull. Mus. Comp. Zool. Harv. Coll. 43(6): 205-478.

DALL, W.H. 1927. Note on the genera of Coast's Microdoride. Nautilus. 40(4):134.

D'ORBIGNY, A. 1834-1847. Voyage dans l'Amerique Meridionale. Mollusques. Chez P. Bertrand, Paris & Chez Levrault, Strasbourg. 5(3), Text: 1-28(1834); 129-176 (1935); 177-184 (1836); 185-376(1837), 377-424 (1840); 425-488(1841); 489-528 (1846); 529-600 (1845); 601-728 (1846); 729-758 (s.d.). 9. Atlas, pls. 1-2, 9-13, 15-16, 56 (1934); 3-8, 17-23, 25, 55 (1835); 14, 21, 26-28, 30-35, 37, 58 (1836); 29, 38-52, 57 (1837); 54, 59-66, 68-69 (1839); 53, 67, 70-71 (1840); 72-76, 79-80 (1841); 83, 85 (1842); 78-79, 81-82 (1847); 84 (s.d).

EYDOUX, F. & SOULEYET, F.L.A. 1840. Description sommaire de plusieurs Ptéropodes nouveaux ou imparfaitement connus, destinés à être publiés dans le Voyage de *la Bonite*. Rev. Zool. Soc. Cuvier. 3: 235-239. http://www.biodiversitylibrary.org/item/42039#page/9/mode/1up.(último acesso em: 10/12/2013).

FISCHER, P. 1883. Manuel de Conchyliologie et de Paléontologie conchyliologique. F. Savy. Paris: IXII, 1-1369.

FLORES MONTES, M.J.F., MACEDO, S.J. & COSTA, K.M.P. 2009. Estrutura hidrodinâmica da região oceânica do nordeste brasileiro. In Meteorologiaô eô sensoriamento remoto, Oceanografia Física, Oceanografia Químicaô eô Oceanografia Geológica. (Programa REVIZEE – Score Nordeste) (F.H.V. Hazin, ed.). Editora Martins & Cordeiro, Fortaleza, p.192-213.

FURNESTIN, M. 1964. Les indicateurs planctoniques dans la Baie Ibero-Marocaine. Rev. Trav. Inst. Peches Marit. 28(3), 257-264.

FURNESTIN, M. 1979. VIII. Planktonic mollusks as hydrological and ecological indicators. In Pathyways in Malacology (S. van der

Spoel, A.C. van Bruggen & J. Lever, eds.). Bohn, Scheltema & Holkema, Utrecht, p.175-194.

GASCA, R.S. & SUAREZ-MORALES, E. 1992. Pteropodos (Mollusca: Gastropoda; Thecosomata) de la bahia de la Ascension, reserva de la biosfera de Sian Ka'an, Quintana Roo, Mexico. In Vol II. Diversidad biológica en la reserva de la biosfera de Sian Ka'an Quintana, Roo, Mexico (D. Navarro & E.M. Suárez, eds.). CIQRO/SEDESOL, México, p.115-121.

GRAY, J.E. 1840. Sinopsis of the contents of British Museum. 42th ed. London.

GRAY, J.E. 1850. Explanation of plates. In Figures of the molluscous animals selected from various authors, etched for the use of students, 4 (J.E GRAY, ed). Longman, Brown, Green & Longmans: London: i-iv:1-124. http://www.biodiversitylibrary.org/item/60819.(último acesso: 6/12/2013).

GLOBAL SPECIES. 2013. Data base. globalspecies.org/intaxa/1038569. (último acesso em: 10/12/2013.

GOULD, A.A. 1852. Mollusca & Shells. United States Exploring Expedition 12: xv + 510 pp. Gould & Lincoln: Boston. http://www.biodiversitylibrary.org/item/124949#page/22/mode/1up. (último acesso em: 10/12/2013).

HAAGENSEN, D.A. 1976. Part II – Thecosomata. Caribean zooplankton (Office of Naval Research, ed.). Departament of the Navy, Washington, p.551-712.

HEDLING, N.J.; MANTELATTO, F.L.M.; NEGREIROS-FRANSOZO, M.L. & FRANSOZO, A. 1994. Levantamento e distribuição de braquiúros e anumuros (Crustácea, Decapoda) dos sedimentos sublitorais da região da ilha Anchieta, Ubatuba (SP). Bol. Inst. Pesca. 21:1-9.

HUBENDICK, B. 1951. Pteropoda, with a new genus. In Further Zoological Results of the Swedish Antarctic Expedition 1901-1903. (H.J. Odhner, ed.), Norsted & Söner, Stockolm, IV(6): 3-10.

INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE. 1999. Internacional Code of Zoological Nomenclature. 5 th edition. The Internacional Trust for Zoological Nomenclature, London, 1-306. iczn.org/iczn/index.jsp. (último acesso: 10/12/2013).

JANSSEN, A.W. 1990. Pteropoda (Gastropoda, Eutehcosomata) from the Australian Cainozoic. Scripta Geol. 91(1989):1-76.

JANSSEN, A.W. 1999. Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 4. Aô colletion of euthcosomatous pteropods from the Miocene of the Karaman Basin, Turkey. Basteria. 63:11-15.

JANSSEN, A.W. 2003. Notes on the systematics, morphology and biostratigraphy of fossil holoplanktonic Mollusca, 13 Considerations on a subdivision of Thecosomata, with the emphasis on genus group classification of Limacinidae. Cainozoic Research 2(1-2): 163-170.

JANSSEN, A.W. 2004. Holoplanktonic Molluscan Assemblages (gastropoda, Heretopoda, Thecosomata) from the Plioceno of Estepona (Spain, Málaga). Palaeontos. 5:103-131.

JANSSEN, A.W. 2007. Holoplanktonic Molluca (Gastropoda: Pterotracheoidea, Janthinoidea, Thecosomata and Gymnosomata) from the Pliocene of Pangasinan (Luzon, Philipines). Scripta Geol. 135: 29-177.

JANSSEN, A.W. 2012. Late Quaternary to recente holoplanktonic Mollusca (Gastropoda) from bottom samples of the eastern Mediterranean Sea: systematics, morphology. Boll. Malacol. 48: 1-105 (suppl. 9).

JEFFREYS, J.G. 1869. Bristish Conchology. The Mollusca. vol. V. Marine Shells. John van Voorst London. http://archive.org/stream/britishconcholog05jeff#page/6/mode/2up>. (ultimo acesso: 23/10/2014).

JEFFREYS, J.G. 1870. V. Mediterranean Mollusca. Ann. Mag. Nat. Hist. 4(6):65-86. http://archive.org/stream/mobot31753002133806#page/458/mode/2up. (último acesso:25/03/2014/)., doi: http://dx.doi.org/10.1080/00222937008696204

JEFFREYS, J.G. 1877. New and peculiar Mollusca of the Eulimidae ans other familias of Gastropoda, as well as of the Pteropoda, procured in the "Valorous" Expedition. Ann. Mag. Nat. Hist. XIX. (4):317-339.

LALLI, C.M. & WELLS-JR F.E. 1973. Brood protection in an epipelagic Thecosomatous pteropod, *Spiratella* ("*Limacina*") *inflata* (d'Orbigny), Miami, Florida. Bull. mar. sci. 23(4):933-941.

LALLI, C.M. & GILMER, R.W. 1989. Pelagic Snails: the biology of holoplanktonic gastropod mollusks. Stanford University Press, California.

LARRAZÁBAL, M.E. & OLIVEIRA, V.S. 2003. Thecosomata e Gymnosomata (Mollusca, Gastropoda) da cadeia Fernando de Noronha, Brasil. Rev. Bras. Zool. 20(2):351-360, doi: http://dx.doi.org/10.1590/S0101-81752003000200028

LARRAZÁBAL, M.E., CAVALCANTI, E.A.H., NASCIMENTO VIEIRA, D.A., OLIVEIRA-KOBLITZ, V.S., ARAÚJO, E.M., BARRETO, T.M.S & NUNES, T.R.S. 2009. Parte VII. Oceanografia biológica: macro-zooplâncton na ZEE da região Nordeste do Nordeste do Brasil. In Oceanografia Biológica: biomassa primáriaô eô secundária, macrozooplâncton, ictioplancton, ictioneuston, macrofauna bêntica (Programa REVIZEE – Score Nordeste) (F.H.V. Hazin, ed.). Martins & Cordeiro, Fortaleza, p.48-102.

LOBO, E. & LEIGHTON, G. 1986. Estructuras comunitarias de las fitocenosis planctónicas de los sistemas de desembocadura de rios y esteros de la zona central del Chile. Rev. biol. mar. oceanogr. 22(1):1-29.

LOCARD, A. 1897. Mollusques testacés, 1. In A. Expédition scientifique du Travailleur et du Talisman pendant les années 1880, 1881, 1882, 1883, 1 (A. Milne-Edwards ed.). Masson & Cie, Paris, p.22-26. http://www.biodiversitylibrary.org/page/10994071#page/11/mode/1up. (último acesso: 9/12/2013).

MAFALDA JÚNIOR, P.O., MOURA, G.F., MELO, G.N., SAMPAIO, J.A.A., FEITOSA, F.A., PASSAVANTE, J.Z., MOREIRA, M.O. & SOUZA, C.S. 2009. Oceanografia biológica: biomassa fitoplanctônica na ZEE da região Nordeste do Nordeste do Brasil. In Oceanografia Biológica: Biomassa primáriaô eô secundária, macrozooplâncton, ictioplâncton, Ictioneuston, macrofauna bêntica (Programa REVIZEE – Score Nordeste) (F.H.V. Hazin, ed.). Martins & Cordeiro, Fortaleza., p.11-26.

MAGALDI, N.H. 1974. Moluscos holoplanctonicos del Atlantico Sudoccidental. I. Pteropodos Euthecosomata colectados por El "Atlantis II" en marzo de 1971. Com. Soc. Malacol. Urug. 4(27):1-20.

MAGALDI, N.H. 1977. Moluscos holoplanctonicos del Atlantico Sudoccidental. III. Heterópodosô yô Pterópodos de aguas superficiales brasileñasô yô uruguayas. Com. Soc. Malacol. Urug. 4(33):295-320.

MAGALDI, N.H. 1981. Moluscos holoplanctonicos del Atlantico Sudoccidental. IV. Tecosomadosô yô Gimnosomados de la campaña del "Hero" entre Puerto Deseadoô yô Buenos Aires. Com. Soc. Malacol. Urug. 5(41):381-389.

MASSY, A.L. 1932. Mollusca: Gastropoda Thecosomata and Gymonosomata. Discovery Repeorts. 3: 267-296.

MATTEUCCI, S.D. & COLMA, A. 1982. La metodologia para el estudio de la vegetación. [s.l.]. Colleción de Monografias Científicas. Série Biologia, Monografia. Secretaría General de la OEA, Washington, D. C. 168p.

MEDEIROS, C., ARAÚJO, M., FREITAS, I. & ROLLNIC, M. 2009. Massas d'água da região oeste do Atlântico Tropical. Meteorologiaô eô sensoriamento remoto. In Oceanografia Física, Oceanografia Químicaô eô Oceanografia Geológica (Programa REVIZEE – Score Nordeste) (F.H.V. Hazin, ed.). Martins & Cordeiro, Fortaleza, p.56-67.

MEISENHEIMER, J. 1905. IX. Pteropoda. In Wissenschaftliche Ergebnisse der deutschen Tiefsee-Expedition, Valdivia 1898 – 1899 (C. Chun, ed.). Verlag von Gustav Fischer, Jena, p.3-314.

MELO-FILHO, G.A. & MELO, G.A.S. 2001. Taxonomia e zoogeografia das espécies do gênero Munida Leach, 1820 (Crustacea:

Decapoda: Galatheidae) distribuição ao longo da costa temperada-quente do Atlântico Sul Ocidental. Trop. Oceanography. 29(1): 37-59.

OLIVEIRA, V.S. 2002. Pteropoda (Mollusca Gastropoda: Thecosomata e Gymnosomata) do Nordeste do Brasil. Dissertação de Mestrado, Universidade Federal de Pernambuco, Recife.

OLIVEIRA, V.S. & LARRAZÁBAL, M.E. 2002. Pteropoda (Gastropoda, Thecosomata e Gymnosomata) coligidos ao largo dos arquipélagos de São Pedro e São Paulo, costa nordeste, Brasil. Rev. Bras. Zool. 19(1):215-227, doi: http://dx.doi.org/10.1590/S0101-81752002000500016

PARRA-FLORES, A. & GASCA, R. 2009. Distribution of pteropods (Mollusca: Gastropoda: Thecosomata) in surface waters (0-100 m) of the Western Caribbean Sea (winter, 2007). Rev. biol. mar. oceanogr. 44(3): 647-662.

PELSENEER, P. 1888. XXIII. Repport on the Pteropoda collected by H. M. S. Challenger during the years 1873-1876 – Zoology, Johnson Reprint Corporation, New York.

PICKARD, G.L. & EMERY, W.J. 1982. Descriptive physical oceanography. Pergamon Press, Oxford.

PRUVOT-FOL, A. 1942. Les gymnosomes. Dana Report n° 20. Carlsberg Foundation, Copenhagen.

PRUVOT-FOL, A. 1954. Mollusques Opisthobranches. Faune de France, 58. Paul Lechevalier, Paris.

RESGALLA JÚNIOR, C. 1993. Influência das massas de água na distribuição espaço temporal de Pteropoda, Cladocera e Chaetognata na Plataforma Sul do Brasil (31°40'S-33°45'S). Tese de doutorado, Fundação Universidade do Rio Grande, Rio Grande.

ROSENBERG, G. 2009. Malacolog 4.1.1: A Database of Western Atlantic Marine Mollusca. [www.database (version 4.1.1.)]. URL http://www.malacolog.org/.

RIOS, E.C. 1994. Seashells of Brazil. 2. ed. Editora da FURG. Rio Grande.

SEMENSATTO JUNIOR, D.L. 2006. O sistema estuarino do delta do São Francisco-SE: análise ambiental com base no estudo de foraminíferos e tecamebas. Tese de doutorado, Universidade Estadual Paulista, Rio Claro, São Paulo,.

SCARABINO, V. 1967. Sobre Heteropoda y Pteropoda en la plataforma continental uruguaya. Com. Soc. Malac. Urug. 2(13):137-141.

SOARES-GOMES, A. & FIGUEIREDO, A.G. 2009. O ambiente marinho. In Biologia marinha (R.C. Pereira & A. Soares-Crespo, eds). 2. ed. Interciência, Rio de Janeiro, p.1-34.

SOULEYET, L.F.A. 1955. Voyage autour du monde execute pendant les annés 1836 et 1837 sur la convette "La Bonite" In. Voyage autour du monde exécuté pendant les années 1836 et 1837 sur la Corvette "La Bonite" (F. Eydoux & L.F.A. Souleyet, eds.). Bertrand, Paris. Zoologie 2: 2: 1-664 + atlas pl. 1-45. A. http://www.biodiversitylibrary.org/item/42039#page/9/mode/1up. (último acesso: 9/12/2013).

SPOEL, S. vander. 1964. Notes on some Pteropods from the North Atlantic. Beaufortia. 10(121):167-176.

SPOEL, S. vander 1967. Euthecosomata a group with remarkable developmental stages (Gastropoda, Pteropoda), J. Noorduijn en Zoon N. V., Gorinchem.

SPOEL, S.van der.1972. Pteropoda Thecosomata. Zooplankton. 8:140-142.

SPOEL, S.van der 1996. Pteropoda In Introducción al estudio del zooplancton marino. (R. Gasca & E. Suárez, eds.). El Colegio de la Fronteira Sur (ECOSUR)/CONACYT, México, p.459-528.

SPOEL, S.van der & BOLTOVSKOY, D. 1981. Pteropoda. In Atlas del zooplancton del Atlántico sudoccidentalô yô métodos de trabajo com el zooplancton marino (D. Boltovskoy, ed.). Publicación especial del Instituto Nacional de Investigaciónô yô Desarrollo Pesquero, Mar del Plata, p.493-533.

SPOEL, S.van der & HEYMAN, R.P. 1983. A comparative atlas of zooplankton, biological patterns in the oceans. Springer-Verlag, Netherlands.

SPOEL, S.van der & DADON, J.R. 1999. Pteropoda. In South Atlantic Zooplankton (D. Boltovskoy, ed.). Backhuys Publishers, Netherlands, p.640-706.

STREBEL, H. 1908. Die Gastropoden (mit Ausnahme de nacketen Ophisthobranchier). Wissenschaftliche Ergebnisse der Schewedischen Südpolar-Expedition 1901-1903. 6(11):111. 6pls. http://www.biodiversitylibrary.org/biliography/6756#/summary. (último acesso: 6/12/2013).

SUÁREZ-MORALES, E. & GASCA, R. 1998. Thecosomata Pteropod (Gastropoda) assemblages of the Mexican Caribbean Sea (1991). The Nautilus, 112(2):43-51.

SUÁREZ-MORALES, E., GASCA, R. & CASTELLANOS, I. 2009. Part 29. Pelagic gastropods.. In Marine biodiversity of Costa Rica, Central America (I.S. Wehrtmann & J. Cortés, eds.). [Monographiae Biologicae, v. 86]. Springer, Costa Rica, p.357-369.

STUBBINGS, H.G. 1938. Pteropoda. The John Murray Exp. 1933-1934. Sci. Rep.ô V (2):3-33.

SYKES, E.R. 1905. On the Mollusca procured during the "Porcupine" Expeditions 1869-1870. Supplemental Notes. II. Proc. Malacol. Soc. London. VI:322-332.

TESCH, J.J. 1904. The Thecosomata and Gymnosomata of the Siboga-expedition. Boekhandel en Drukkerij, Leiden.

TESCH, J.J. 1907. Pteropoda of Leyden Museum. Not. Leyden Mus. 29:181-203.

TESCH, J.J. 1913. Pteropoda. In Das Tierreich (herausgegeben von T. E. Schulze). 36: 1-154, 108 figs. R. Friedländer & S., Berlin. http://archive.org/stream/ptetopoda.00test#page/n11/mode/2up. (último acesso em 9/12/2013).

TESCH, J.J. 1946. The Thecosomatous pteropods. I. The Atlantic. Bianco Luno A/S, Copenhagen.

VAYSSIÈRE, A. 1913. Mollusques de la France et des Régions voisines. I:1-418. Doin. Paris. http://www.biodiversitylibrary.org/item/47452#page/9/mode/1up. summary. (último acesso: 6/12/2013).

VAYSSIÈRE, A. 1915. Mollusques euptéropodes (ptéropodes thécosomes) provenant des campagnes des yachts "Hirodelle" et "Princesse Alice" (1885-1913). Rès. Camp. Sci. acomplies sur son yacht por Albert Ier Prince souverain de Monaco: 47:3-226.

