Biota Neotropica 14(4): e20140115, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Gastropoda (Mollusca) associated to *Sargassum* sp. beds in São Sebastião Channel - São Paulo, Brazil

Pedro Augusto dos Santos Longo[1,2], Marjorie Cattaneo Fernandes[1], Fosca Pedini Pereira Leite[1] &

Flávio Dias Passos[1]

[1]Departamento de Biologia Animal, Universidade Estadual de Campinas, Instituto de Biologia, Rua Monteiro Lobato, 255,CEP 13083-862, Campinas, SP, Brazil.
[2]Corresponding author: Pedro Augusto dos Santos Longo, Programa de Pós-Graduação em Ecologia, Universidade Estadual de Campinas (UNICAMP) CEP 13083-970, Campinas, SP, Brasil. e-mail: pedro.slongo@gmail.com

LONGO, P.A.S., FERNANDES, M.C., LEITE, F.P.P., PASSOS, F.D. Gastropoda (Mollusca) associated to *Sargassum* sp. beds in São Sebastião Channel - São Paulo, Brazil**.** Biota Neotropica. 14(4): e20140115. http://dx.doi.org/10.1590/1676-06032014011514

Abstract: The phytal is characterized by the formation of seaweed beds and a great diversity of associated species, the malacofauna being one of its main components. Aiming to record the species of Gastropoda associated to the brown algae *Sargassum* sp. C. Agardh, 1820, this study was carried out in São Sebastião Channel, northern coast of São Paulo, and nearby areas. A total of 13945 individuals were identified, belonging to 35 families and 62 species. Cerithiidae, Phasianellidae and Columbellidae were the most abundant families, represented by 34, 33 and 17% of the total collected individuals, respectively. *Bittiolum varium* (Pfeiffer, 1840) (Cerithiidae) and *Eulithidium affine* (C. B. Adams, 1850) (Phasianellidae) are the dominant species, followed by the columbelids *Mitrella dichroa* (G. B. Sowerby I, 1844), *Anachis fenneli* Radwin, 1968 and *Costoanachis sertulariarium* (d'Orbigny, 1839). Among the least abundant species, some of them may be considered as of fortuitous occurrences, while others seem to be typical in those habitats, although rare. The presence of juvenile specimens was recurrent, this indicating that the algae can function as a nursery for most of these species. The expressive values found, for both abundance and number of species, illustrate the great ecological importance of the phytal habitats for the gastropod species.
Keywords: *Biodiversity, marine gastropods, phytal.*

LONGO, P.A.S., FERNANDES, M.C., LEITE, F.P.P., PASSOS, F.D. Gastropoda (Mollusca) associados a bancos de *Sargassum* sp. no Canal de São Sebastião – São Paulo, Brasil**.** Biota Neotropica. 14(4): e20140115. http://dx.doi.org/10.1590/1676-06032014011514

Resumo: O fital é caracterizado pela formação de bancos de algas marinhas e uma grande diversidade de espécies associadas, estando a malacofauna entre seus principais componentes. Com o objetivo de registrar as assembleias de gastrópodes associadas à alga parda *Sargassum* C. Agardh, 1820, este estudo foi realizado no Canal de São Sebastião, litoral norte do estado de São Paulo, e áreas próximas. Um total de 13945 indivíduos foram identificados, pertencentes a 35 famílias e 62 espécies. Em termos de abundância, Cerithiidae, Phasianellidae e Columbellidae foram as famílias mais representativas, com 34, 33 e 17% do total de indivíduos coletados, respectivamente. *Bittiolum varium* (Pfeiffer, 1840) (Cerithiidae) e *Eulithidium affine* (C. B. Adams, 1850) (Phasianellidae) foram as espécies dominantes, seguidas pelos columbelídeos *Mitrella dichroa* (G. B. Sowerby I, 1844), *Anachis fenneli* Radwin, 1968 e *Costoanachis sertulariarium* (d'Orbigny, 1839). Entre as espécies pouco abundantes, algumas podem ser consideradas como de ocorrência ocasional, enquanto outras parecem ser típicas deste ambiente, porém raras. A presença de formas juvenis mostrou-se muito recorrente para a maioria das espécies, o que parece indicar que a alga pode atuar como berçário. Os valores expressivos encontrados, tanto para a abundância de indivíduos como para o número de espécies, ilustram a grande importância ecológica apresentada por este ambiente para as espécies de gastrópodes.
Palavras-chave: *Biodiversidade, gastrópodes marinhos, fital.*

Introduction

Seaweed beds carrying an associated fauna form a singular community known as the phytal, a generally rich assemblage of organisms regulated by both biotic (*e.g.* predation, competition, recruitment and migration) and abiotic factors (*e.g.* hydrodynamism, nutrients availability, habitat structure, light incidence and temperature) (Chemello & Milazzo 2002, Jacobucci & Leite 2002, Leite et al. 2009). In these communities, algae provide several advantages for invertebrate and vertebrate animals inhabiting their fronds, including protection against desiccation, wave action and predators, better temperature and salinity conditions, as well as food resources (Jacobucci & Leite 2002, Jacobucci et al. 2006, Leite et al. 2009). Among macroalgae groups composing the phytal, those of *Sargassum* can be considered one of the most representative in some localities of the Brazilian coast (Széchy & Paula 2000), with the malacofauna standing out both in abundance and diversity (Montouchet 1979, Schézy & Paula 2000, Chemello & Milazzo 2002, Jacobucci & Leite 2002, Leite et al. 2009, Veras 2011).

Gastropods, in particular, are an important part of the phytal fauna. Studies highlighting and describing the diversity of phytal molluscan assemblages are scarce in Brazil, especially in the coast of São Paulo state, some of which are Montouchet (1979), Jacobucci et al. (2006) and Leite et al. (2009). Furthermore, illustrated inventories are practically absent in the literature, this kind of work being an important tool to the development of future studies of the phytal gastropod assemblages, as it can facilitate the species identification.

The aim of this study is to provide such an inventory of the gastropod fauna associated to *Sargassum* sp. beds from São Sebastião Channel and nearby areas, thereby increasing knowledge on the biodiversity of this environment, as well as illustrating its species.

Material and Methods

This study was carried out in the northern part of the coast of São Paulo State, southeastern Brazil (23°43'-23°52'S; 45°20'-45°27'W), where algae bed samples were obtained from thirteen sites in March, September and December of 2007, and in February of 2008. Two of these sites are placed in Caraguatatuba and Ubatuba municipalities (at Tabatinga and Ubatumirim beaches, respectively) and eleven are distributed in the São Sebastião Channel. In this channel, six sites were chosen from its insular part (São Sebatião Island, Ilhabela municipality) and five from the continental part (São Sebatião municipality) (Figure 1).

At each site, a horizontal transect was established, where ten fronds were randomly collected, each of them with its holdfast being detached from the substratum. These fronds were enclosed in a bag of 0.2 mm mesh size and at the laboratory were washed in seawater in order to separate the associated animals from algae, and to sort the gastropods for to be fixed and preserved in a solution of 70% ethanol. The obtained gastropods were examined under the stereomicroscope, identified through their shell characteristics, counted from each collecting site and then separated in lots which were deposited in the Zoology Museum of the State University of Campinas "Prof. Adão José Cardoso". For each species, well preserved specimens were chosen to be photographed by a camera coupled to a Zeiss "Discovery V8" stereomicroscope. All these lots are georeferenced and registered in the Center of Reference in Environmental Information (CRIA) database. About five morphotipes of shelless opisthobranch gastropods could be distinguished, but most of the total specimens were poorly preserved, hence, precluding an accurate identification; these were, therefore, excluded in this inventory.