WORMELLE, R.L. 1962. A survey of the standing crop of plankton of the Florida Current. Bull. Mar. Sci. Gulf & Carib. 12(1):95-136.

WoRMS EDITORIAL BOARD. 2013. Word Register of Marine Species. http://www.marinespecies.org. at VLIZ. (último acesso: 16/12/2013).

WORMUTH, J.H. 1981. Vertical distribuitions and diel migrations of Ethecosomata in the northwest Sargasso Sea. Deep-Sea Res. 28(12):1493-1515.

Received 24/08/2013
Revised 16/04/2014
Accepted 23/04/2014

Biota Neotropica 14(2): e20130006, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Butterflies (Lepidoptera: Hesperioidea and Papilionoidea) of Porto Mauá, Upper Paraná Atlantic Forest Ecoregion, Rio Grande do Sul State, Brazil

Sabrina Campos Thiele[1], *Oscar Milcharek*[2], *Fábio Luis dos Santos*[3] & *Lucas Augusto Kaminski*[4,5]

[1] *PPG-Biologia Animal, Departamento de Zoologia, Universidade Federal do Rio Grande do Sul – UFRGS, Av. Bento Gonçalves, 9500, CEP 91501-970, Porto Alegre, Rio Grande do Sul, Brazil.*
[2] *Rua Caxias, 1376, Centro, CEP 98900-000, Santa Rosa, Rio Grande do Sul, Brazil.*
[3] *PPG-Entomologia, Departamento de Zoologia, Universidade Federal do Paraná – UFPR, C.P. 19020, CEP 81531-980, Curitiba, Paraná, Brazil.*
[4] *Departamento de Biologia Animal, Universidade Estadual de Campinas – UNICAMP, C.P. 6109, CEP 13.083-970, Campinas, São Paulo, Brazil.*
[5] *Corresponding author: Lucas Augusto Kaminski, e-mail: lucaskaminski@yahoo.com.br*

THIELE, S.C., MILCHAREK, O., SANTOS, F.L. & KAMINSKI, L.A. **Butterflies (Lepidoptera: Hesperioidea and Papilionoidea) of Porto Mauá, Upper Paraná Atlantic Forest Ecoregion, Rio Grande do Sul State, Brazil.** Biota Neotropica. 14(2): e20130006. http://dx.doi.org/10.1590/1676-06032014000613

Abstract: This paper presents a list of species of butterflies (Lepidoptera: Hesperioidea and Papilionoidea) sampled in Porto Mauá municipality (27°34'S, 28°40'W), Rio Grande do Sul State, Brazil. Sampling was carried out monthly between March 2008 and March 2009. After 204 net-hours of sampling effort, a total of 1,993 individuals from 253 species were recorded. With a single additional expedition, eight new species were added, reaching a total of 261 species recorded in the region of Porto Mauá. These new reports and the species accumulation curves may indicate a much richer fauna. The distribution of richness among butterfly families is compared with other inventories in seasonal semi-deciduous forest areas in the Atlantic Forest. We also discuss the importance of riparian forests of the Uruguay River as an ecological corridor that enables the maintenance of the butterfly fauna on the southern edge of the Upper Paraná Atlantic Forest Ecoregion.
Keywords: *Atlantic Forest, connectivity, conservation, seasonal semi-deciduous forest, species richness.*

THIELE, S.C., MILCHAREK, O., SANTOS, F.L. & KAMINSKI, L.A. **Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de Porto Mauá, Ecorregião Florestas do Alto Paraná, Rio Grande do Sul, Brasil.** Biota Neotropica. 14(2): e20130006. http://dx.doi.org/10.1590/1676-06032014000613

Resumo: Este estudo apresenta uma lista de espécies de borboletas (Lepidoptera: Hesperioidea e Papilionoidea) para o município de Porto Mauá (27°34'S, 28°40'W), Rio Grande do Sul, Brasil. As amostragens foram realizadas mensalmente, entre março de 2008 e março de 2009. Após 204 horas/rede de esforço amostral foram amostrados 1.993 indivíduos pertencentes a 253 espécies. Com apenas uma coleta adicional foram obtidos oito novos registros, totalizando 261 espécies para a região de Porto Mauá. Estes novos registros somados às curvas de acumulação de espécies indicam que a riqueza de borboletas pode ser ainda mais alta. A distribuição da riqueza entre as famílias de borboletas é comparada com inventários em áreas de floresta estacional semidecidual na Mata Atlântica. Além disso, discute-se a importância das matas ciliares do Rio Uruguai como um corredor ecológico, permitindo a manutenção da fauna de borboletas no limite sul da Ecorregião Florestas do Alto Paraná.
Palavras-chave: *Conectividade, conservação, floresta estacional semidecidual, Mata Atlântica, riqueza de espécies.*

Introduction

The Atlantic Forest is a hotspot of biodiversity (Mittermeier et al. 2005) consisting of a complex of 15 ecoregions sharing the same biogeographic history with similar flora and fauna. This biome extends along the Brazilian coastal region to eastern Paraguay and northeastern Argentina (Olson & Dinerstein 1998, Di Bitetti et al. 2003). Among the 15 ecoregions, the Upper Paraná Atlantic Forest once covered the largest original area (471,204 km^2), extending from the western slope of the Serra do Mar mountains in Brazil to eastern Paraguay and the Misiones Province in Argentina (Di Bitetti et al. 2003, Figure 1A). This area was originally covered by a continuous semi-deciduous forest with high biodiversity rates. Nowadays, this ecoregion has the largest area of remaining forest and is home to a large part of the original biota, including several endangered species (Di Bitetti et al. 2003, Ruschel et al. 2007).

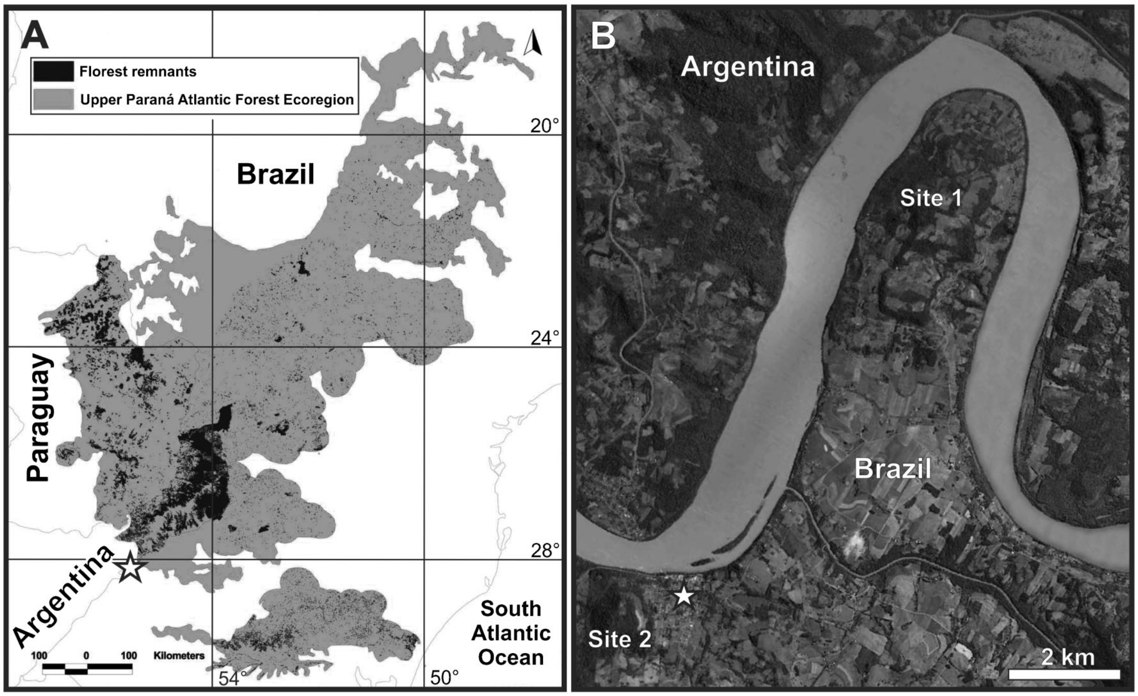


Figure 1. A, location of Porto Mauá municipality (star), Rio Grande do Sul State, Brazil, in relation to the Upper Paraná Atlantic Forest (modified from Di Bitetti et al. 2003); B, satellite image showing the urban area (star), the study sites (Site 1 (27°31'S, 54°40'W) and Site 2 (27°34'S'; 54°40'W)), and the Uruguay River (modified from Google Earth).

Species inventories are the foundation for the understanding of biodiversity and the distribution pattern of species, and they provide support for actions on conservation and management, which are especially important in areas undergoing rapid environmental degradation (Lewinsohn et al. 2005). Although the butterfly fauna of the Atlantic Forest is relatively well known (see Brown & Freitas 2000, Santos et al. 2008), in some regions the knowledge is still incipient or much localized. Moreover, the historical of anthropogenic pressure in this biome make it indispensable to perform continuous inventory studies in these areas, in which the native forest containing many endemic and/or threatened species is being replaced by monocultures (Freitas & Marini-Filho 2011, Freitas et al. 2011, 2012). This situation is even more visible in southern Brazil (Coelho 2000, Rambo 2005), where the few existing forest remnants are limited to riparian forests and protected areas (SOS Mata Atlântica 2008).

Although the published inventories for the Upper Paraná Atlantic Forest Ecoregion (UPAF) report a richer butterfly fauna (e.g. Mielke & Casagrande 1997, Canals 2003, Núñez-Bustos 2008, 2009, Núñez-Bustos et al. 2011, Francini et al. 2011), relatively few such inventories have been published, most of them for the southern boundary of this ecoregion. Our aim is to provide a list of butterflies for Porto Mauá, expanding the available knowledge about the distribution of this group of Lepidoptera at the southern border of the UPAF.

Material and Methods

1. *Study site*

Collections were carried out in Porto Mauá municipality (27°34'S, 28°40'W), in the northwestern part of Rio Grande do Sul State (RS), Brazil (Figure 1). Porto Mauá has a total area of 106 km^2, in which the predominant forest type is seasonal semi-deciduous forest. Currently, 13.75 km^2 (12.97%) of this area is covered by forest, only 4.02 km^2 of it (3.79%) in fragments larger than 0.05 km^2 (IBGE 2006, SOS Mata Atlântica 2008, see also Figure 1B). The climate is subtropical humid, with the absence of a dry period (Mota 1951). Rainfall is well distributed throughout the year, with annual averages of 1,960 mm to 1,990 mm (IBGE 2006). Average temperatures are 31–34°C in summer and 6–9°C in winter (INMET 2009).

2. *Sampling*

In order to maximize species richness and describe the community of butterflies, we chose two sites adjacent to the Uruguay River (Figure 1B). Four transects were selected at these sites, including vegetation with different levels of succession and degrees of anthropogenic activity (Figure 2). Samplings were carried out monthly between March 2008 and March 2009. Each transect was sampled by two collectors with entomological nets, between 8:00 and 18:00, according to standardized sampling efforts of 1.5 hours, totaling 12 net-hours per day on each month. The sequence of transects was alternated in each monthly sampling to ensure that each one would be sampled at different times of day. Individuals were captured, identified in the field and/or collected for identification.

3. *Data analysis*

The specimens were mounted and identified by consulting specialized literature, collections, and experts. The higher level classification used here follows Lamas (2004), Mielke (2005), and Wahlberg et al. (2009), with nomenclatural updates when necessary. The specimens were deposited in the following collections: Departamento de Zoologia, Universidade Federal

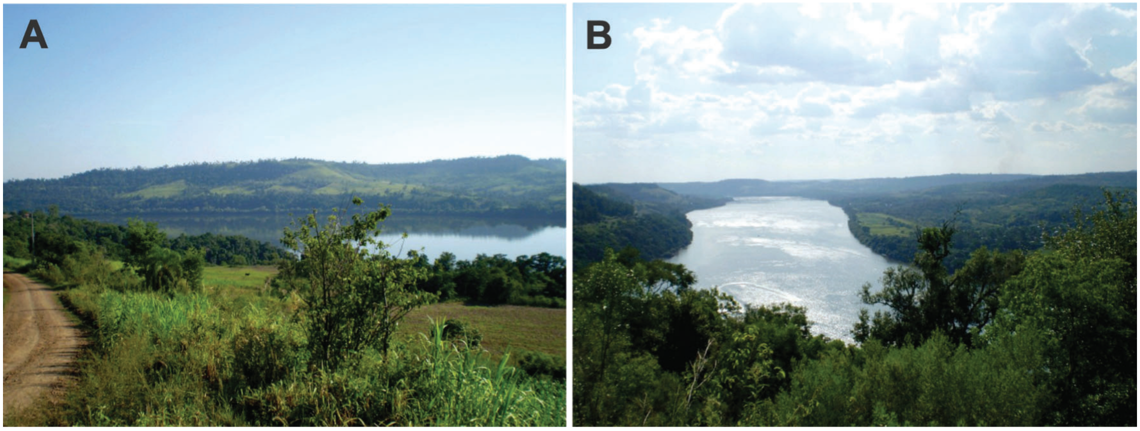


Figure 2. General view of the study sites in Porto Mauá municipality, Rio Grande do Sul State, Brazil. A, detail of Site 1, showing the road, pastures and riparian vegetation on the Brazilian side, and the Argentinean side on the bottom; B, view from the top of a hill in Site 2, showing the Uruguay River.

do Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul State, Brazil; Coleção Entomológica Pe. Jesus Santiago Moure (DZUP), Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Paraná State, Brazil; Museu de Zoologia "Adão José Cardoso" (ZUEC), Universidade Estadual de Campinas, Campinas, São Paulo State, Brazil.

Abundance (N) and richness (S) of butterflies were analyzed. Species acumulation curve was also plotted, including the observed and estimated total richness with confidence interval (95%), using the EstimateS 8.0 software (Colwell 2007). This same procedure was also performed separately for each family. Also, we have an estimated of richness using the "Jackknife 2" estimator, which considers the abundance in the samplings. An additional sampling was conducted in May 2009, which resulted in new additions to the list (Table 1); however, because the sampling protocol is not standardized, these sampling was not included in the analysis.

Results and Discussion

After a total sampling effort of 204 net-hours, 1,993 individuals from 253 species were sampled (Table 1). In the additional sampling, eight new species were added, reaching

Table 1. Butterflies (Papilionoidea and Hesperioidea) recorded in Porto Mauá municipality, Rio Grande do Sul State, Brazil. The number of species from each major taxon is reported within parentheses. *Species collected during one additional visit. Total: 261 species.

Families	Subfamilies	Tribes	Species	N
Hesperiidae (86)	Eudaminae (18)	Eudamini (18)	*Astraptes alardus alardus* (Stoll, 1790)	2
			Astraptes aulus (Plötz, 1881)	1
			Astraptes fulgerator fulgerator (Walch, 1775)	1
			Autochton zarex (Hübner, 1818)	5
			Polygonus leo pallida Röber, 1925	1
			Polygonus savigny savigny (Latreille, [1824])	3
			Spathilepia clonius (Cramer, 1775)	1
			Urbanus albimargo rica Evans, 1952	2
			Urbanus dorantes dorantes (Stoll, 1790)	18
			Urbanus doryssus albicuspis (Herrich-Schäffer, 1869)	1
			Urbanus esta Evans, 1952	1
			Urbanus evenus (Ménétriés, 1855)	3
			Urbanus pronta Evans, 1952	2
			Urbanus proteus proteus (Linnaeus, 1758)	1
			Urbanus simplicius (Stoll, 1790)	5
			Urbanus sp.	1
			Urbanus teleus (Hübner, 1821)	6
			Urbanus virescens (Mabille, 1877)	3
	Hesperiinae (40)	Anthoptini (03)	*Anthoptus epictetus* (Fabricius, 1793)	2
			Corticea corticea (Plötz, 1882)	3
			Synapte silius (Latreille, [1824])	9
		Calpodini (04)	*Evansiella cordela* (Plötz, 1882)	2
			Lychnuchoides ozias ozias (Hewitson, 1878)	6
			Saliana longirostris (Sepp, [1840])	1

Continued on next page

Table 1. Continued.

Families	Subfamilies	Tribes	Species	N
			Zenis jebus jebus (Plötz, 1882)	2
		Hesperiini (07)	*Hylephila phyleus phyleus* (Drury, 1773)	1
			Nyctelius nyctelius nyctelius (Latreille, [1824])	1
			Pompeius pompeius (Latreille, [1824])	2
			Quinta cannae (Herrich-Schäffer, 1869)	3
			Thespieus ethemides (Burmeister, 1878)	1
			Vacerra bonfilius bonfilius (Latreille, 1824)	1
			Wallengrenia premnas (Wallengren, 1860)	1
		Incertae-sedis (01)	*Lycas argentea* (Hewitson, 1866)	7
		Moncini (25)	*Arita mubevensis* (Bell, 1932)	3
			Callimormus rivera (Plötz, 1882)	2
			Callimormus saturnus (Herrich-Schäffer, 1869)	1
			Callimormus simplicius Hayward, 1939	2
			Cobalopsis miaba (Schaus, 1902)	2
			Cumbre triumviralis (Hayward, 1939)	2
			Cymaenes gisca Evans, 1955	1
			Cymaenes lepta (Hayward, 1939)	1
			Cymaenes perloides (Plötz, 1882)	3
			Cymaenes sp.	2
			Eprius veleda obrepta (Kivirikko, 1936)	5
			Lento krexoides (Hayward, 1940)	5
			Lucida ranesus (Schaus, 1902)	1
			Miltomiges cinnamomea (Herrich-Schäffer, 1869)	5
			Moeris striga striga (Geyer, 1832)	1
			Monca branca Evans, 1955	1
			Phanes rezia (Plötz, 1882)	1
			Pheraeus odilia odilia (Plötz, 1884)	1
			Psoralis stacara (Schaus, 1902)	7
			Sodalia coler (Schaus, 1902)	7
			Vehilius inca (Scudder, 1872)	5
			Vehilius stictomenes stictomenes (Butler, 1877)	3
			Vettius marcus (Fabricius, 1787)	1
			Virga austrinus (Hayward, 1934)	1
			Zariaspes mys (Hübner, [1808])	1
	Pyrginae (28)	Achlyodidini (04)	*Achlyodes thraso* (Hübner, [1807])	5
			Aethilla echina coracina Butler, 1870	2
			Milanion leucaspis (Mabille, 1878)	2
			Quadrus cerialis (Stoll, 1782)	2
		Carcharodini (05)	*Bolla atahuallpai* (Lindsey, 1925)	2
			Nisoniades macarius (Herrich-Schäffer, 1870)	4
			Staphylus incisus (Mabille, 1878)	10
			Staphylus minor minor Schaus, 1902	1
			Staphylus sp.	7
		Celaenorrhinini (01)	*Celaenorrhinus similis* Hayward, 1933	2
		Erynnini (06)	*Erynnis funeralis* (Scudder & Burgess, 1870)	1
			Gorgythion begga begga (Prittwitz, 1868)	8
			Grais stigmaticus stigmaticus (Mabille, 1883)	1
			Helias phalaenoides palpalis (Latreille, [1824])	1
			Mylon maimon (Fabricius, 1775)	3
			Sostrata cronion (C. Felder & R. Felder, 1867)	5
		Pyrgini (11)	*Antigonus liborius areta* Evans, 1953	3
			Carrhenes canescens pallida Röber, 1925	2
			Diaeus lacaena (Hewitson, 1869)	3
			Heliopetes alana (Reakirt, 1868)	4
			Heliopetes arsalte (Linnaeus, 1758)	11
			Heliopetes libra Evans, 1944	1
			Heliopetes omrina (Butler, 1870)	7

Continued on next page

Table 1. Continued.

Families	**Subfamilies**	**Tribes**	**Species**	**N**
			Pyrgus orcus (Stoll, 1780)	136
			Pyrgus orcynoides (Giacomelli, 1928)	5
			Trina g. geometrina (C. Felder & R. Felder, 1867)	33
			Xenophanes tryxus (Stoll, 1780)	10
		Pyrrhopygini (01)	*Mysoria barcastus barta* Evans, 1951	1
Lycaenidae (36)	Polyommatinae (02)		*Leptotes cassius cassius* (Cramer, 1775)	5
			Zizula cyna (Edwards, 1881)	47
	Theclinae (34)	Eumaeini (34)	*Arawacus ellida* (Hewitson, 1867)	2
			Arawacus meliboeus (Fabricius, 1793)	2
			Arawacus separata (Lathy, 1926)	17
			Aubergina vanessoides (Prittwitz, 1865)*	-
			Brevianta celelata (Hewitson, 1874)	1
			Calycopis caulonia (Hewitson, 1877)	9
			Celmia celmus (Cramer, 1775)	1
			Contrafacia imma (Prittwitz, 1865)	1
			Dicya eumorpha (Hayward, 1949)	1
			Gargina caninius (Druce, 1907)	1
			Ignata cf. *elana* (Hewitson, 1874)	1
			Nicolaea cupa (Druce, 1907)*	-
			Ocaria ocrisia (Hewitson, 1868)	1
			Ocaria thales (Fabricius, 1793)	2
			Ostrinotes sophocles (Fabricius, 1793)	1
			Panthiades hebraeus (Hewitson, 1867)	1
			Parrhasius orgia (Hewitson, 1867)	2
			Parrhasius polibetes (Stoll, 1781)	1
			Rekoa malina (Hewitson, 1867)	1
			Rekoa palegon (Cramer, 1780)	2
			Siderus eliatha (Hewitson, 1867)	1
			Strephonota ambrax (Westwood, 1852)	1
			Strymon astiocha (Prittwitz, 1865)	3
			Strymon bazochii bazochii (Godart, [1824])	4
			Strymon cestri (Reakirt, [1867])	1
			Strymon eurytulus (Hübner, [1819])	3
			Strymon megarus (Godart, [1824])	2
			Strymon mulucha (Hewitson, 1867)	3
			Strymon ziba (Hewitson,1868)	1
			Symbiopsis cf. *strenua* (Hewitson, 1877)*	-
			Symbiopsis lenitas (Druce, 1907)	1
			Theritas chaluma (Schaus, 1902)	1
			Theritas hemon (Cramer, 1775)	3
			Tmolus echion echion (Linnaeus, 1767)	1
Nymphalidae (103)	Apaturinae (04)		*Doxocopa agathina* (Cramer, 1777)*	-
			Doxocopa kallina (Staudinger, 1886)	2
			Doxocopa laurentia laurentia (Godart, [1824])	4
			Doxocopa zunilda zunilda (Godart, [1824])	1
	Biblidinae (29)	Ageroniini (06)	*Ectima thecla thecla* (Fabricius, 1796)	1
			Hamadryas amphinome (Linnaeus, 1767)*	-
			Hamadryas epinome (C. Felder & R. Felder, 1867)	6
			Hamadryas februa februa (Hübner, [1823])	5
			Hamadryas feronia feronia (Linnaeus, 1758)	1
			Hamadryas fornax fornax (Hübner, [1823])	1
		Biblidini (01)	*Biblis hyperia nectanabis* (Fruhstorfer, 1909)	43
		Callicorini (07)	*Callicore hydaspes* (Drury, 1782)	1
			Callicore pygas thamyras (Ménétriés, 1857)	2
			Callicore sorana sorana (Godart, [1824])	1
			Diaethria candrena candrena (Godart, [1824])	1

Continued on next page

Table 1. Continued.

Families	Subfamilies	Tribes	Species	N
			Diaethria clymena janeira (C. Felder, 1862)	1
			Haematera pyrame pyrame (Hübner, [1819])	2
			Paulogramma pyracmon pyracmon (Godart, [1824])	1
		Catonephelini (03)	*Cybdelis phaesyla* (Hübner, [1831])	1
			Eunica eburnea Fruhstorfer, 1907	1
			Myscelia orsis (Drury, 1782)	3
		Epiphelini (04)	*Epiphile hubneri* Hewitson, 1861	3
			Epiphile orea orea (Hübner, [1823])	1
			Pyrrhogyra neaerea arge Gosse, 1880	2
			Temenis laothoe meridionalis Ebert, 1965	1
		Eubagini (08)	*Dynamine aerata* (Butler, 1877)	2
			Dynamine agacles agacles (Dalman, 1823)	10
			Dynamine artemisia artemisia (Fabricius, 1793)	1
			Dynamine athemon athemaena (Hübner, [1824])	9
			Dynamine coenus coenus (Fabricius, 1793)	2
			Dynamine myrrhina (Doubleday, 1849)	29
			Dynamine postverta postverta (Cramer, 1779)	15
			Dynamine tithia tithia (Hübner, [1823])	21
	Charaxinae (03)	Anaeini (03)	*Fountainea ryphea phidile* (Geyer, 1837)	2
			Hypna clytemnestra huebneri Butler, 1866	2
			Memphis acidalia victoria (H. Druce, 1877)	4
	Cyrestinae (02)		*Marpesia chiron marius* (Cramer, 1779)	3
			Marpesia petreus petreus (Cramer, 1776)	1
	Danainae (19)	Danaini (02)	*Danaus erippus* (Cramer, 1775)	44
			Danaus gilippus gilippus (Cramer, 1775)	5
		Ithomiini (08)	*Dircenna dero celtina* Burmeister, 1878	12
			Episcada carcinia Schaus, 1902	1
			Episcada hymenaea hymenaea (Prittwitz, 1865)	20
			Epityches eupompe (Geyer, 1832)	2
			Mechanitis lysimnia lysimnia (Fabricius, 1793)	4
			Placidina euryanassa (C. Felder & R. Felder, 1860)	6
			Pseudoscada erruca (Hewitson, 1855)	10
			Pteronymia sylvo (Geyer, 1832)	6
		Acraeini (01)	*Actinote melanisans* Oberthür, 1917	1
		Argynnini (01)	*Euptoieta hegesia meridiania* Stichel, 1938	1
		Heliconiini (07)	*Agraulis vanillae maculosa* (Stichel, [1908])	5
			Dione juno juno (Cramer, 1779)	2
			Dryas iulia alcionea (Cramer, 1779)	32
			Eueides aliphera aliphera (Godart, 1819)	26
			Eueides isabella dianasa (Hübner, [1806])	1
			Heliconius erato phyllis (Fabricius, 1775)	68
			Heliconius ethilla narcaea (Godart, 1819)	3
	Libytheinae (01)		*Libytheana carinenta carinenta* (Cramer, 1777)	1
	Limenitidinae (05)		*Adelpha abia* (Hewitson, 1850)	1
			Adelpha epizygis epizygis Fruhstorfer, 1915*	-
			Adelpha malea goyama Schaus, 1902*	-
			Adelpha syma (Godart, [1824])	1
			Adelpha thessalia indefecta Fruhstorfer, 1913	1
	Nymphalinae (13)	Junoniini (01)	*Junonia evarete flirtea* (Fabricius, 1793)	118
		Melitaeini (07)	*Chlosyne lacinia saundersi* (Doubleday, [1847])	5
			Eresia lansdorfi (Godart, 1819)	5
			Ortilia dicoma (Hewitson, 1864)	3
			Ortilia ithra (Kirby, 1900)	26
			Ortilia orthia (Hewitson, 1864)	7
			Ortilia velica durnfordi (Godman & Salvin, 1878)	6
			Tegosa claudina (Eschscholtz, 1821)	140
		Nymphalini (03)	*Hypanartia bella* (Fabricius, 1793)	13

Continued on next page

Table 1. Continued.

Families	**Subfamilies**	**Tribes**	**Species**	**N**
			Hypanartia lethe lethe (Fabricius, 1793)	9
			Vanessa braziliensis (Moore, 1883)	40
		Victorinini (02)	*Anartia amathea roeselia* (Eschscholtz, 1821)	46
			Siproeta epaphus trayja Hübner, [1823]	14
	Satyrinae (27)	Brassolini (02)	*Caligo illioneus pampeiro* Fruhstorfer, 1904	1
			Narope cyllastros E. Doubleday, [1849]	1
		Melanitini (01)	*Manataria hercyna hercyna* (Hübner, [1821])	1
		Morphini (01)	*Morpho helenor achillides* C. Felder & R. Felder, 1867	49
		Satyrini (23)	*Carminda griseldis* (Weymer, 1911)*	-
			Eteona tisiphone (Boisduval, 1836)	5
			Forsterinaria necys (Godart, [1824])	11
			Forsterinaria quantius (Godart, [1824])	12
			Godartiana muscosa (Butler, 1870)	4
			Hermeuptychia atalanta (Butler, 1867)	67
			Moneuptychia griseldis (Weymer, 1911)	2
			Pareuptychia ocirrhoe interjecta (d'Almeida, 1952)	1
			Pareuptychia summandosa (Gosse, 1880)	29
			Paryphthimoides eous (Butler, 1867)	16
			Paryphthimoides grimon (Godart, [1824])	3
			Paryphthimoides phronius (Godart, [1824])	76
			Paryphthimoides poltys (Prittwitz, 1865)	2
			Pharneuptychia pharnabazos (Bryk, 1953)	1
			Praepedaliodes phanias (Hewitson, 1862)	24
			Pseudodebis euptychidia (Butler, 1868)	1
			Splendeuptychia libitina (Butler, 1870)	11
			Taygetis tripunctata Weymer, 1907	2
			Taygetis ypthima Hübner, [1821]	10
			Yphthimoides celmis (Godart, [1824])	9
			Yphthimoides mimula (Hayward, 1954)	2
			Yphthimoides ordinaria Freitas, Kaminski & Mielke, 2012	10
			Yphthimoides straminea (Butler, 1867)	1
Papilionidae (08)	Papilioninae (08)		*Battus polydamas polydamas* (Linnaeus, 1758)	11
			Battus polystictus polystictus (Butler, 1874)	4
			Heraclides anchisiades capys (Hübner, [1809])	1
			Heraclides astyalus astyalus (Godart, 1819)	6
			Heraclides hectorides (Esper, 1794)	6
			Heraclides thoas brasiliensis (Rothschild & Jordan, 1906)	2
			Parides agavus (Drury, 1782)	28
			Parides anchises nephalion (Godart, 1819)	9
Pieridae (14)	Coliadinae (10)		*Aphrissa statira statira* (Cramer, 1777)	8
			Eurema albula sinoe (Godart, 1819)	2
			Eurema deva deva (Doubleday, 1847)	29
			Eurema elathea flavescens (Chavannes, 1850)	2
			Phoebis argante argante (Fabricius, 1775)	11
			Phoebis neocypris neocypris (Hübner, [1823])	19
			Phoebis philea philea (Linnaeus, 1763)	7
			Phoebis sennae marcellina (Cramer, 1777)	12
			Pyrisitia leuce leuce (Boisduval, 1836)	2
			Rhabdodryas trite banksi (Breyer, 1939)	4
	Dismorphinae (03)		*Dismorphia astyocha* (Hübner, [1831])	1
			Enantia lina psamathe (Fabricius, 1793)	3
			Pseudopieris nehemia nehemia (Boisduval, 1836)	6
	Pierinae (01)		*Ascia monuste orseis* (Godart, 1819)	3
Riodinidae (14)	Euselasiinae (01)	Euselasiini (01)	*Euselasia eucerus* (Hewitson, 1872)	1
	Riodininae (13)	Incertae-sedis (03)	*Emesis diogenia* Prittwitz, 1865	9

Continued on next page

Table 1. Continued.

Families	Subfamilies	Tribes	Species	N
			Emesis ocypore zelotes Hewitson, 1872	5
			Emesis satema (Schaus, 1902)	2
		Mesosemiini (01)	*Ionotus alector* (Geyer, 1837)	2
		Nymphidiini (02)	*Adelotypa argiella* Bates, 1868	1
			Synargis calyce (C. Felder & R. Felder, 1862)	1
		Riodinini (07)	*Barbicornis basilis mona* Westwood, 1851	4
			Calephelis braziliensis McAlpine, 1971	2
			Calephelis aymaran McAlpine, 1971	2
			Caria marsyas Godman, 1903	1
			Chalodeta theodora (C. Felder & R. Felder, 1862)	3
			Lasaia agesilas agesilas (Latreille, [1809])	1
			Melanis xenia xenia (Hewitson, [1853])	2

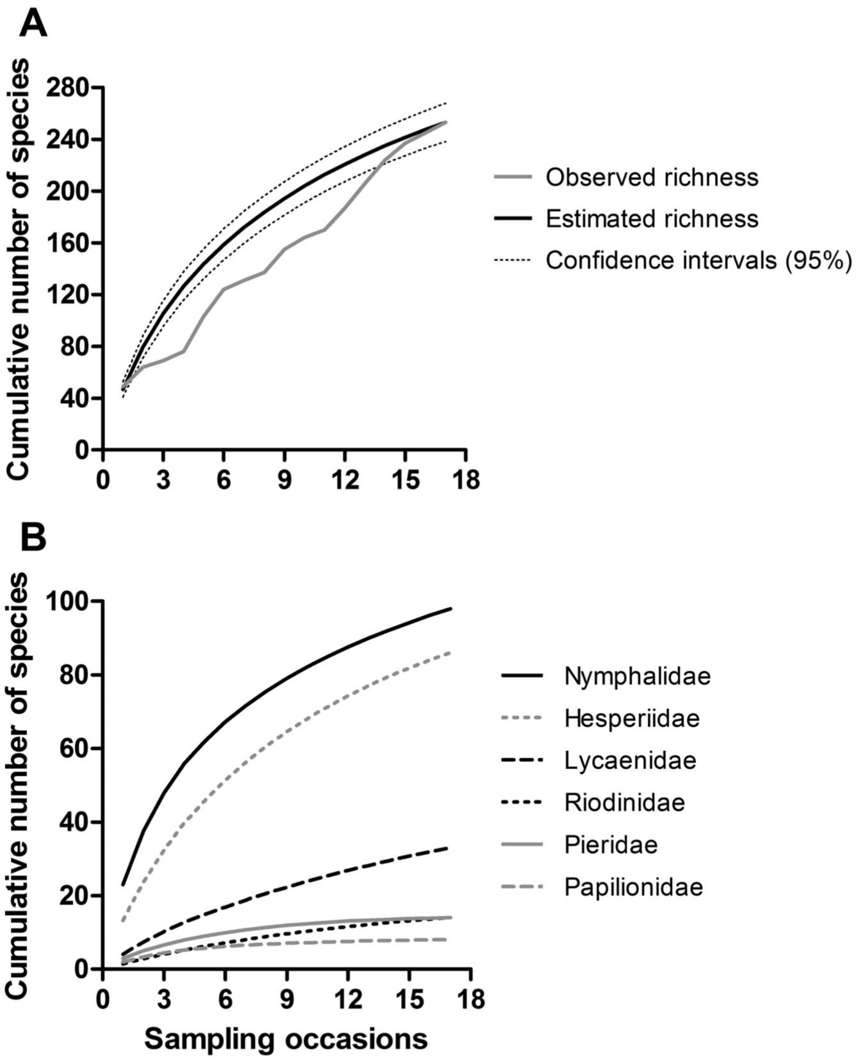


Figure 3. Cumulative number of species recorded after 17 sampling occasions in Porto Mauá municipality, Rio Grande do Sul State, Brazil, from March 2008 to March 2009. A, total cumulative richness for observed and expected curves with confidence intervals of 95%; B, cumulative number of species per butterfly family.

Table 2. Comparison of butterfly richness and composition in locations with predominance of semi-deciduous forest in the Upper Paraná Atlantic Forest Ecoregion. The relative percentages are reported in parentheses.

Localities	NYM	HESP	LYC	RIO	PIE	PAP	Total	Sampling effort
Porto Mauá (RS)[1]	103(39.5)	86(33)	36(13.8)	14(5.3)	14(5.3)	8(3.1)	261	204 hours
Northwest Region (RS)[2]	110(31.2)	119(33.7)	54(15.3)	35(9.9)	21(5.9)	14(4)	353	~1000 hours
Frederico Westphalen (RS)[3,4]	108(49.5)	54(24.8)	16(7.3)	11(5)	18(8.3)	11(5)	218	220 hours
Val da Serra (RS)[5]	54(50.5)	21(19.6)	9(8.4)	7(6.5)	9(8.4)	7(6.5)	107	105 hours
Santa Maria (RS)[6]	51(35.2)	58 (40)	9(6.2)	7(4.8)	8(5.5)	12(8.3)	145	135 hours
Reserva Privada Yacutinga (Misiones)[7]	174(30.4)	248(43.4)	68(11.9)	49(8.6)	21(3.7)	12(2.1)	572	1860 hours
Reserva Nacional Iguazú (Misiones)[8]	189(28.9)	284(43.5)	72(11)	60(9.2)	30(4.6)	18(2.8)	653	948 hours

References: 1, this study; 2, Fábio L. dos Santos (unpublished data, including records from Augusto Pestana, Catuípe, Ijuí, Boa Vista do Cadeado, Bozano, and Pejuçara); 3, Giovenardi et al. (2008); 4, Bonfanti et al. (2009); 5, Morais et al. (2012); 6, Dessuy & Morais (2007); 7, Núñez-Bustos (2008); 8, Núñez-Bustos (2009). Butterfly families: HESP, Hesperiidae; PAP, Papilionidae; PIE, Pieridae; LYC, Lycaenidae; RIO, Riodinidae; NYM, Nymphalidae.