Results

A total of 13945 individuals from 62 species belonging to 35 families was obtained (Table 1). These specimens compose 2437 deposited lots (Table 1). All the identified species are shown in Figures 2, 3, 4 and 5. Except for 32 specimens of the single Calliostomatidae (*Calliostoma* sp.), one of the single Marginellidae (*Volvarina* sp.), one of the Eulimidae *Vitreolina* sp., and 32 juveniles of Columbellidae and 14 of Fissurellidae, all the animals were identified up to the species level. Most families (31) are represented by one or two species (Table 1). Pyramidellidae, Columbellidae, Eulimidae and Cerithiopsidae are the only exceptions to this rule, each one with eight, six, four and three species, respectively.

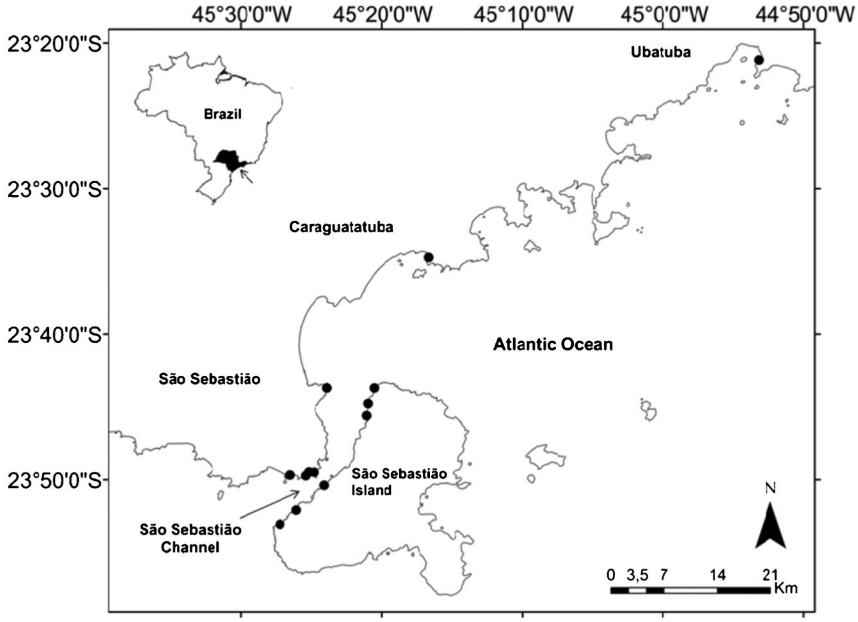

Figure 1. Collecting sites in the insular and continental part of the São Sebastião Channel, and in the Caraguatatuba and Ubatuba municipalities. The placement of this area is indicated by an arrow pointing the north coast of the State of São Paulo (SP), southeastern Brazil.

Table 1. Species, number of individuals (N), series number, literature used for the identification and places where species occurred (✗). S.Sb. = São Sebastião; Ib. = Ilhabela (São Sebastião Island); Tb. = Tabatinga (Caraguatatuba) and Ubm. = Ubatumirim (Ubatuba)