261 species recorded in the region of Porto Mauá. The species accumulation curve is far from stabilization with a marked ascending pattern (Figure 3), clearly indicating that the community of butterflies was not fully sampled. When compared with other inventories with more extensive sampling efforts completed in the UPAF, such as those conducted in the Province of Misiones, Argentina, with 572 species collected in Reserva Privada Yacutinga and 653 in Reserva Nacional Iguazú (Nunez-Bustos 2008, 2009), it becomes evident that the richness of butterflies of Porto Mauá should be greater. Based on the sampling sufficiency curves, and considering the richness observed in nearby well-sampled areas, i.e., with more than 1,000 net-hours (see Table 2), we expect that the complete list of butterflies of Porto Mauá includes 300 to 400 species. This prediction is confirmed by the "Jackknife 2" estimator that indicates 377 species to Porto Mauá.

Taking into account that our sampling effort represents only 11% of the effort made in Reserva Privada Yacutinga, we note that the list of butterflies obtained for Porto Mauá is rich and surpasses other nearby areas in Rio Grande do Sul (Table 2), such as Frederico Westphalen, with 220 net-hours (Giovenardi et al. 2008, Bonfanti et al. 2009), Val da Serra, with 105 net-hours (Morais et al. 2012), and Santa Maria, with 135 net-hours (Dessuy & Morais 2007). Regarding taxonomic composition, the richest family was Nymphalidae, followed by Hesperiidae, Lycaenidae, Pieridae and Riodinidae, and Papilionidae (Table 2). Nymphalidae and Hesperiidae are commonly reported as the most representative families in Neotropical inventories (see Table 2). As proposed by Francini et al. (2011), we expect that with an increased sampling effort, the richness of Hesperiidae will outweigh Nymphalidae. We also expect the richness of Lycaenidae and Riodinidae to increase, since the populations of these butterflies vary greatly over time, requiring longer temporal surveys for adequate sampling of these families (Iserhard et al. 2013).

Some characteristics of the study area, such as its proximity to large interconnected forest fragments in Argentina, make it an important riparian corridor along the Uruguay River, since this river does not represent a barrier for most butterflies. About 80% of the species present in Porto Mauá are also found in these preserved areas of Argentina, which shows the importance of these remnants of riparian forest on the Brazilian side of the river. These data highlight the need for conservation of this area, as it is one of the last sites occupied by forest patches in the region (Figure 1A). According to Freitas (2010), the reduction of riparian forests with consequent loss of connectivity can cause serious impacts to butterfly communities, bringing on structural changes, especially in regions that are already severely modified, like the Upper Paraná Atlantic Forest. Accordingly, forest management and restoration initiatives should consider this area as key to the establishment of ecological corridors.

Our study emphasizes the importance of faunal inventories, especially in sites in which there is urgency for preservation. In the case of butterflies, species lists may provide relevant information about diversity, distribution and ecology (Motta 2002, Freitas et al. 2003), and such information can serve as the basis for ecological zoning and conservation action plans.

Acknowledgements

We thank Peter Pisoni for his kind reception and promptness during the collection expeditions, and Silvana Gasparetto for suggesting sampling areas and mediating our interactions with local residents. To Alfred Moser, André V. L. Freitas, Diego R. Dolibaina, Eduardo S. Carneiro, Fernando M. Dias, Luis A. R. Leite, Gilson R. P. Moreira, Olaf H. H. Mielke, and Noemy Seraphim for help with species identification. Special thanks to Cristiano Iserhard for discussions about butterfly ecology and statistical assistance. LAK thanks Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP 10/51340-8), RedeLep "Rede Nacional de Pesquisa e Conservação de Lepidópteros" SISBIOTA-Brasil/CNPq (563332/2010-7), and the BIOTA FAPESP program (11/50225-3).

References

BONFANTTI, D., DI MARE, R.A. & GIOVENARDI, R. 2009. Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) from two forest fragments in northern Rio Grande do Sul, Brazil. Check List 5:819-829.

BROWN Jr., K.S & FREITAS, A.V.L. 2000. Atlantic Forest butterflies: indicators for landscape conservation. Biotropica 32:934-956.

CANALS, G.R. 2003. Mariposas de Misiones. L.O.L.A., Buenos Aires, 492p.

COELHO, G.C. 2000. A floresta nativa do Noroeste do RS – questões relevantes para a conservação. Caderno de Pesquisa Sér. Bot. (Santa Cruz do Sul) 12:17-44.

COLWELL, R.K. 2007. Estimates 8.0: statistical estimation of species richness and shared species from samples. University of Connecticut, Connecticut. http://viceroy.eeb.ucon.edu/estimates.

DESSUY, M.B. & MORAIS, A.B.B. 2007. Diversidade de borboletas (Lepidoptera, Papilionoidea e Hesperioidea) em fragmentos de Floresta Estacional Decidual em Santa Maria, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 24:108-120.

DI BITETTI, M.S., PLACCI, G & DIETZ, L.A. 2003. A Biodiversity vision for the Upper Paraná Atlantic Forest Ecoregion: Designing a biodiversity conservation landscape and setting priorities for conservation Action. World Wildlife Fund, Washington.

FRANCINI, R.B., DUARTE, M., MIELKE, O.H.H., CALDAS, A. & FREITAS, A.V.L. 2011. Butterflies (Lepidoptera, Papilionoidea and Hesperioidea) of the "Baixada Santista" region, coastal São Paulo, southeastern Brazil. Rev. Bras. Entomol. 55:55-68.

FREITAS, A.V.L. 2010. Impactos potenciais das mudanças propostas no Código Florestal Brasileiro sobre as borboletas. Biota Neotrop. 10:53-57.

FREITAS, A.V.L. & MARINI-FILHO, O.J. 2011. Plano de Ação Nacional para Conservação dos Lepidópteros Ameaçados de Extinção. ICMBio, Brasília, 124p.

FREITAS, A.V.L., FRANCINI, R.B. & BROWN Jr., K.S. 2003. Insetos como indicadores ambientais. In Métodos de estudos em biologia da conservação e manejo da vida silvestre (L. Cullen Junior, C. Valladares-Pádua & R. Rudran, orgs.). Editora da UFPR, Curitiba, p.125-151.

FREITAS, A.V.L., KAMINSKI, L.A., ISERHARD, C.A., BARBOSA, E.P. & MARINI-FILHO, O.J. 2011. The endangered butterfly *Charonias theano* (Boisduval) (Lepidoptera: Pieridae): current status, threats and its rediscovery in São Paulo state, southeastern Brazil. Neotrop. Entomol. 40:669-676.

FREITAS, A.V.L., WAHLBERG, N., MATOS-MARAVI, P.F., MARIN, M.A. & MIELKE, O.H.H. 2012. *Euptychia boulleti* (Le Cerf) n. comb. (Lepidoptera: Nymphalidae: Satyrinae), a rare and endangered butterfly from Southeastern Brazil. Neotrop. Entomol. 41:461-467.

GIOVENARDI, R., DI MARE, R.A., SPONCHIADO, J., ROANI, S.H., JACOMASSA, F.A.F., JUNG, A.B. & PORN, M.A. 2008. Diversidade de Lepidoptera (Papilionoidea e Hesperioidea) em dois fragmentos de floresta no município de Frederico Westphalen, Rio Grande do Sul, Brasil. Rev. Bras. Entomol. 52:599-605.

INMET. Normais Climatológicas 1931-1990. www.inmet.gov.br (último acesso em 23/06/2009).

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Cidades. Censo Agropecuário 2006. http://www.ibge.gov.br/cidadesat/default.php (último acesso em 16/06/2008).

ISERHARD, C.A., QUADROS, M.T., ROMANOWSKI, H.P. & MENDONÇA-JUNIOR, M.S. 2010. Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) ocorrentes em diferentes ambientes na Floresta Ombrófila Mista e Campos de Cima da Serra do Rio Grande do Sul, Brasil. Biota Neotrop. 10:309-320.

ISERHARD, C.A., BROWN Jr., K.S & FREITAS, A.V.L. 2013. Maximized sampling of butterflies to detect temporal changes in tropical communities. J. Insect Conserv. 17:615-622.

LAMAS, G. 2004. Checklist: Part 4A. Hesperioidea-Papilionoidea. In Atlas of Neotropical Lepidoptera. (J.B. Heppner, ed.). Association for Tropical Lepidoptera/Scientific Publishers, Gainesville, p.1-439.

LEWINSOHN, T.M., FREITAS, A.V.L & PRADO, P.I. 2005. Conservation of terrestrial invertebrates and their habitats in Brazil. Conserv. Biol. 19:640-645

MARCHIORI, M.O. & ROMANOWSKI, H.P. 2006. Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) do Parque Estadual do Espinilho e seu entorno, Rio Grande do Sul, Brasil. Rev. Bras. Zool. 23:1029-1037.

MIELKE, O.H.H. 2005. Catalogue of the American Hesperioidea: Hesperiidae (Lepidoptera). Sociedade Brasileira de Zoologia, Curitiba, 1536p.

MIELKE, O.H.H. & CASAGRANDE, M.M. 1997. Papilionoidea e Hesperioidea (Lepidoptera) do Parque Estadual do Morro do Diabo, Teodoro Sampaio, São Paulo, Brasil. Rev. Bras. Zool. 14(4):967-1001.

MITTERMEIER, R.A., GIL, R.P., HOFFMAN, M., PILGRIM, J., BROOKS, T., MITTERMEIER, C.G., LAMOREUX, J. & FONSECA, G.A.B. 2005. Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions, 2. ed. University of Chicago Press, Boston.

MORAIS, A.B.B., LEMES, R. & RITTER, C.D. 2012. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de Val da Serra, região central do Rio Grande do Sul, Brasil. Biota Neotrop 12(2):1-9 http://www.biotaneotropica.org.br/v12n2/en/abstract?inventory+bn01412022012 (último acesso em 13/12/2012).

MOTA, F.S. 1951. Estudos do clima do Estado do Rio Grande do Sul, segundo o sistema de W. Köppen. Rev. Bras. Geog. 13:275-284.

MOTTA, P.C. 2002. Butterflies from the Uberlândia region, central Brazil: species list end biological comments. Braz. J. Biol. 62(1):151-163.

NÚNEZ-BUSTOS, E.O. 2008. Diversidad de mariposas diurnas em la Reserva Privada Yacutinga, Provincia de Misiones, Argentina (Lepidoptera: Hesperioidea y Papilionoidea). Trop. Lepid. Res. 18:78-87.

NUÑEZ-BUSTOS, E.O. 2009. Mariposas diurnas (Lepidoptera: Papilionoidea y Hesperioidea) del Parque Nacional Iguazú, Provincia de Misiones, Argentina. Trop. Lepid. Res. 19:71-81.

NÚÑEZ-BUSTOS, E.O., FAVRE, P., BERTOLINI, M.P., TURNER, J.D. & SOURAKOV, A. 2011. Mariposas diurnas (Lepidoptera: Papilionoidea y Hesperioidea) de la Reserva Privada Osununú-Parque Provincial Teyú Cuaré y alrededores de San Ignacio, Provincia de Misiones, Argentina. Trop. Lepid. Res. 21:34-42.

OLSON, D.M. & DINERSTEIN, E. 1998. The Global 200: A representation approach to conserving the earth's most biologically valuable ecoregions. Conserv. Biol. 12:502-515.

RAMBO, B. 2005. A fisionomia do Rio Grande do Sul: ensaio de monografia natural. Unisinos, São Leopoldo.

RUSCHEL, A.R., NODARI, R.O. & MOERSCHBACHER, B.M. 2007. Woody plant species richness in the Turvo State park, a large remnant of deciduous Atlantic forest, Brazil. Biodivers. Conserv. 16:1699-1714.

SANTOS, E.C., MIELKE, O.H.H. & CASAGRANDE, M.M. 2008. Inventários de borboletas no Brasil: estado da arte e modelo de áreas prioritárias para pesquisa com vistas à conservação. Nat. Conservação 6:68-90.

SOS MATA ATLÂNTICA. Atlas Mata Atlântica. http://www.sosmataatlantica.org.br/ (último acesso em 06/06/2008).

WAHLBERG, N., LENEVEU, J., KODANDARAMAIAH, U., PEÑA, C., NYLIN, S., FREITAS, A.V.L. & BROWER, A.V.Z. 2009. Nymphalid butterflies diversify following near demise at the Cretaceous/Tertiary boundary. Proc. R. Soc. B 276:4295-4302.

Received 26/07/2013
Revised 20/12/2013
Accepted 30/04/2014

Biota Neotropica 14(2): e20140003, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

Sweet trap: *Boa constrictor* (Serpentes: Boidae) preying on passerines on *Cecropia pachystachya* (Urticales: Cecropiaceae) in fruiting period

Gilson da Rocha-Santos[1,3], *Eder Barbier*[1] & *Marcelo Oscar Bordignon*[2]

[1] *Programa de Pós-Graduação em Biologia Animal – Universidade Federal de Mato Grosso do Sul – UFMS – Av. Costa e Silva, s/n, Caixa Postal 549, CEP 79070-900, Campo Grande, MS, Brasil. (http://www.bioanimal.ufms.br)*
[2] *Centro de Ciências Biológicas e da Saúde – Universidade Federal de Mato Grosso do Sul – UFMS – Av. Costa e Silva, s/n, Caixa Postal 549, CEP 79070-900, Campo Grande, MS, Brasil. (http://www.ufms.br)*
[3] *Corresponding author: e-mail: gilsonsantos.bio@gmail.com*

ROCHA-SANTOS, G.; BARBIER E. and BORDIGNON M.O. **Sweet trap: *Boa constrictor* (Serpentes: Boidae) preying on passerines on *Cecropia pachystachya* (Urticales: Cecropiaceae) in fruiting period.** Biota Neotropica. 14(2): e20140003. http://dx.doi.org/10.1590/10.1590/1676-06032014000314

Abstract: Fruits of trumpet tree (*Cecropia* spp.) attract different species of birds and mammals. Boas (*Boa constrictor*) are sit-and-wait strategists, able to choose to ambush in microhabitats that are frequently visited by prey. We have seen two events of predation of passerines (*Pitangus sulphuratus*, *Turdus rufiventris*) by boas on the same trumpet tree (*Cecropia pachystachya*) in a remnant of Cerrado, in the city of Campo Grande/MS. These reports may be evidence of strategic association of boas to trumpet trees, considering the density of snakes recorded on the tree and the constant visits by potential prey during fruiting periods. Besides encouraging a more detailed investigation on the strategies of predation by boas, our records constitute relevant information about the snake natural history.
Keywords: *ambush predators, boa,* Pitangus sulphuratus*, sit-and-wait, trumpet tree,* Turdus rufiventris.

ROCHA-SANTOS, G.; BARBIER E. and BORDIGNON M.O. **Doce armadilha: *Boa constrictor* (Serpentes: Boidae) predando passeriformes sobre *Cecropia pachystachya* (Urticales: Cecropiaceae) em período de frutificação.** Biota Neotropica. 14(2): e20140003. http://dx.doi.org/10.1590/10.1590/1676-06032014000314

Resumo: Frutos de embaúba (*Cecropia* spp.) atraem diversas espécies de aves e mamíferos. Jiboias (*Boa constrictor*) são estrategistas senta-espera, capazes de selecionar micro-habitats que são frequentemente visitados por presas. Nós presenciamos dois eventos de predação de passeriformes (*Pitangus sulphuratus*, *Turdus rufiventris*) por jiboias sobre uma mesma embaúba (*Cecropia pachystachya*) em um remanescente de Cerrado, localizado na cidade de Campo Grande/MS. Esses relatos podem ser indícios de associações estratégicas das jiboias às embaúbas, considerando a densidade de serpentes na árvore e a constante visitação de presas potenciais durante os períodos de frutificação. Além de estimular uma investigação mais detalhada sobre as estratégias de predação das jiboias, esses registros constituem informações relevantes sobre sua história natural.
Palavras-chave: *Embaúba, jiboia,* Pitangus sulphuratus*, predadores de emboscada, senta-espera,* Turdus rufiventris.

Introduction

Sit-and-wait predators remain still for long periods of time, awaiting for prey within the range of their attacks (O'Brien et al. 1990). The choice of locations for ambushing can be determinant of the successful capture of prey, and some snakes (e.g., *Boa constrictor* Linnaeus, 1758; *Crotalus horridus* Linnaeus, 1758; *Echis coloratus* Günther, 1878; *Epicrates inornatus* (Reinhardt, 1843); *Gloydius shedaoensis* (Zhao, 1979)), increase their chances by selecting microhabitats that are frequently visited by prey (Greene 1983, Rodriguez & Reagan 1984, Rodríguez-Durán 1996, Shine & Li-Xin 2002, Clark 2004, Tsairi & Bouskila 2004).

Trumpet trees (*Cecropia* spp.) are fast growing pioneers, associated mainly to secondary forests (Lorenzi 1992, Santos 2000), found throughout the Neotropical area, from the south of Mexico to the north of Argentina (Franco Rosselli 1997). They can reach up to 22 meters (Sposito & Santos 2001) and have long fruiting periods (up to 12 months; see Ferraz et al. 1999) and attract several omnivore and frugivorous species, including passerines (Oniki et al. 1994, Chatellenaz 2008), galliforms (Mikich 2002), parrots (Ragusa-Netto & Fecchio 2006), marmosets (Passamani & Rylands 2000), bats (Lobova et al. 2003) and coatis (Alves-Costa et al. 2004).

Boas (*B. constrictor*) are robust snakes that can reach up to 300 cm of total lenght (see Norman 1994, Marques et al. 2005).

They are present in the Neotropical area, exploring various vegetation types, such as rainforests, savannas and wetlands (Henderson et al. 1995). They are sit-and-wait strategists (Greene 1983) capable of detecting prey, probably through the association of visual, thermal and chemical stimuli (Scartozzoni & Molina 2004). They have semi-arboreal habits and feed efficiently both in terrestrial and arboreal environments (Pizzatto et al. 2009). There are several published records on the consumption of birds (Boback 2005, Begoti & Filho 2012), amphibians (Pizzatto et al. 2009), mammals (Ferrari et al. 2004, Cisneros-Heredia et al. 2005, Sorrell et al. 2011) and reptiles (Quick et al. 2005) by boas, obtained through direct observations or stomach content analysis.

We record here the predation of passerines by boas (*B. constrictor*) in a same fruiting trumpet tree (*Cecropia pachystachya* Trécul).

Material and Methods

The predatory behavior of boas was occasionally observed and recorded on two consecutive days during fieldwork in a Cerrado remnant of 50 ha belonging to Private Natural Heritage Reserve, Universidade Federal de Mato Grosso do Sul (RPPN/UFMS), Campo Grande, Brazil (20°30’18.99" S, 54°36’49.97" W). The reserve is located in an urban area, which is surrounded by boulevards and buildings of the UFMS *campus*. Vegetation type in the reserve is classified as “cerradão” composed by trees reaching 15-18 m tall, smaller trees, shrubs, and herbaceous plants (Assunção et al. 2011).