Family/Species	n	Series number	Literature used	Species occurrence			
Cerithiidae				S.Sb.	Ib.	Tb.	Ubm.
Cerithium atratum (Born, 1778)	81	1652–1660	Marcus & Marcus 1964, Rios 2009	✗	✗		
Bittiolum varium (Pfeiffer, 1840)	4642	2389–2870	Houbrick 1977, Houbrick 1993, Simone 2001	✗	✗	✗	✗
Phasianellidae							
Eulithidium affine (C. B. Adams, 1850)	4630	752–1037; 1881–1887	Robertson 1958, Marcus & Marcus 1960; Pereira et al. 2010	✗	✗	✗	✗
Columbellidae							
Anachis fenneli Radwin, 1968	626	1366–1420; 1422–1478	Radwin 1968	✗	✗	✗	
Costoanachis sertulariarum (d'Orbigny, 1839)	600	2871–3051	Marcus & Marcus 1962	✗	✗	✗	✗
Costoanachis sparsa (Reeve, 1859)	124	1306–1365; 1421; 1479–1484	Marcus & Marcus 1962	✗	✗	✗	✗
Anachis obesa (Adams, 1845)	121	2227–2269	Marcus & Marcus 1962	✗	✗	✗	✗
Mitrella dichroa (G. B. Sowerby I, 1844)	813	1142–1305	Marcus & Marcus 1962	✗	✗	✗	✗
Astyris lunata (Say, 1826)	1	1608	Marcus & Marcus 1962	✗			
Columbella mercatoria (Linnaeus, 1758)	15	1588–1607	Marcus & Marcus 1962, Radwin 1977	✗	✗		
Columbellidae jovens	32	1812–1825		✗	✗	✗	
Caecidae							
Caecum ryssotitum de Folin, 1867	323	1038–1100	Mello 1986, Bendel 1996, Gomes & Absalão 1996	✗	✗	✗	✗
Caecum brasilicum de Folin, 1874	294	1101–1141	Mello 1986, Bendel 1996, Gomes & Absalão 1996, Rios 2009	✗	✗		
Rissoidae							
Alvania auberiana (d'Orbigny, 1842)	302	1994–2070	Abbott 1974, Rios 2009	✗	✗	✗	✗
Fissurellidae							
Fissurella rosea (Gmelin, 1791)	200	2270–2359	Righi 1965, Abbott 1974, Rios 2009	✗	✗	✗	✗
Fissurellidae jovens	14	1794–1770	Sasaki 1998, Reynoso–Granados et al. 2007			✗	
Pyramidellidae							
Fargoa bushiana (Bartsch, 1909)	5	1863–1869	Abbott 1974, Pimenta et al. 2009	✗	✗		
Folinella robertsoni (Van Regteren Altena, 1975)	37	1847–1862	Mello 1990, Pimenta et al. 2008, Rios 2009	✗	✗	✗	
Boonea jadisi (Olsson & McGinty, 1958)	16	1717–1727	Rios 1985, Pimenta et al. 2009	✗	✗	✗	
Chrysallida nioba (Dall & Bartsch, 1911)	33	1692–1716	Pimenta 2012	✗	✗	✗	
Turbonilla multicostata (C. B. Adams, 1850)	160	2147–2226	Rios 2009	✗	✗	✗	✗
Eulimastoma didyma (Verrill & Bush, 1900)	22	2071–2080	Pimenta et al. 2004	✗	✗		
Turbonilla penistoni Bush, 1899	10	1633–1643	Bush 1899, Absalão & Pimenta 1999	✗	✗		
Trabecula krumpermani (De Jong &Coomans, 1988)	4	1687–1691	Pimenta et al. 2009, Rios 2009	✗	✗		

Continued on next page

Table 1. Continued.

Family/Species	**n**	**Series number**	**Literature used**	**Species occurrence**			
Cerithiidae				**S.Sb.**	**Ib.**	**Tb.**	**Ubm.**
Rissoellidae							
Rissoella ornata Simone, 1995	194	1953–1993	Simone 1995	✗	✗		✗
Litiopidae							
Alaba incerta (d'Orbigny, 1841)	148	2081–2146	Houbrick 1987, Simone 2001, Rios 2009	✗	✗		
Barleeidae							
Amphithalamus glabrus Simone, 1996	123	1930–1952	Simone 1995	✗	✗		
Scaliolidae							
Finella dubia (d'Orbigny, 1840)	43	1752–1763	Abbott 1974, Simone 2001, Rios 2009	✗	✗		
Cerithiopsidae							
Retilaskeya bicolor (C. B. Adams, 1845)	2	1888–1889	Rios 2009		✗		
Seila adamsii (H. C. Lea, 1845)	2	1892–1893	Rólan & Fernandes 1990, Rios 2009	✗			
Cerithiopsis gemmulosa (C. B. Adams, 1850)	35	1826–1846	Rios 1985, Rolán & Espinosa 1995	✗	✗	✗	
Assimineidae							
Assiminea succinea (Pfeiffer, 1840)	18	1905–1917	Marcus & Marcus 1965, Rios 2009	✗	✗		
Buccinidae							
Engina turbinella (Kiener, 1836)	34	1771–1799	Abbott 1974, Rios 2009	✗	✗		
Triphoridae							
Marshallora nigrocincta (C. B. Adams, 1839)	6	1800–1802	Rios 2009	✗	✗	✗	
Nototriphora decorata (C. B. Adams, 1850)	11	1803–1811	Rios 2009, Fernandes et al. 2013		✗		
Littorinidae							
Echinolittorina lineolata (d'Orbigny, 1840)	16	1623–1632; 1899–1901	Rios 2009	✗	✗	✗	
Muricidae							
Stramonita brasiliensis Claremont& D. G. Reid, 2011	25	1738–1751	Rios 1985, Rios 2009, Claremont et al. 2011	✗	✗	✗	
Muricopsis necocheana (Pilsbry, 1900)	6	1902–1904	Absalão & Pimenta 2005, Rios 2009	✗	✗	✗	
Calliostomatidae							
Calliostoma sp. Swainson, 1840	13	1678–1686	Quinn 1992, Dornellas 2012	✗	✗		
Scissurellidae							
Scissurella alexandrei Montouchet, 1972	10	1728–1731	Montouchet 1972	✗	✗		
Tornidae							
Circulus cf. *liratus* (A. E. Verrill, 1882)	2	1927–1928	Spencer & Campbell 1987		✗		
Parviturboides interruptus (C. B. Adams, 1850)	8	1644–1651	Abbott 1974, Rios 2009	✗	✗		
Eulimidae							
Melanella cf. eulimoides (C. B. Adams, 1850)	2	1734–1735	Rios 2009	✗			
Vitreolina arcuata (C. B. Adams, 1850)	1	1732	Rios 2009		✗		
Vitreolina sp.	1	1733	Warén 1983	✗	✗		
Melanella eburnea (Mühlfeld, 1824)	1	1736–1737	Queiroz et al. 2013		✗		

Continued on next page

Table 1. Continued.

Family/Species	**n**	**Series number**	**Literature used**	**Species occurrence**			
Cerithiidae				**S.Sb.**	**Ib.**	**Tb.**	**Ubm.**
Turbinidae							
Lithopoma phoebium (Röding, 1798)	2	1919–1920	Abbott 1974, Williams 2007, Rios 2009	✗	✗		
Tegula viridula (Gmelin, 1791)	3	1896–1898	Williams et al. 2008; Rios 2009	✗	✗		
Nassariidae							
Nassarius albus (Say, 1826)	2	1890–1891	Matthews 1968, Absalão & Pimenta 2005, Rios 2009		✗		
Mangeliidae							
Tenaturris fulgens (E. A. Smith, 1888)	2	1923–1924	Rios 2009	✗	✗		
Glyphoturris rugirima (Dall, 1889)	2	1894–1895	Absalão et al. 2005, Rios 2009		✗	✗	
Epitoniidae							
Epitonium cf. *worsfoldi* Robertson, 1994	1	1929	Robertson 1993	✗	✗		
Retusidae							
Pyrunculus caelatus (Bush, 1885)	1	1926	Absalão & Pimenta 2005, Rios 2009	✗	✗		
Ellobiidae							
Pedipes mirabilis (Mühlfeld, 1816)	1	1925	Abbott 1974, Rios 2009		✗		
Modulidae							
Modulus modulus (Linnaeus, 1758)	1	1922	Houbrick 1980		✗		
Pseudomelatomidae							
Crassispira cf. fuscescens (Reeve, 1843)	1	1921	Rios 2009, Fallon 2011		✗		
Rissoinidae							
Schwartziella bryerea (Montagu, 1803)	23	1609–1622	Rios 2009	✗	✗		✗
Planaxidae							
Fossarus ambiguus (Linnaeus, 1758)	1	3350	Houbrick 1990		✗		
Bullidae							
Bulla occidentalis A. Adams, 1850	82	2360–2388	Malaquias & Reid 2008	✗	✗	✗	✗
Haminoeidae							
Haminoea antillarum (d'Orbigny, 1841)	16	1871–1879	Abbott 1974	✗	✗		✗
Cylichnidae							
Cylichna discus Watson, 1883	2	1880	Marcus 1970, Absalão & Pimenta 2005, Rios 2009		✗		
Marginellidae							
Volvarina sp.	1	1918	Rios 2009		✗		