Results and Discussion

We witnessed two events of predation of passerines by boas on a fruiting trumpet tree (*C. pachystachya*). On 01/31/2013, at 09:47 a.m. (28°C), we observed the capture of a Rufous-bellied Thrush (*Turdus rufiventris* Vieillot, 1818) by a boa (individual 1) that had the body partially aligned on the branch of a 8m trumpet tree (except by the tail, which remained coiled on the branch) (Figure 1a). The Rufous-bellied Thrush landed on the branch in which the snake was positioned (<50 cm from the snake), probably in search of fruit, and was instantly captured and constricted. Then, the snake touched the bird with the labial scales, inspecting it, and started ingesting by the bird’s head. Ingestion lasted about 14min, and the snake returned to its initial position (partially aligned on the branch). At the same time, we spotted two other snakes (individuals 2 and 3) positioned on parallel branches, summing up three individuals foraging on that same tree. Individual 1 was located about 50 cm from individual 2, and individual 3 was positioned 1.5 m away from 1 and 2 m away from the individual 2.

The next morning (02/01/2013), we observed three snakes in the same positions, probably the same individuals sighted in the previous day. At 8:07 a.m. (29°C) we observe another Rufous-bellied Thrush landing on the tree, on a branch near individual 2 (<50 cm from the snake). However, in this event, this bird managed to dodge the attack, escaping capture. Three minutes later we recorded the capture of a Great Kiskadee (*Pitangus sulphuratus* (Linnaeus, 1766)), by individual 3 (Figure 1b). This event was similar to predation described earlier that morning, with the exception of the time the snake spent eating the bird (19min). After the events of predation, we observed other *C. pachystachya* in the study area, but no snakes were observed on them. No interactions among the snakes were observed.

Figure 1. a) *Boa constrictor* (individual 1) predating Rufous-bellied Thrush (*Turdus rufiventris*) on a trumpet tree (*Cecropia pachystachya*). The black arrow indicates the bird’s wing and the white arrow points out a conspecific (individual 2) on a parallel branch. b) Boa (individual 3) at the time of constriction of a Great Kiskadee (*Pitangus sulphuratus*) on the same trumpet tree as the other two. Picture: Gilson da Rocha Santos.

Fruits of *C. pachystachya* are used as food resource by many birds (e.g., Ragusa-Neto 2004, Ragusa-Netto & Fecchio 2006, Chatellenaz 2008), including those belonging to the genus *Turdus* and *Pitangus* (Oniki et al. 1994). Published data on the diet of boas show a high proportion of passerine birds (e.g., Boback 2005, Quick et al. 2005). In addition to the *T. rufiventris* and *P. sulphuratus* recorded in the predation events we also observed *Trogon curucui* Linnaeus, 1766 feeding on the fruits of the *C. pachystachya,* but in branches farther from the snakes. Moreover, a primate, potential prey of boas, *Callithrix penicillata* (É. Geoffroy, 1812), has also being observed visiting trumpet trees (Rocha-Santos, G., pers. obs.).

Trophic interactions may influence the distribution and density of a predator, directly affecting their behavior and habitat use (Slip & Shine 1988). The frequent visitation of trumpet trees by boas’ potential preys, together with our records of successful predation and aggregation of the snakes on the tree, suggest that boas may be selecting *C. pachystachya* as ambushing habitat. Some snakes, including *B. constrictor*

(Boidae), *Crotalus horridus, E. coloratus* (Viperidae) may use chemical signals and ultraviolet traces left by prey and thus track favorable places for ambushing (Sillman et al. 2001, Clark 2004, Tsairi & Bouskila 2004, Scartozzoni & Molina 2004). *Gloydius shedaoensis* (Viperidae), for example, is able to select trees with high visitation rates of birds (Shine & Li-Xin 2002), while *E. inornatus* (Boidae) groups in cave entrances with large density of bats (see Rodriguez & Reagan 1984, Rodríguez-Durán 1996).

Favorable locations for ambushes can also be selected through chemical cues left by snakes of the same species (e.g., *C. horridus*), which succeeded in capturing prey (Clark 2007). Boas are able to recognize chemical signals and discriminate the age of other individuals, apparently in the context of partner selection (Gabirot et al. 2012). But it is possible that, as *C. horridus* (see Clark 2007), they also use these chemical clues, and/or visual signals, to detect conspecifics in areas with higher food availability.

Obviously, the assumptions mentioned are not mutually exclusive and the mechanisms of selection of sites for ambushes may be more complex, involving other factors such as previous experiences of success, positive relationships of perception of the predator instead of the prey and ease of capture (Shine & Li-Xin 2002, Clark 2004). However, regardless of the mechanisms of selection and screening, our data may still be evidence of strategic association of boas to trumpet trees, considering the density of these snakes and constant visits from potential prey during periods of fruiting.

Acknowledgements

To CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for granting the scholarship for the first two authors.

References

ALVES-COSTA, C.P., FONSECA, G.A.B., & CHRISTÓFARO, C. 2004. Variation in the diet of the brown-nosed coati (*Nasua nasua*) in southeastern Brazil. J. Mammal. 85(3):478-482.

ASSUNÇÃO, V.A., GUGLIERI-CAPORAL, A. & SARTORI, A.L.B. 2011. Florística do estrato herbáceo de um remanescente cerradão em Campo Grande, Mato Grosso do Sul, Brasil. Hoehnea 38(2):281-288.

BEGOTTI, R.A. & FILHO, A.M. 2012. Fatal attack on an adult Chestnut-fronted Macaw *Ara severus* by a *Boa constrictor* in the brazilian Amazon. Cotinga 34:106-107.

BOBACK, S.M. 2005. Natural history and conservation of island boas (*Boa constrictor*) in Belize. Copeia 2005(4):880-885.

CHATELLENAZ, M.L. 2008. Diet of the Grayish Saltator (*Saltator coerulescens*) in northeastern Argentina. Ornitol. Neotrop. 19(1):617-625.

CISNEROS-HEREDIA, D.F., LEÓN-REYES, A. & SEGER, S. 2005. *Boa constrictor* predation on a Titi monkey, *Callicebus discolor*. Neotrop. Primates 13(3):11-12.

CLARK, R.W. 2004. Feeding experience modifies the assessment of ambush sites by the Timber Rattlesnake, a sit-and-wait predator. Ethology 110(6):471-483.

CLARK, R.W. 2007. Public information for solitary foragers: timber rattlesnakes use conspecific chemical cues to select ambush sites. Behav. Ecol. 18(2):487-490.

FERRARI, S.F., PEREIRA, W.L.A., SANTOS, R.R. & VEIGA, L.M. 2004. Fatal attack of a *Boa constrictor* on a Bearded Saki (*Chiropotes satanas utahicki*). Folia Primatol. 75(2):111-113.

FERRAZ, D.K., ARTES, R., MANTOVANI, W. & MAGALHÃES, L.M. 1999. Fenologia de árvores em fragmento de mata em São Paulo, SP. Braz. J. Biol. 59(2):305-317.

FRANCO-ROSELLI, P. 1997. Distribution patterns of *Cecropia* (Cecropiaceae): a panbiogeographic analisis. Caldasia 19(1-2):285-296.

GABIROT, M., PICERNO, P., VALENCIA, J., LOPEZ, P. & MARTIN, J. 2012. Chemosensory age discrimination in the snake *Boa constrictor* (Serpentes: Boidae). Ver. Biol. Trop. 60(4):1603-1611.

GREENE, H.W. 1983. *Boa constrictor* (boa, béquer, boa constrictor). In Costa Rican Natural History (D.H. Janzen, ed.). University of Chicago Press, Chicago, p.380-382.

HENDERSON, R.W., MICUCCI, T.W.P., PUORTO, G. & BOURGEOIS, R.W. 1995. Ecological correlates and patterns in the distribution of Neotropical boines (Serpentes: Boidae): a preliminary assessment. Herpetol. Nat. Hist. 3(1):15-27.

LOBOVA, T.A., MORI, S.A., BLANCHARD, F., PECKHAM, H. & CHARLES-DOMINIQUE, P. 2003. *Cecropia* as a food resource for bats in French Guiana and the significance of fruit structure in seed dispersal and longevity. Am. J. Bot. 90(3):388-403.

LORENZI, H. 1992. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Editora Plantarum, Nova Odessa.

MARQUES, O.AV., ETEROVIC, A., STRÜSSMANN, C. & SAZIMA, I. 2005. Serpente do Pantanal: guia ilustrado. Editora Holos, Ribeirão Preto.

MIKICH, A.B. 2002. A dieta frugívora de *Penelope superciliaris* (Cracidae) em remanescentes de florestas estacional semidecidual no centro-oeste do Paraná, Brasil e sua relação com *Euterpe edulis* (Arecaceae). Ararajuba 10(2):207-217.

NORMAN, D.R. 1994. Anfibios y reptiles del Chaco Paraguayo – Tomo I. University of Texas Press, San José.

O'BRIEN, W.J., BROWMAN, H.I. & EVANS, B.I. 1990. Search strategies of foraging animals. Am. Sci. 78(2):152-150.

ONIKI, Y., JÚNIOR, T.A.M., SCOPEL, E.T. & WILLIS, E.O. 1994. Bird use of *Cecropia* (Cecropiaceae) and nearby trees in Espirito Santo state, Brazil. Ornitol. Neotrop. 5(2):109-114.

PASSAMANI, M. & RYLANDS, A B. 2000. Feeding behavior of Geoffroy's marmoset (*Callithrix geoffroyi*) in an atlantic forest fragment of South-eastern Brazil. Primates 41(1):27-38.

PIZZATTO, L., MARQUES, O.A. & FACURE, K. 2009. Food habits of Brazilian boid snakes: overview and new data, with special reference to *Corallus hortulanus*. Amphibia-Reptilia 30(4):533-544.

QUICK, J.S., REINERT, H.K., DE CUBA, E.R & ODUM, R.A. 2005. Recent occurrence and dietary habits of *Boa constrictor* on Aruba, Dutch West Indies. J. Herpetol. 39(2):304-307.

RAGUSA-NETTO, J. & FECCHIO, A. 2006. Plant food resources and the diet of a parrot community in a gallery forest of the southern Pantanal (Brazil). Braz. J. Biol. 66(4):1021-1032.

RAGUSA-NETTO, J. 2004. Flowers, fruits and the abundance of the Yellow-chevroned parakeet (*Brotogeris chiriri*) at a gallery forest in the South Pantanal (Brazil). Braz. J. Biol. 64(4):867-877.

RODRIGUEZ, G.A. & REAGAN, D.P. 1984. Bat predation by the Puerto Rican Boa, *Epicrates inornatus*. Copéia 1984(1):219-220.

RODRÍGUEZ-DURÁN, A. 1996. Foraging ecology of the Puerto Rican Boa (*Epicrates inornatus*): bat predation, carrion feeding, and piracy. J. Herpetol. 30(4): 533-536.

SANTOS, F.A.M. 2000. Growth and leaf demography of two *Cecropia* species. Rev. Bras. Bot. 23(2):133-141.

SCARTOZZONI, R.R. & MOLINA, F.B. 2004. Comportamento Alimentar de *Boa constrictor*, *Epicrates cenchria* e *Corallus hortulanus* (Serpentes: Boidae) em Cativeiro. Rev. Etol. 6(1):25-31.

SHINE, R. & LI-XIN, S. 2002. Arboreal ambush site selection by pit-vipers *Gloydius shedaoensis*. Anim. Behav. 63(3):565-576.

SILLMAN, A.J., JOHNSON, J.L. & LOEW, E.R. 2001. Retinal photoreceptors and visual pigments in *Boa constrictor imperator*. J. Exp. Zool. 290(4):359-365.

SLIP, D.J. & SHINE, R. 1988. Feeding habits of the Diamond Python, *Morelia s. spilota*: ambush predation by a boid snake. J. Herpetol. 22(3):323-330.

SORRELL, G.G., BOBACK, S.M., REED, R.N., GREEN, S., MONTGOMERY, C.E., DE SOUZA L.S & CHIARAVIGLIO, M. 2011. *Boa constrictor* – foraging behavior. Herpetol. Rev. 42(2):281.

SPOSITO, T.C. & SANTOS, F.A.M. 2001. Scaling of stem and crown in eight *Cecropia* (Cecropiaceae) species of Brazil. Am. J. Bot. 88(5):939-949.

TSAIRI, H. & BOUSKILA, A. 2004. Ambush site selection of a desert snake (*Echis coloratus*) at an oasis. Herpetologica 60(1):13-23.

Received 06/01/2014
Accepted 12/05/2014

http://dx.doi.org/10.1590/10.1590/1676-06032014000314

Biota Neotropica 14(2): e20130001, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

article

Diversity and distribution of riffle beetle assemblages (Coleoptera, Elmidae) in montane rivers of Southern Brazil

***Bruna Marmitt Braun*[1], *Andrea Vanesa Batalla Salvarrey*[1], *Carla Bender Kotzian*[2], *Marcia Regina Spies*[3] & *Mateus Marques Pires*[4,5]**

[1] Programa de Pós-Graduação em Biodiversidade Animal, Centro de Ciências Naturais e Exatas, Universidade Federal de Santa Maria, Faixa de Camobi km 9, CEP 97105-900, Santa Maria, RS, Brazil.
[2] Departamento de Biologia e Programa de Pós-graduação em Biodiversidade Animal, Centro de Ciências Naturais e Exatas, Universidade Federal de Santa Maria, Faixa de Camobi km 9, CEP 97105-900, Santa Maria, RS, Brazil.
[3] Universidade Federal do Pampa, Av. Antônio Trilha, 1847, CEP 97300-000, São Gabriel, RS, Brazil.
[4] Programa de Pós-Graduação em Biologia, Centro de Ciências da Saúde, Universidade do Vale do Rio dos Sinos, Avenida Unisinos, 950, CEP 93022-000, São Leopoldo, RS, Brazil.
[5] Corresponding author: Mateus Marques Pires, e-mail: marquespiresm@gmail.com

BRAUN, B.M., SALVARREY, A.V.B., KOTZIAN, C.B., SPIES, M.R., PIRES, M.M. **Diversity and distribution of riffle beetle assemblages (Coleoptera, Elmidae) in montane rivers of Southern Brazil.** Biota Neotropica. 14(2): e20130001. http://dx.doi.org/10.1590/1676-060320140615183046

Abstract: The diversity and spatio-temporal distribution of Elmidae (Coleoptera) assemblages in montane rivers and streams of southernmost Brazil (Rio Grande do Sul state) were studied. Six genera were found, represented mostly by larval specimens. *Austrolimnius* and *Macrelmis* are new occurrences in the region. Assemblages' genera composition and dominance were related to the presence of the macrophyte *Podostemum*. Also, water temperature and stream depth and velocity were the most important drivers related to the assemblages' distribution. Richness and abundance were positively related to high water velocity and negatively to stream depth. Temporal patterns were detected especially in assemblage abundance, yet a slight pattern in richness was also observed. The seasonal structure was related to warm temperatures, but temporal distribution of Elmidae assemblages appears to be related to the dominant genera life cycles. The studied area shows an overall Elmidae richness similar to that found in some tropical areas and the role of mountainous environments in sustaining high rates of regional diversity in the Neotropics is stated.

Keywords: *aquatic insects, streams, Neotropical region.*

BRAUN, B.M., SALVARREY, A.V.B., KOTZIAN, C.B., SPIES, M.R., PIRES, M.M. **Diversidade e distribuição de comunidades de Elmidae (Coleoptera) em rios montanhosos do sul do Brasil.** Biota Neotropica. 14(2): e20130001. http://dx.doi.org/10.1590/1676-060320140615183046

Resumo: A diversidade e a distribuição espaço-temporal de comunidades de Elmidae (Coleoptera) em rios e riachos de uma área montanhosa no sul do Brasil (estado do Rio Grande do Sul) foram estudadas. Sete gêneros foram encontrados, representados principalmente pelo estágio larval. *Austrolimnius* e *Macrelmis* são novas ocorrências no estado. A composição e a dominância dos gêneros estiveram relacionadas com a presença da macrófita *Podostemum*. Além disso, a temperatura da água, a velocidade da corrente e a profundidade dos riachos foram os fatores mais importantes relacionados à distribuição das comunidades. A riqueza e a abundância foram positivamente relacionadas com a velocidade da corrente e negativamente com a profundidade. Não foram detectados fortes padrões temporais na riqueza, mas certa sazonalidade na abundância das comunidades foi observada. A distribuição temporal não esteve relacionada a um fator abiótico específico. Assim, a distribuição temporal das comunidades de Elmidae parece estar relacionada aos ciclos de vida dos gêneros dominantes. Por fim, ressalta-se que a área de estudo apresenta uma riqueza total Elmidae semelhante à de algumas áreas tropicais e o importante papel dos riachos montanhosos na manutenção de altas taxas de diversidade regional na região Neotropical.

Keywords: *insetos aquáticos, riachos, região Neotropical.*

Introduction

Riffle beetles (Elmidae Curtis 1830) are coleopterans whose larvae and adults live especially in lotic environments with high oxygen concentration (Merritt & Cummins 1996, Domínguez & Fernández 2009) and strong water current, in stony bottoms containing leaves (Passos et al. 2003a, b, Elliot 2008, Fernandes 2010). Although abundant in rivers and streams, riffle beetles can also be found in ponds and lakes (Passos et al. 2003a). Their feeding habit is herbivorous (Cummins 1973, White & Brigtam 1996) or herbivorous-detritivorous (Seagle Jr. 1982). Functionally, they are considered scrapers, collectors or shredders (Cummins 1973, White & Brigham 1996), and adults and larvae obtain food scraping rocks, roots, leaves, and woods, or consuming detritus and periphyton (Seagle Jr. 1982). Elmids are also considered important environmental indicators, because they are sensible to physical and chemical changes in the aquatic environment (Jäch & Balke 2008) and, consequently, have low tolerance to pollutants (Brown 1987). Thus, anthropic activities, such as agriculture and domestic and industrial waste, influence their occurrence (Merritt & Cummins 1996). The temporal distribution is associated to life cycle, which is few studied in the adult stage, but better known for the larvae (Kodada & Jäck 2003). The larval stage lasts from six to 36 months, and is affected by temperature and food availability (Brown 1987). Periods of low precipitation also drive the temporal distribution because water depth and velocity become stable (Passos et al. 2003a).

Until now, 1,330 species of Elmidae were described in the world, but estimates indicate that almost 520 species remain unknown (Jäch & Balke 2008). Their diversity is higher in tropical regions (Jäch & Balke 2008), but in South America the family is little studied. Approximately 350 species have been assigned to the Neotropics, and in Brazil, which comprehends ca 40% of the Neotropical region, only ca. 150 species were recorded (Segura et al. 2013). Besides, the knowledge about riffle beetles is restricted to few Brazilian regions. Most taxonomic studies deal with species of Southeastern and Northern regions (e.g., Passos & Felix 2004a,b, Passos et al. 2007, Passos et al. 2009, Passos et al. 2010, Fernandes 2010, Fernandes et al. 2011, Sampaio et al. 2011, Miranda et al. 2012, Sampaio et al. 2012, Segura et al. 2012). Ecological aspects such as spatial distribution, substrate influence and life cycles were studied especially in Southeastern region (Passos et al. 2003a, b, Segura et al. 2007).