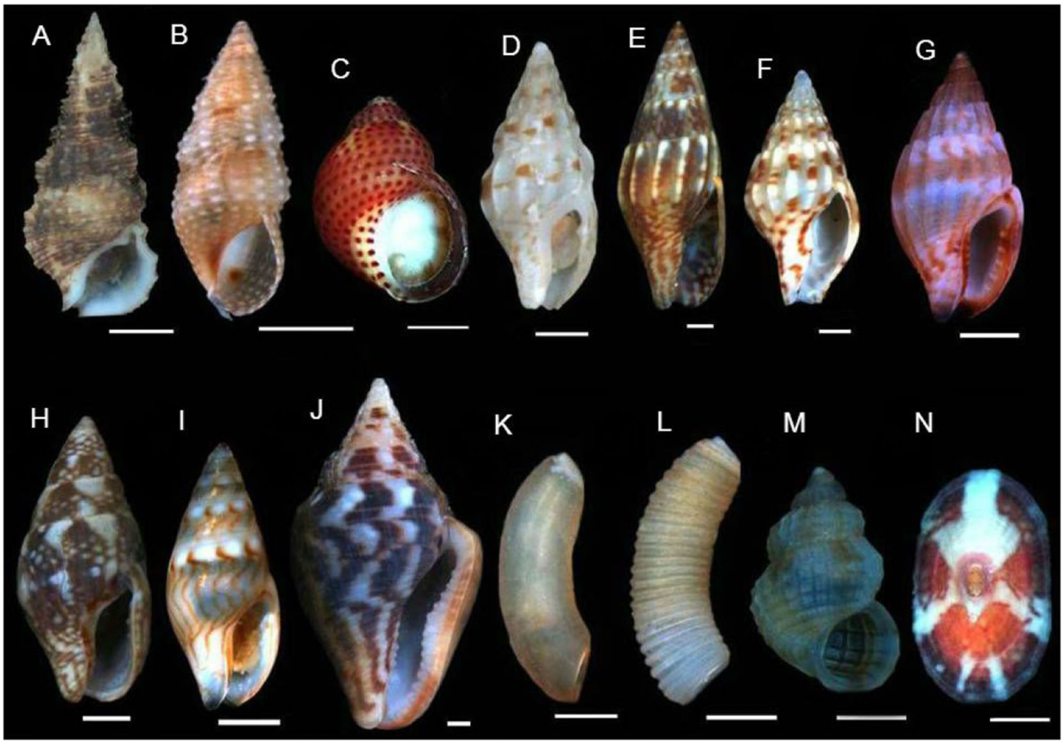

Figure 2. Photomicrographs of the gastropod species collected in *Sargassum* sp. beds from the São Sebastião Channel, Caraguatatuba and Ubatuba (continues in Figures 3 to 5). Cerithiidae: *Cerithium atratum* (A) and *Bittiolum varium* (B). Phasianellidae: *Eulithidium affine* (C). Columbellidae: *Anachis fenneli* (D), *Costoanachis sertulariarum* (E), *Costoanachis sparsa* (F), *Anachis obesa* (G), *Mitrella dichroa* (H), *Astyris lunata* (I), and *Columbella mercatoria* (J). Caecidae: *Caecum ryssotitum* (K) and *Caecum brasilicum* (L). Rissoidae: *Alvania auberiana* (M). Fissurellidae: *Fissurella rosea* (N). **Scale bars: 500um for A and K-N; 1000um for B-J.**