The Southernmost Brazil (Rio Grande do Sul state, RS) has environmental characteristics that favor the occurrence of riffle beetles. The escarpment of the Serra Geral Formation is ca. 450 km east-west extension (Pedrón & Dalmolin 2011), and presents numerous rivers and streams with stony substrate (Simões 2002). The humid temperate climate (Maluf 2000) allows the occurrence of a rich drainage net, with well oxygenated waters. However, the diversity and ecology of elmids in Rio Grande do Sul remains poorly known (Hinton 1972, Benetti et al. 1998, Salvarrey 2011). In general, the spatial distribution of these beetles has been registered especially at family level, in studies of freshwater macroinvertebrates (e.g., Wiedenbrug et al. 1997, Bueno et al. 2003, Pereira & De Luca 2003). The occurrence of 14 genera in Santa Catarina state (Segura et al. 2013) and of 19 genera in Argentina (Archangelsky & Manzo 2006) suggests that the diversity of elmids genera in Rio Grande do Sul could be greater than it is known so far.

This study presents an inventory of the Elmidae genera in the middle course of the Jacuí River. Previous studies show that this region contains a very diversified macroinvertebrate assemblage (Neri et al. 2005, Spies et al. 2006, Siegloch et al. 2008, Floss et al. 2012), due to its location in a transitional relief area, and also to the occurrence of the incrusting aquatic macrophyte *Podostemum* A. Michaux, 1803 (Floss et al. 2012). Besides, the middle Jacuí course has part of its marginal areas protected by a state park, Parque Estadual da Quarta Colônia (PEQC). An analysis of the spatial and temporal distribution of the assemblages, according to some environmental factors along one year is also presented. These data will contribute to future preservation programs of the PEQC, as well as to the knowledge of the RS biodiversity.

Material and methods

1. *Study Area*

The Jacuí River basin is one of the largest watersheds of the Rio Grande do Sul state, presenting 800 km of extension and 71.600 km^2 of drainage area (Zamanillo et al. 1989). The middle course, where this study was conducted, is located in altitudes ranging from 50 to 500 m (Marchiori et al. 1982), showing a rugged landscape. Rivers are of 1st to 7th order, according to Strahler (1952) classification, and their beds are constituted mainly by gravels, cobbles and boulders (Neri et al. 2005). Aquatic vegetation is scarce, but *Podostemum* can be common in certain stretches (Spies et al. 2006, Floss et al. 2012). Lentic environments are rare, represented by few backwaters located near the beginning of the lower Jacuí (Spies et al. 2006).

The climate of the region is subtropical humid, according to Köppen's classification, showing mean annual temperature varying from 13°C in winter to 18-22°C in summer, and mean annual precipitation of 1708 mm. Thus, clime can be consider temperate (Maluf 2000). The vegetation belongs to the Seasonal Deciduous Forest, integrating the Atlantic Forest biome (Quadros & Pillar 2002). Present day, it is represented by small fragments of secondary growth and by sparse riparian vegetation (Marchiori et al. 1982), protected near the rivers banks by the PEQC (SEMA, 2005).

2. *Sampling and data analysis*

For the spatial and temporal distribution analyses, samplings were conducted between June 2001 and May 2002 on a monthly basis in four sites (Table 1, Fig. 1). Larvae and adults were collected in areas with running water and stony substrate, with Surber sampler (area = 0.36 m^2, mesh = 1 mm). The margins and the center of the streams were sampled, except in Site 4, in which only the left bank was sampled. When the macrophyte *Podostemum* was found, it was scraped off and included in the samples. The specimens were preserved with 80% ethyl alcohol. For the identification to genus level the keys of Benetti et al. (2006), Manzo & Archangelsky (2008), Domínguez & Fernández (2009) and Segura et al. (2011) were used.

For the overall inventory, additional specimens were obtained from samplings conducted with the same methodology, but with irregular frequency, between April 2000 and May 2002, in other six sites (Fig. 1, Table 1). Voucher specimens are deposited in the Coleção de Macroinvertebrados of the Departmento de Biologia, Universidade Federal de Santa Maria (UFSM), RS (numbered from IA 3606 to IA 3779).

Table 1. Description of the sampling sites of the Elmidae larvae and adults assemblages sampled between April 2000 and May 2002 in the middle course of the Jacuí River, Rio Grande do Sul, Brazil.

Sites	Rivers	Altitude (m)	Order	Width (m)	Grain Size (%)	Site description
1	Rio Carijinho	92	4th	8	Boulder: 54.9 Cobble: 33.9 Gravel: 7.8	arboreous vegetation in one bank; little shading; *Podostemum* sp. present
2	Lajeado da Gringa	107	3rd	6	Boulder: 48 Cobble: 49 Gravel: 1.1	shrubby vegetation in one bank; no shading; *Podostemum* sp. present
3	Lajeado do Gringo	140	4th	5	Boulder: 35.8 Cobble: 49.5 Gravel: 6.8	arboreous vegetation in one bank; little shading
4	Rio Jacuí	57	7th	200	Boulder: 30.1 Cobble: 66.6 Gravel: 2.1	little arboreous vegetation; little shading; stony bottom; anthropogenic influence
5	Rio Carijinho	95	4th	8	Boulder: 15.8 Cobble: 57.1 Gravel: 22.2	arboreous vegetation in one bank
6	Lajeado do Tigre	140	1st	3	Boulder: 44.7 Cobble: 52.1 Gravel: 0.62	well preserved riparian; much shading
7	Lajeado do Tigre	107	2nd	6	Boulder: 0 Cobble: 68.1 Gravel: 20.7	arboreous vegetation in one bank; one bank shaded
8	Lajeado do Tigre	107	2nd	5	Boulder: 50 Cobble: 36.8 Gravel: 7.8	arboreous vegetation in one bank; onde bank shaded
9	Lajeado da Gringa	152	3rd	13,5	Boulder: 66.8 Cobble: 30.6 Gravel: 0.4	arboreous vegetation in one bank; no shading
10	Lajeado do Gringo	140	4th	9	Boulder: 26.3 Cobble: 56.1 Gravel: 10.5	arboreous vegetation in one bank; little shading

In each sampling site, the data of air and water temperature (AT and WT), dissolved oxygen (DO), pH, depth (WD), and water velocity (WV) were taken. Data on monthly accumulated rainfall (mm) and average monthly regional temperature (TMM, °C) were taken from the Departamento de Fitotecnia of the UFSM.

Differences in abiotic data among sites and months were analyzed by means of variance analysis (ANOVA one-way), followed by Tukey test. The significance level used was 5% (Zar 1999).

The diversity in the study area was assessed considering absolute (N) and relative (%) abundance, richness (S) and taxonomic composition. The cumulative richness of genera considered monthly (2001 and 2002) and additional samples was estimated using the collector curve, based on the generation of 500 curves through random addition of samples, using EstimateS 8.2 software (Colwell 2006).

The richness of the genera of the four sampling sites used for studying temporal and spatial distribution was compared using the rarefaction technique (1,000 permutations) (Simberloff 1972). The comparison of richness by means of the rarefaction technique must be done to the highest level of comparison between communities (Gotelli & Entsminger 2006). The curves were generated by EcoSim 700 software (Gotelli & Entsminger 2006). Site 4 was excluded from the analysis due to its very low number of individuals (five specimens).

Seasonal patterns in the temporal distribution of the abundance and richness of Elmidae assemblages were verified by means of Statistical Circular Analysis (Zar 1999). In this analysis, the sampling months were transformed into 30°- angle intervals (May/2002 = 0°; June/2001 = 30°). For each site, the following parameters were estimated: i) mean vector angle (μ), which represents the time of the year during which the greatest abundance and richness was registered; ii) circular standard deviation (SD); and iii) length of the vector (r), a measure of the concentration of the data along the cycle analyzed (year), of which the value varies from 0 (maximum dispersion of data) to 1 (maximum concentration of data). The significance of the mean angle was determined using Rayleigh's Test (Z) (Zar 1999). The circular analysis was performed using Oriana 4.01 software (Kovach 2012).

The influence of the environmental variables in the spatial and temporal distributions of assemblages was analyzed by means of Canonical Correspondence Analysis (CCA) (Legendre & Legendre 1998), using the software CANOCO

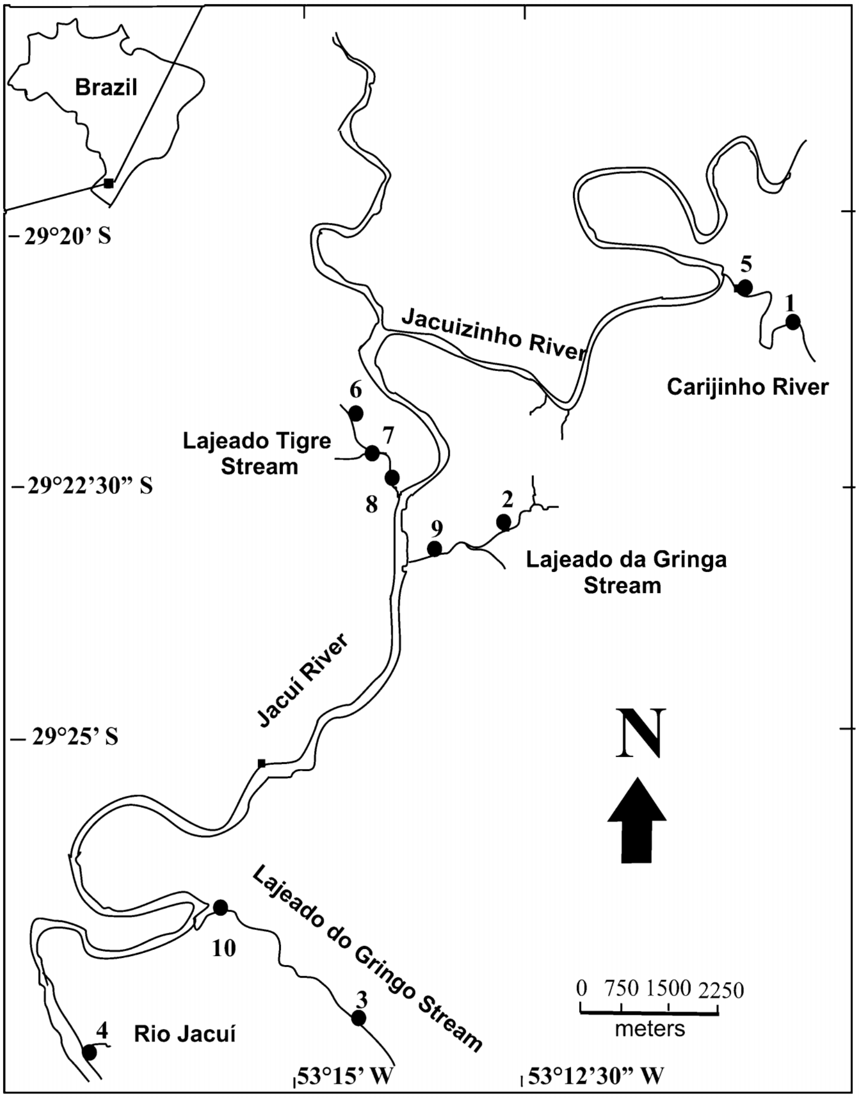


Figure 1. Map of the study area, indicating the ten sampling sites in the middle course of the Jacuí River Basin, Brazil. (Sites 1 – 4 = sampled between June 2001 and May 2002; Sites 1–10 = sampled between April 2000 and May 2002).

4.5 (Ter Braak & Šmilauer 2002). Due to the spatially structured character of the samplings (Legendre & Legendre 1998), a possible relationship between spatially correlated samples was checked out by a Principal Coordinates Matrix Neighboring (PCNM) analysis. In the CCA, the following environmental variables were tested in addition to the model through the *manual forward stepwise* selection procedure ($p < 0.05$ according to Monte Carlo's permutation test with 999 randomizations): pH, DO, WT, AT, WD, WV, altitude, and rainfall. Only three of these variables — WT, WD, WV — were

Table 2. Diversity ;larvae and adults of Elmidae found at the ten sampling sites, in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil (l = larvae; a = adults).

Sites	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
Genera	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**	**l**	**(a)**
Austrolimnius				*(x)*																
Heterelmis	x		x		x		x		x								x		x	
Hexacylloepus	x	*(x)*	x	*(x)*			x		x			*(x)*		*(x)*		*(x)*	x	*(x)*	x	
Macrelmis			x		x	*(x)*											x		x	
Neoelmis	x	*(x)*	x	*(x)*	x	*(x)*	x		x								x	*(x)*	x	*(x)*
Phanocerus																	x		x	
Stegoelmis	x		x		x					*(x)*	x						x		x	

Table 3. Abundance (N) and richness (S) of Elmidae assemblages found in the middle course of the Jacuí River, Rio Grande do Sul, Brazil (l = larvae, a = adults; l+a = sum of larvae and adults).

Sites	**1**		**2**		**3**		**4**		**TOTAL**		
Genera	**l**	***a***	**l**	***a***	**l**	***a***	**l**	***a***	**l**	**a**	**l+a**
Heterelmis	25	*0*	92	*0*	24	*0*	1	*0*	**142**	**0**	**142**
Hexacylloepus	2	*0*	6	*13*	0	*13*	0	*1*	**8**	**27**	**35**
Macrelmis	0	*0*	31	*0*	13	*0*	0	*0*	**44**	**0**	**44**
Neoelmis	36	*1*	208	*43*	81	*4*	3	*0*	**328**	**48**	**376**
Phanocerus	0	*0*	3	*0*	1	*0*	0	*0*	**4**	**0**	**4**
Stegoelmis	26	*0*	35	*0*	15	*0*	0	*0*	**76**	**0**	**76**
N	**89**	***1***	**375**	***56***	**134**	***17***	**4**	***1***	**622**	**75**	**697**
S	**4**	***1***	**6**	***2***	**5**	***2***	**2**	***1***	**7**	**2**	**7**

included. This method was also efficient in removing the multicollinearity among the explaining variables, since none has showed a high variance inflation factor (VIF) (*sensu* Ter Braak & Šmilauer 2002). Monte Carlo's test (999 randomizations) was used to test the significance of the canonical axes (Ter Braak & Šmilauer 2002). The abundance matrix was log transformed (log X+1).

Results

Among the abiotic data, Site 3 had higher pH values than Sites 1 and 2 (F=7.03; p<0.05); Site 4 had lower DO than Site 2 (F = 2.88; p<0.05); Site 1 had higher WD than others (F=5.235; p<0.05); Site 3 had higher WV than Site 4 (F=3.774; p<0.05). Monthly differences between variables were recorded for TMM (F=18.25; p<0.05), WT (F=25.01; p<0.05) (winter-spring and winter-summer months), and DO (F=2.339; p<0.05) (winter-summer months). The higher monthly precipitations were recorded in September 2001 (237.1 mm) and March 2002 (252.1 mm).

Considering both samplings, i.e., those used for the spatial and temporal distribution analyses and the additional samplings, 1,433 specimens, represented by 119 adults and 1,314 larvae, were found in the middle course of the Jacuí River (Table 3). Larvae were identified in seven genera (Table 3). Only Elminae genera were recorded in adult stage. *Hexacylloepus* Hinton, 1940 was the best distributed genera, occurring in nine of the ten sampling sites (Table 3). The cumulative curve of genera, for the ten sampling sites, showed stabilization, indicating that the asymptote was reached (Fig. 2).

From June 2001 to May 2002, 697 specimens (662 larvae and 75 adults) were found in the four sites sampled for the community structures analysis. They were represented by the genera *Heterelmis* Sharp, 1882, *Hexacylloepus*, *Macrelmis* Mostchulsky, 1859, *Neoelmis* Musgrave, 1935, *Phanocerus* Sharp, 1882, and *Stegoelmis* Hinton, 1939 (Table 5). *Neoelmis* was the dominant genus (64%), and together with *Hexacylloepus* and *Heterelmis*, was recorded in all sampling sites. *Phanocerus* was the rarest genus (0.2%), occurring only in two sites (Table 5). The rarefaction graphic, based on 90 specimens, showed overlapping estimated richness for Sites 2 and 3, which had both higher values than Site 1 (Fig. 3).

No specimens of Elmidae were found in February, March and April 2002. Excluding these months, the lowest abundance was found in December 2001, with five specimens collected. The highest abundance was recorded in November 2001, when 148 specimens were collected. Temporal structure was detected by the Circular Analysis, indicating seasonality in elmid assemblages, with most of abundance concentrations in spring periods. Abundance data showed significant Rayleigh test statistics in all sites (Table 4), with mean vector concentrated between August and November (i.e., end of winter and through spring), except for Site 3, in which the mean vector concentrated in the end of fall (Fig. 4). However, richness data in Rayleigh test did not show statistical significance for all sites but Site 3, which concentrated in the end of fall, although the angle of mean vector had indicated spring periods in all sites (excluding Site 4, Fig. 5).

No spatial dependence was detected by the PCNM (p = 0.16) among the sampling sites. Thus, the influence of space was not considered in the following analyses. In the CCA, all axes were significantly different from chance (F = 2.782, p = 0.006). The two first axes together resumed 32.1% of the variability of the Elmidae abundance data, and 97.6% of these data were explained by the relationship with the environmental data (Table 5). The first axis of the CCA evidenced positive correlation with the WT and WV, and negative with WD (Table 6, Fig. 6). The second axis showed strong positive correlation with WT and weak with WD, and negative with WV. In general, Axis 1, resumed the temporal structure, segregating autumn and winter samples from spring and summer ones (Fig. 6). Some genera and their respective life stages were influenced by environmental factors (Fig. 6).