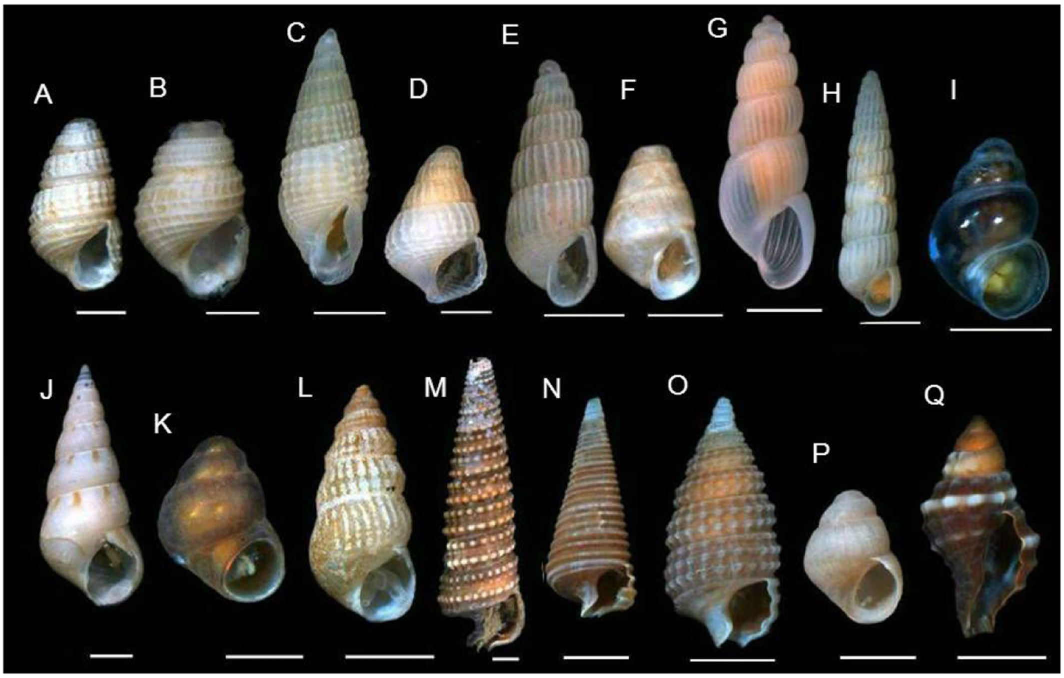

Figure 3. Photomicrographs of the gastropod species collected in *Sargassum* sp. beds from the São Sebastião Channel, Caraguatatuba and Ubatuba. Pyramidellidae: *Fargoa bushiana* (A), *Folinella robertsoni* (B), *Boonea jadisi* (C), *Chrysallida nioba* (D), *Turbonilla multicostata* (E), *Eulimastoma didyma* (F), *Trabecula krumpermani* (G), *Turbonilla penistoni* (H). Rissoellidae: *Rissoella ornata* (I). Litiopidae: *Alaba incerta* (J). Barleeidae: *Amphithalamus glabrus* (K). Scaliolidae: *Finella dubia* (L). Cerithiopsidae: *Retilaskeya bicolor* (M), *Seila adamsii* (N) and *Cerithiopsis gemmulosa* (O). Assimineidae: *Assiminea succinea* (P). Buccinidae: *Engina turbinella* (Q). **Scale bars: 500um for A, D, F, K and P; 250 um for B; 1000um for C, E, G-J, L-O and Q.**