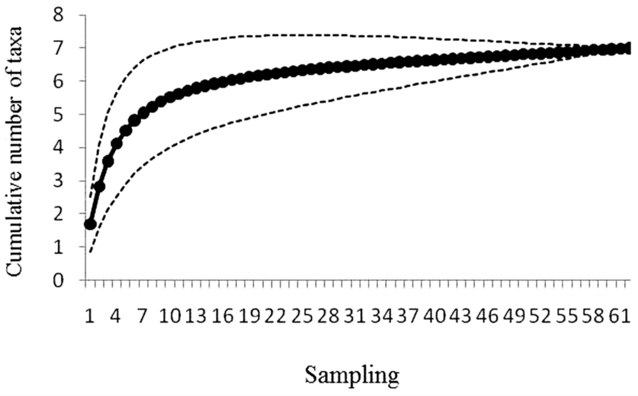


Figure 2. Cumulative curve of genera of the Elmidae adults and larvae assemblages recorded in four rivers, between June 2001 and May 2002, in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

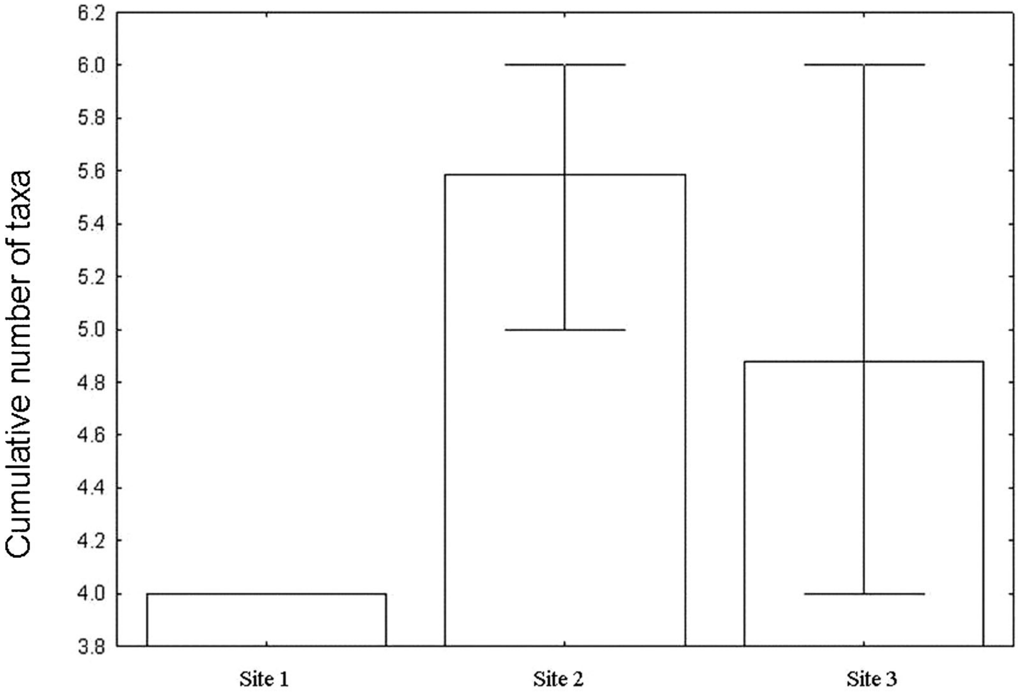


Figure 3. Comparison of the estimated richness of genera of the Elmidae assemblages among the sampled sites in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

Neoelmis and *Hexacylloepus* adults were negatively related to WD and positively to WV, while larvae, like those from *Heterelmis* and *Stegoelmis*, were more related to lower WV. *Macrelmis*, *Hexacylloepus* and *Phanocerus* larvae were slightly related to higher WT.

Discussion

The stabilization of the collector curve (Fig. 2) suggests that a small enhancement in richness should be expected for the riffle beetle genera of the middle Jacuí River, if sampling effort was increased. Richness of elmid genera usually varies from six to eight in southeastern Brazilian rivers (Passos et al. 2003a, Buss et al. 2004, Paula & Fonseca-Gessner 2010), and increases towards northern Brazilian region, according to Fernandes (2010) and Barbosa et al. (2013) information. Thus, southernmost Brazil should sustain a lower richness of riffle beetles than northern and tropical areas, but higher than recorded in this study here (seven genera), because other southern Brazilian regions (e.g., Santa Catarina state) have ca. 13 elmid genera (Segura et al. 2013).

The first record of *Austrolimnius* and *Macrelmis* in Rio Grande do Sul is not a surprise. These genera have been found in others southernmost countries of South America, such as Argentina (Fernández et al. 2008) and Chile (Jerez & Moroni 2006). Besides, all genera recorded in this study have been

Table 4. Circular Analysis of the abundance (N.) and richness (S.) of the larvae and adults Elmidae assemblages in the middle course of the Jacuí River Basin, Rio Grande do Sul, Brazil.

Sites	1		2	
Descriptor	N	S	N	S
Mean vector (μ)	134.05°	78.43°	90.62°	69.40°
Circular standard deviation	52.75°	86.51°	98.19°	101.83°
Average vector length (r)	0.65	0.32	0.23	0.21
Rayleigh Test (Z)	38.56	1.02	23.91	1.40
Rayleigh Test (p)	<0.01	0.37	<0.01	0.25

Sites	3		4	
Descriptor	N	S	N	S
Mean vector (μ)	109.20°	118.41°	116.56°	281.56°
Circular standard deviation	48.06°	63.31°	72.17°	72.17°
Average vector length (r)	0.70	0.54	0.45	0.45
Rayleigh Test (Z)	74.21	5.31	1.02	1.02
Rayleigh Test (p)	<0.01	<0.01	<0.01	0.38

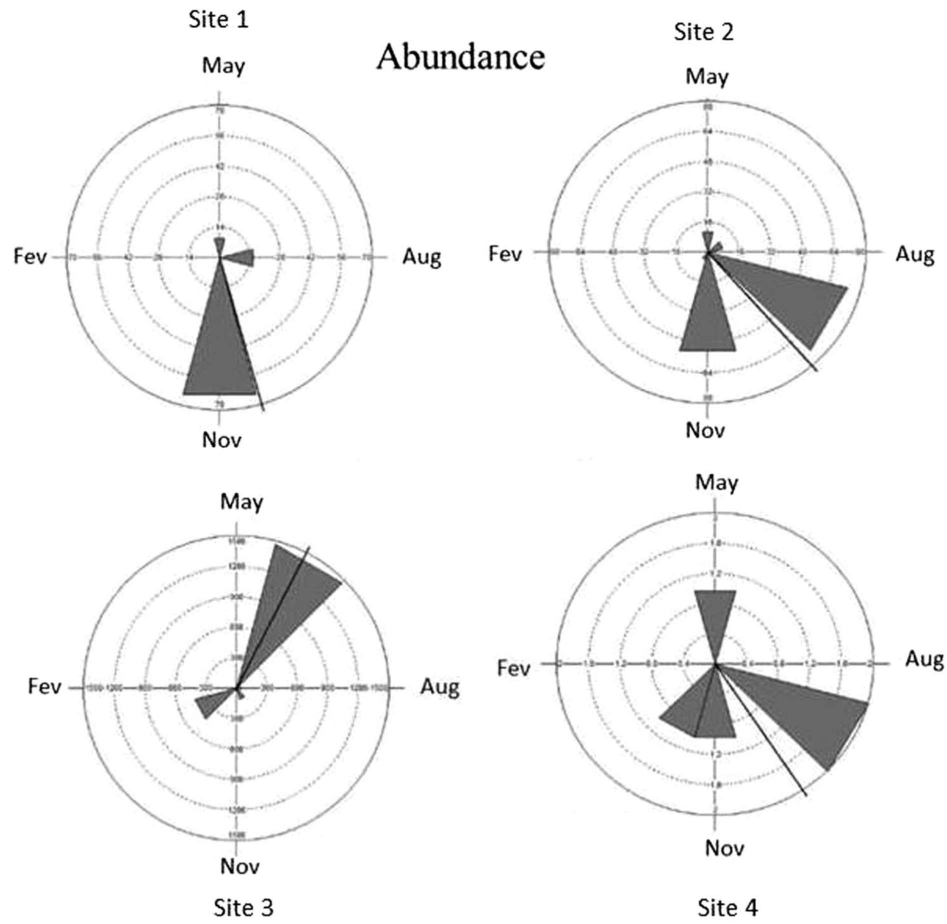


Figure 4. Temporal distribution of the abundance of the Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

previously found in other Brazilian states (Spangler & Santiago-Fragoso 1992, Passos et al. 2007, Paula & Fonseca-Gessner 2010, Fernandes 2010, Segura et al. 2012, Segura et al. 2013). On the other hand, *Stegoelmis* had its distribution extended southwards in the Neotropical region, because until now it had only been recorded below northwards (02°S) (Fernandes 2010, Segura et al. 2013). Additionally, the elmid community composition found in the Jacuí River is similar to those recorded in tropical rivers also showing stony bottoms and strong water current (Passos et al. 2003a, Buss et al. 2004, Mugnai et al. 2008, Fernandes 2010).

The higher abundance and richness registered in Sites 2 and 3 (Figs. 3 and 4) should be associated to the lower WD of both sites, as well as to the expressive presence of the macrophyte *Podostemum*. Aquatic vegetation usually favors the occurrence of high diversity of macroinvertebrates, because it increases the habitat heterogeneity (Taniguchi & Tokeshi 2004). Besides, great macrophyte biomass also represents shelter for larvae and a local for retention of their food (Connel 1978).

Site 1 showed higher WD than Sites 2 and 3, conditions not suitable to Elmidae, especially to *Macrelmis* and *Neoelmis* (Spangler 1997, Passos et al. 2007, Fernandes, 2010). Site 4 is of 7th order, and had the lowest DO and WC mean values, accounting for the lowest richness and abundance. However, the strong water level fluctuation determined by the operation of the Hydroelectric Power Station Dona Francisca (only 2 km upstream), as well as the absence of riparian vegetation and of *Podostemum* (Spies et al. 2006, Floss et al. 2012), are possibly the most important factors avoiding the Elmidae assemblages establishment.

In the end of spring (November 2001), when the highest mean TMM was registered, the highest Elmidae abundance and richness were observed. Similar TMM value was also recorded in October 2001. Previous studies conducted in other temperate regions of the world showed that high WT values favor the occurrence of these coleopterans, because determine faster growth rates (Brown 1987). But riffle beetles are also usually associated to high DO concentrations (Brown 1987). Thus, in March 2002 (summer), when the lowest DO value was registered, no individuals were found. The absence of Elmidae in February and April 2002 can be related to the heavy rainfall that concentrated days before collections of February (100 mm) and along March 2002 (252.1 mm). Rain can exert high influence on the aquatic fauna, washing out the substrate, causing organisms to drift, and altering habitat characteristics (Nessimian and Sanseverino 1998).

The relationships of WT and DO with abundance and richness of the communities were not clear. During the sampling period, months with low DO (September 2001 and May 2002), had regular abundance and richness, and months with high temperature (e.g., December 2001), showed low abundance and richness. Thus, it is possible that these factors affect the genera differently. The Circular Analysis and the Rayleigh Test corroborated seasonality concerning Elmidae

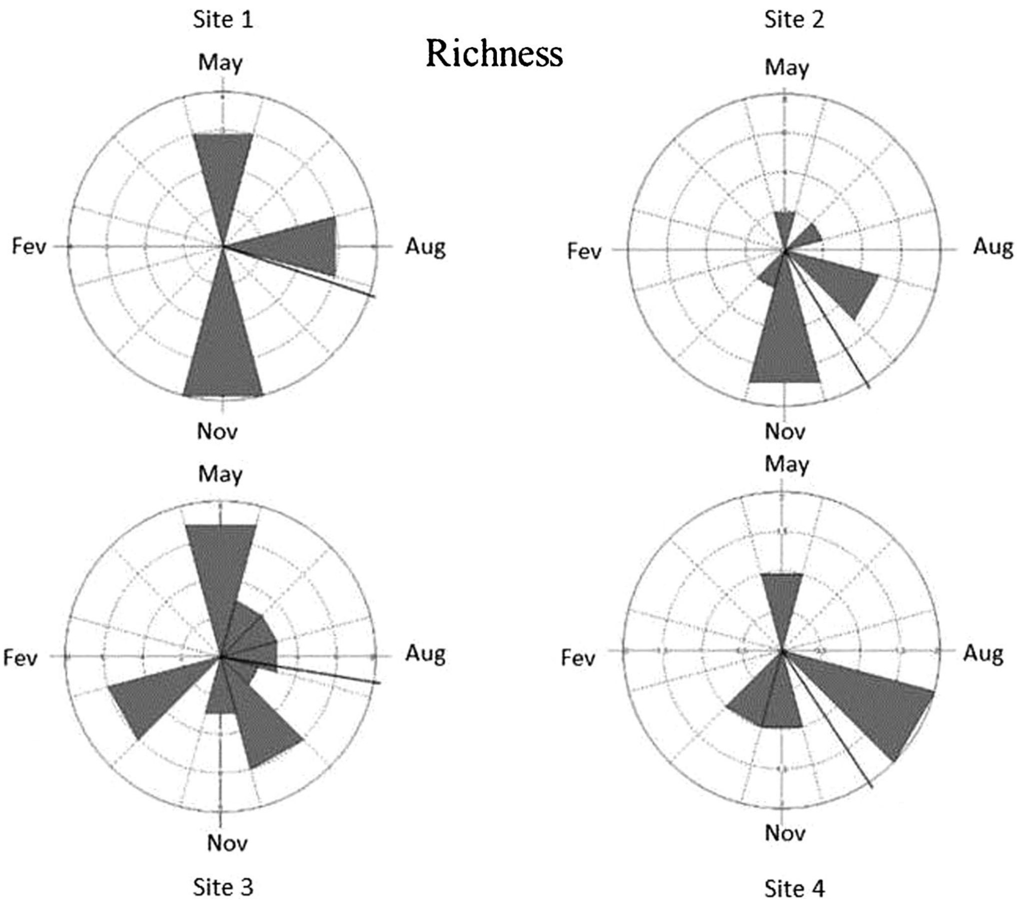


Figure 5. Temporal distribution of the richness of the Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

Table 5. Eigenvalues, taxon-environment coefficients of correlation and explained cumulative percentage of the four first axes of the Canonical Correspondence Analysis of the Elmidae assemblages of the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil.

	Axis 1	Axis 2	Axis 3	Axis 4	Total variance
Eigenvalues	0.25	0.05	0.01	0.25	0.94
Taxon-environment relation	0.75	0.56	0.28	0	
Cumulative variance percentage of the data of taxa	26.5	32.1	32.9	59.8	
Taxon-environment relationship	80.5	97.6	100	0	
Total sum of the eigenvalues					0.94
Total sum of canonical eigenvalues					0.31

Table 6. Inter-set correlations between the first two axes of the Canonical Correspondence Analysis and the environmental variables (water temperature = WT, water depth = WD, water velocity = WV) of the Elmidae assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil, between June 2011 and May 2002.

Environmental factors	Axis 1	Axis 2
WT	0.3425	0.4841
WD	-0.4914	0.0933
WV	0.5292	-0.2545

abundance in spring, but only suggests similar relationship concerning richness (no statistical significance). These results are probably related to life cycle particularities of the most abundant genera in each sampling site, as will be discussed.

Temperature is one of the main factors that affect elmids development, because their life cycle usually synchronizes with warmer temperatures (Brown 1987). In North America, adults emerge mainly in summer, and females wait until the next summer to lay eggs (Elliot 2008). In Brazil, no studies concerning elmid life cycle have been conducted, but some larvae were observed pupating by spring (for one to two weeks), when adults emerge (M. O. Segura pers. comm.). Thus, the data obtained here suggest that warmer temperatures may also influence Neotropical elmids life cycle, favoring the finding of diversified assemblages.

In the middle course of the Jacuí River, DO, WT and WV were the most important factors related to the structure of the

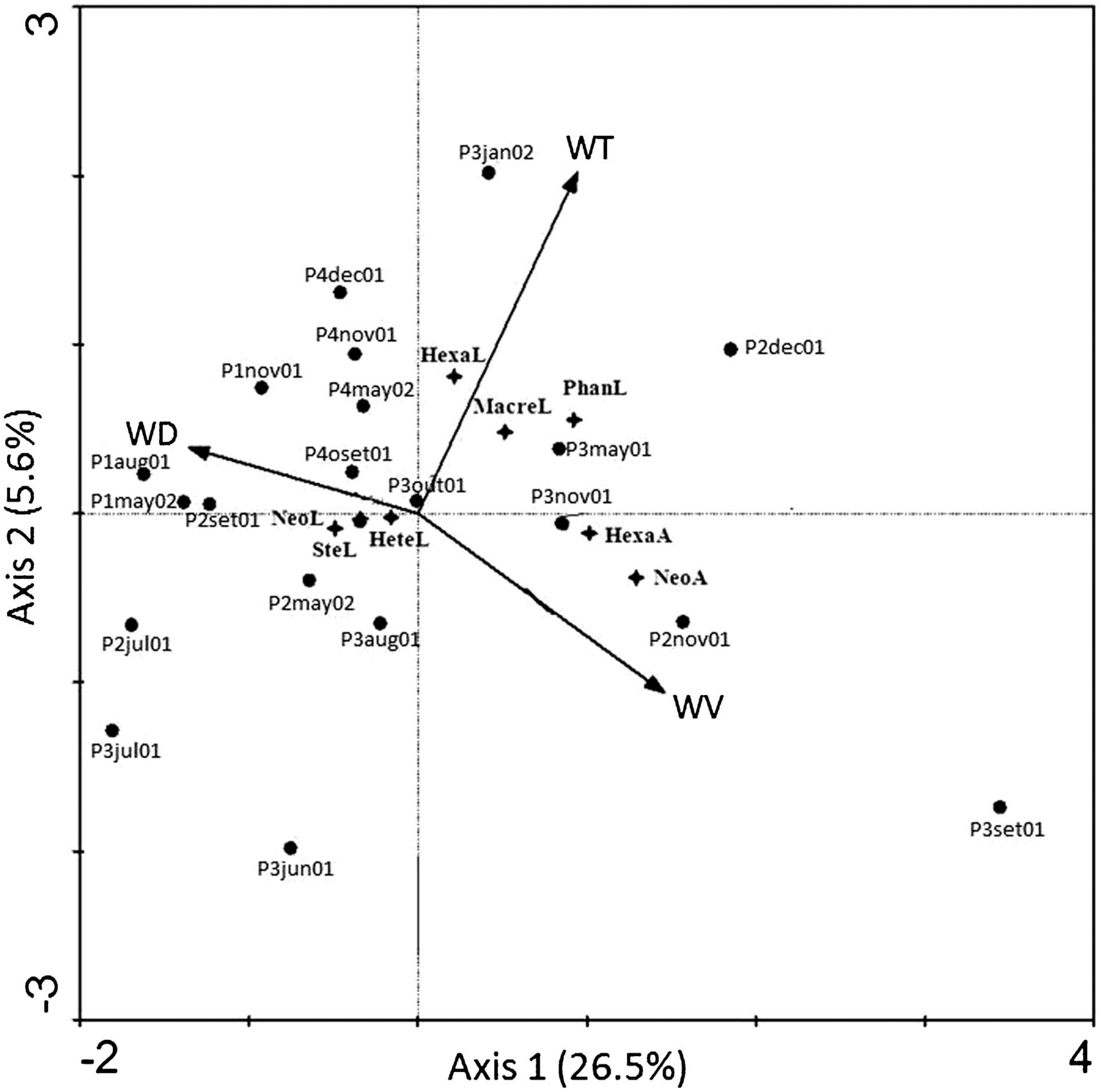


Figure 6. Diagram of ordination of the samples and taxa for the first two axes of the Canonical Correspondence Analysis of Elmidae larvae and adults assemblages in the middle course of the Jacuí River basin, Rio Grande do Sul, Brazil, and environmental variables, surveyed between June 2001 and May 2002. Abbreviations of the taxa: NeoA= *Neoelmis* adult, NeoL= *Neoelmis* larva, HexaA= *Hexacylloepus* adult, HexaL= *Hexacylloepus* larva, PhanL= *Phanocerus* larva, MacreL= *Macrelmis* larva, HeteL=*Heterelmis* larva, SteL= *Stegoelmis* larva, WD= water depth, WV= water velocity, WT= water temperature.

communities of the riffle beetles in a spatial and temporal perspective. In fact, Sites 1 and 4, which tended to segregate according high WD and low WV, exhibited the lowest richness. On the other hand, in months with warmer WT, and when the WV diminished, a relationship of these factors with certain genera were observed. *Neoelmis*, which was abundant in Sites 2 and 3, are typical dwellers of habitats with stony substrate with stems and leaves, and also occur in shallow areas with strong water current (Passos et al. 2003a, b, Passos et al. 2007, Fernández et al. 2008, Fernandes 2010). Thus, the predominance of this genus in the studied area reflects the general environmental conditions of the middle Jacuí River. Habitat preferences of *Hexacylloepus* are not mentioned in literature, but it is probably similar to those of *Neoelmis*, because their larvae have been found together with *Heterelmis* in leaf packs (Spangler & Santiago-Fragoso 1992). *Heterelmis* are found in shallow waters with in running waters, and in warmer temperatures sites (Fernandes 2010). In this study, their larvae were associated to lower WV, as well as those of *Stegoelmis*. *Macrelmis* and *Phanocerus* larvae, which were slightly related to higher WT in the studied area, have been found in riverine habitats containing submerse stems and roots (Spangler & Santiago-Fragoso 1992, Spangler 1997, Fernandes 2010). The genus *Phanocerus* was very rare in the middle Jacuí. Members of this genus were found above the water line (Spangler & Santiago-Fragoso 1992), living in streams with fast and clear waters (Hinton 1940).

Final remarks

River basins located in the escarpment of the Serra Geral Formation, in southernmost Brazil, can sustain Elmidae assemblages with similar richness of genera to that recorded in basins of tropical/warmer climate regions of Brazil. Shallow streams, stony substrate, presence of aquatic macrophytes and especially the occurrence of periods of low rainfall and warm water temperature are important drivers of the spatial and temporal distribution of elmids. Thus, the presence of these environmental conditions in the middle course of the Jacuí River basin is important for the diversity of this family in the escarpment region of RS. This study, as well others previously conducted in the Jacuí River, reinforces the role of the middle course as a hotspot of riverine macroinvertebrate diversity in RS.

Acknowledgments

The authors thank Drs. Melissa Ottoboni Segura (UFSCar) and Ana Emilia Siegloch (UNIPLAC) for reviewing the manuscript.

References

ARCHANGELSKY, M. & MANZO, V. 2006. The larva of Hydora annectens Spangler & Brown (Coleoptera: Elmidae, Larainae) and a key to New World Larainae larvae. Zootaxa 1204:41-52.

BENETII, J.C., FIORENTINI, G.L., CUETO, J.A.R & MIGUEL, R.R.P. 1998. Coleopterofauna Aquática na Floresta Estacional de São Francisco de Paula, RS, Brasil. Acta Biol. Leopold. 20:91-101.

BENETTI, J.C., FIORENTINI, G.L., CUETO, J.A.R.& NEISS, U.G. 2006. Chaves de identificação para famílias de coleópteros aquáticos ocorrentes no Rio Grande do Sul, Brasil. Neotrop. Biol. Cons. 1:24-28.

BROWN, H.P. 1987. Biology of Riffle Beetles. Annu Rev Entomol 32:253-273, doi: http://dx.doi.org/10.1146/annurev.en.32.010187.001345

BUENO, A.A.P., BOND-BUCKUP, G. & FERREIRA, B.D.P. 2003. Estrutura da comunidade de invertebrados bentônicos em dois cursos d'água do Rio Grande do Sul, Brasil. Rev. Bras de Zool. 20:115-125, doi: http://dx.doi.org/10.1590/S0101-81752003000100014

BUSS, D.F, BAPTISTA, D.F., NESSIMIAN, J.L. & EGLER, M. 2004. Substrate specificity, environmental degradation and disturbance structuring macroinvertebrate assemblages in neotropical streams. Hydrobiologia 518:179-188, doi: http://dx.doi.org/10.1023/B:HYDR.0000025067.66126.1c

CONNELL, J.H. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302-1310, doi: http://dx.doi.org/10.1126/science.199.4335.1302

COLWELL, R.K. 2006. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8. User's Guide and application published at: http://viceroy.eeb.uconn.edu/estimates (último acesso em 30.10.2012).

CUMMINS, K.W. 1973. Trophic relations of aquatic insects. Annu Rev Entomol. 18:183-206, doi: http://dx.doi.org/10.1146/annurev.en.18.010173.001151

DOMÍNGUEZ, E. & FERNÁNDEZ, H.R. 2009. Macroinvertebrados Bentônicos Sudamericanos. Sistemática y Biologia. Fundacion Miguel Lillo, San Miguel de Tucumán.

ELLIOT, J.M. 2008. The ecology of riffle beetles (Coleoptera: Elmidae). Freshwater Reviews 1:189-203.

FERNANDES, A.S. 2010. Taxonomia de Elmidae (Insecta, Coleoptera) no Município de Presidente Figueiredo, Amazonas. Dissertação de Mestrado, Instituto Nacional de Pesquisas da Amazônia, Amazonas.

FERNANDES, A.S. PASSOS, M.I., HAMADA, N. 2011. STEGOELMIS HINTON, 1939 (Coleoptera: Elmidae: Elminae) in Brazil: two new species and a key to the Brazilian species. Zootaxa 2921:56-64.

FERNÁNDEZ, L.A., ARCHANGELSKY, M. & MANZO, V. 2008. Coleópteros acuáticos y semiacuáticos del Parque Provincial Salto Encantado y Valle del Cuñá Pirú (Misiones, Argentina). Rev. Soc. Entomol. Argent. 67:87-98.

FLOSS, E.C.S., KOTZIAN, C.B., SPIES, M.R., & SECRETTI, E. 2012. Diversity of non-biting midge larvae assemblages in the Jacuí River basin, Brazil. J Insect Sci. 12, doi: http://dx.doi.org/10.1673/031.012.12101

GOTELLI, N.J. & ENTSMINGER, G.L. 2006. EcoSim: Null models software for ecology. Version 7.72. Acquired Intelligence Inc. & Kesey-Bear. Jericho, VT 05465.

HINTON, H.E. 1940. A monographic revision of the mexican water beetles of the family Elmidae. Novitates Zoologicae 42:217-396.

HINTON, H.E. 1972 Two new genera of South American Elmidae (Coleoptera). Coleopts. Bull. 26:37-41.

JÄCH, M.A. & BALKE, M. 2008. Global diversity of water Beetles (Coleoptera) in freshwater. Hydrobiologia 595:419-442, doi: http://dx.doi.org/10.1007/s10750-007-9117-y

JEREZ, V. & MORONI, J. 2006. Diversidad de Coleopteros Acuaticos en Chile. Gayana 70:72-81.

KODADA, J.& JÄCK, M.A. 2003. Elmidae Curtis, 1830, p. 471-496. In: Beutel, R.G. & R.A.B. Leschen (eds.) Handbook of Zoology. Volume IV. Arthropoda: Insecta. Part 38. Coleoptera, Beetles: Morphology and Systematics, 1., Walter de Gruyter, New York.

KOVACH, W. 2012. Oriana v. 4.01. Anglesey Wales: Kovach Computing Services.

LEECH, H.B. & Chandler, H.P. 1956 Aquatic Coleoptera. In: Usinger, R.L. (Ed), Aquatic Insects of California. University of California Press, Berkeley.

LEGENDRE, P. & LEGENDRE, L. 1998. Numerical ecology. Elsevier, Amsterdam.

MALUF, J.M.T. 2000. Nova classificação climática do Estado do Rio Grande do Sul. Rev. Bras. Agrometerologia 8:141-150.

MANZO, V. & ARCHANGELSKY, M. 2008. A key to the known larvae of South American Elmidae (Coleoptera: Byrrhoidea), with a description of the mature larva of *Macrelmis saltensis* Manzo. Int. J. Lim. 44:63-74, doi: http://dx.doi.org/10.1051/limn:2008023

MARCHIORI, J.N.C., LONGUI, S.J. & DURLO, M A. 1982. A vegetação de capoeira na região do curso médio do rio Jacuí, RS. CeN 4:141-150.

MERRITT, R.W.& CUMMINS, K.W. 1996. An introduction to the aquatic insects of North America. Kendall/Hunt, Iowa.

MIRANDA, G.S., SAMPAIO, B.H.L. & PASSOS, M.I.S. 2012. Two new species of *Austrolimnius* Carter & Zeck (Insecta: Coleoptera: Elmidae) from Southeastern Brazil. Zootaxa 3389:14-24.

MUGNAI R., R.B., OLIVEIRA, R.B., DO LAGO CARVALHO, A. & BAPTISTA, D.F. 2008. Adaptation of the Indice Biotico Esteso (IBE) for water quality assessment in rivers of Serra do Mar, Rio de Janeiro State, Brazil. Trop. Zool. 21:57-74.

NERI, D.B., KOTZIAN, C.B. & SIEGLOCH, A.E. 2005. Composição de Heteroptera aquáticos e semi-aquáticos na área de abrangência da U.H.E. Dona Francisca, RS, Brasil: fase de preenchimento. Iheringia Sér. Zool. 95:421-429, doi: http://dx.doi.org/10.1590/S0073-47212005000400013

NESSIMIAN, J.L. & SANSEVERINO, A.M. 1998. Trophic functional characterization of Chironomidae larvae (Diptera: Chironomidae) in a first order stream at the mountain region of Rio de Janeiro State, Brazil. Int. J. Lim. 26:2115-2119.

PASSOS, M.I.S. & FELIX, M. 2004. Description of a new species of *Cylloepus* Erichson from southeastern Brazil (Coleoptera, Elmidae). Rev. Bras. Entomol. 48:181-183, doi: http://dx.doi.org/10.1590/S0085-56262004000200004

PASSOS, M.I.S., NESSIMIAN, J.L. & DORVILLÉ, L.F.M. 2003a. Distribuição espaço-temporal da comunidade de Elmidae (Coleoptera) em um rio na Floresta da Tijuca, Rio de Janeiro, RJ. Bol. Mus. Nac. N. S. Zool. 509:1-9.

PASSOS, M.I.S., NESSIMIAN, J.L. & DORVILLÉ, L.F.M. 2003b. Life strategies in an Elmidae (Insecta: Coleoptera: Elmidae) community from a first order stream in the Atlantic Forest, southeasteam Brazil. Acta Limnol. Bras. 15:29-36.

PASSOS, M.I.S., NESSIMIAN, J.L. & FERREIRA JR, N. 2007. Chaves para identificação para gêneros de Elmidae (Coleoptera) ocorrentes no Estado do Rio de Janeiro, Brasil. Rev. Bras. Entomol. 51:42-53, doi: http://dx.doi.org/10.1590/S0085-56262007000100008

PASSOS, M.I.S., SAMPAIO, B.H.L NESSIMIAN, J.L. & FERREIRA JR, N. 2009. Elmidae (insecta: coleoptera) do Estado do Rio de Janeiro: lista de espécies e novos registros. Arq. Mus. Nac. 67:377-382.

PASSOS, M.I.S, FERNANDES, A.S., HAMADA, N & NESSIMIAN, J.L. 2010. Insecta, Coleoptera, Elmidae, Amazon region. Check List 6:538-545.

PAULA, M.C. & FONSECA-GESSNER, A.A. 2010. Macroinvertebrates in low-order streams in two fragments of Atlantic Forest in different states of conservation, in the State of São Paulo (Brazil). Braz. J. Biol. 70:899-909, doi: http://dx.doi.org/10.1590/S1519-69842010000400021

PEDRÓN, FA. & DALMOLIN, R.S.D. 2011. Solos da região do rebordo do Planalto Meridional no Rio Grande do Sul. In: SCHUMACHER, M.V. et al (Eds.) A Floresta Estacional Subtropical - Caracterização e Ecologia no Rebordo do Planalto Meridional. Editora Pallotti, Santa Maria.

PEREIRA, D. & DE LUCA, S.J. 2003. Benthic macroinvertebrates and the quality of the hydric resources in Maratá Creek basin (Rio Grande do Sul, Brazil). Acta Limnol. Bras. 15:57-68.

QUADROS, F.L.F. & PILLAR, V P. 2002. Transições floresta- campo no Rio Grande do Sul. Fitogeografia do Sul da America. Ciênc. Ambient. 24:109-118.

SALVARREY, A.V.B. 2010. Distribuição espacial de Macroinvertebrados Bentônicos em riachos da região central do Rio Grande do Sul, Brasil. Dissertação de Mestrado Universidade Federal de Santa Maria, Rio Grande do Sul.

SAMPAIO, B.H.L., PASSOS, M.I.S. & FERREIRA-JR, N. 2011. Three new species of *Cylloepus* Erichson (Insecta: Coleoptera: Elmidae) from Southeastern Brazil. Zootaxa 2797:57-64.

SAMPAIO, B.H.L., PASSOS, M.I.S. & FERREIRA-JR, N. 2012. Two new species of Macrelmis Motschulsky (Coleoptera: Elmidae) and a new record of *Macrelmis isis* (Hinton) from Southeastern Brazil. Zootaxa 3478:164-168.

SEGURA, M.O., FONSECA-GESSNER, A.A. & TANAKA, M.O. 2007. Composition and distribution of aquatic Coleoptera (Insecta) in loworder streams in the state of São Paulo, Brazil: influence of environmental factors. Acta Limnol. Bras. 19(3):247-256.

SEGURA, M.O., VALENTE-NETO, F. & FONSECA-GESSNER, A.A. 2011. Chave de famílias de Coleoptera aquáticos (Insecta) do Estado de São Paulo, Brasil. Biota Neotropica 11(1):393-412, doi: http://dx.doi.org/10.1590/S1676-06032011000100037

SEGURA, M.O., VALENTE-NETO, F. & FONSECA-GESSNER, A.A. 2012. Checklist of the Elmidae (Coleoptera: Byrrhoidea) of Brazil. Zootaxa 3260:1-18.

SEGURA, M.O., PASSOS, M.I.S., FONSECA-GESSNER, A.A. & FROEHLICH, C.G 2013. Elmidae Curtis, 1830 (Coleoptera, Polyphaga, Byrrhoidea) of the Neotropical region. Zootaxa 3731(1): 1-57, doi: http://dx.doi.org/10.11646/zootaxa.3731.1.1

SEMA. Secretaria Estadual do Meio Ambiente 2005. Available at: <http://www.sema.rs.gov.br>. (último acesso em: 06/06/2013)

SEAGLE Jr, H.H. 1982. Comparison of the food habitats of three species of riffle beetles, *Stenelmis crenata*, *Stenelmis mera*, and *Optioservus trivittatus* (Coleoptera, Dryopoidea, Elmidae). Freshwat. Invertebr. Biol. 1:33-38, doi: http://dx.doi.org/10.2307/3259452

SIEGLOCH, A.E., FROEHLICH, C.G. & KOTZIAN, C.B. 2008. Composition and diversity of Ephemeroptera (Insecta) nymph communities in the middle section of the Jacuí River and some tributaries, southern Brazil. Iheringia 98:425-432, doi: http://dx.doi.org/10.1590/S0073-47212008000400002

SIMBERLOFF, D. 1972. Properties of the rarefaction diversity measurement. American Naturalist 106:414-418, doi: http://dx.doi.org/10.1086/282781

SIMÕES, R.I. 2002. Avaliação da comunidade de moluscos límnicos na área da usina hidrelétrica Dona Francisca, Rio Jacuí, RS, BR: fase de pré-enchimento do reservatório. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul, Rio grande do Sul.

SPANGLER, P.J. & SANTIAGO-FRAGOSO, S. 1992. The Aquatic Beetle Subfamily Laraine (Coleoptera: Elmidae) in México, Central América, and the West Indies. Sm. C. Zool. 528:1-74, doi: http://dx.doi.org/10.5479/si.00810282.528

SPANGLER, P.J. 1997. Two new species of the aquatic beetle genus *Macrelmis* Motschulsky from Venezuela (Coleoptera: Elmidae: Elminae). Insecta Mundi 11:1-8.

SPIES, M.R., FROEHLICH, C.G. & KOTZIAN, C.B. 2006 Composition and diversity of Trichoptera (Insecta) larvae communities in the middle section of the Jacuí River and some tributaries, State of Rio Grande do Sul, Brazil. Iheringia Ser. Zool. 96:389-398, doi: http://dx.doi.org/10.1590/S0073-47212006000400001

STRAHLER, A.N. 1952. Hypsometric (area-altitude) - analysis of erosion al topography. Geol. Soc. Am. Bull. 63:1117-1142, doi: http://dx.doi.org/10.1130/0016-7606(1952)63[1117:HAAOET]2.0.CO;2

TANIGUCHI, H., TORESHI, M. 2004. Effects of habitat complexity on benthic assemblages in a variable environment. Fresh. Biol. 49:1164-1178, doi: http://dx.doi.org/10.1111/j.1365-2427.2004.01257.x

TER BRAAK, C.J.F & SMILAUER, P. 2002. CANOCO: reference manual and CanoDraw for Windows. User's guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca.

WHITE, D.S. & BRIGHAM, W.U. 1996. Aquatic Coleoptera. *In*: Merritt, R.W. & Cummins, K.W. (Eds), Introduction to the Aquatic Insects of North America Kendall/Hunt Publ. Co., Iowa, p. 399-473

WIEDENBRUG, F., NOLTE, U. & WÜRDIG, N.L. 1997. Macrozoobenthos of a costal lake in the southern Brazil. Arch. Hydrobiol. 140:533-548.

ZAMANILLO, E.A., TUCCI, C.E.M., SIMÕES-LOPES, M.O. & LANNA, A.E., 1989. Management of navigation in the Jacuí River. Water Int., 14:181-192, doi: http://dx.doi.org/10.1080/02508068908692103

ZAR, J.H. 1999. Biostatistical analysis. Prentice-Hall, New Jersey.

Received 22/07/2013
Revised16/04/2014
Accepted15/06/2014