http://dx.doi.org/10.1590/1676-06032014011514

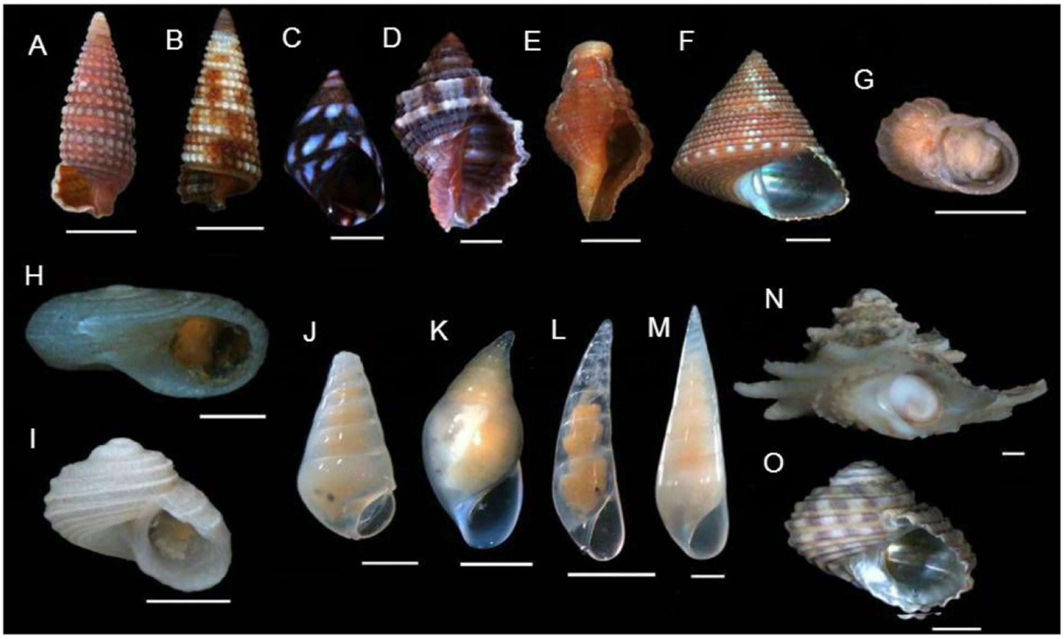

Figure 4. Photomicrographs of the gastropod species collected in *Sargassum* sp. beds from the São Sebastião Channel, Caraguatatuba and Ubatuba. Triphoridae: *Marshallora nigrocincta* (A), *Nototriphora decorata* (B). Littorinidae: *Echinolittorina lineolata* (C). Muricidae: *Stramonita brasiliensis* (D) and *Muricopsis necocheana* (E). Calliostomatidae: *Calliostoma* sp. (F). Scissurellidae: *Scissurella alexandrei* (G). Tornidae: *Circulus* cf. *liratus* (H) and *Parviturboides interruptus* (I). Eulimidae: *Melanella* cf. *eulimoides* (J), *Vitreolina arcuata* (K), *Vitreolina* sp. (L), *Melanella eburnea* (M). Turbinidae: *Lithopoma phoebium* (N) and *Tegula viridula* (O). **Scale bars: 1000um for A-F and K-O; 500um for G-J.**

In terms of abundance, the predominance of a few families is remarkable: specimens of Cerithiidae, Phasianellidae and Columbellidae are the most numerous, representing altogether 84% of the total number of individuals. This is mainly caused by the fact that *Eulithidium affine* (C. B. Adams, 1850) (the single Phasianellidae) and *Bittiolum varium* (Pfeiffer, 1840) (Cerithiidae) are the best represented species (4630 and 4642 specimens, respectively), followed by *Mitrella dichroa* (G. B. Sowerby I, 1844) (n=813), *Anachis fenneli* Radwin, 1968 (n=626) and *Costoanachis sertulariarium* (d'Orbigny, 1839)

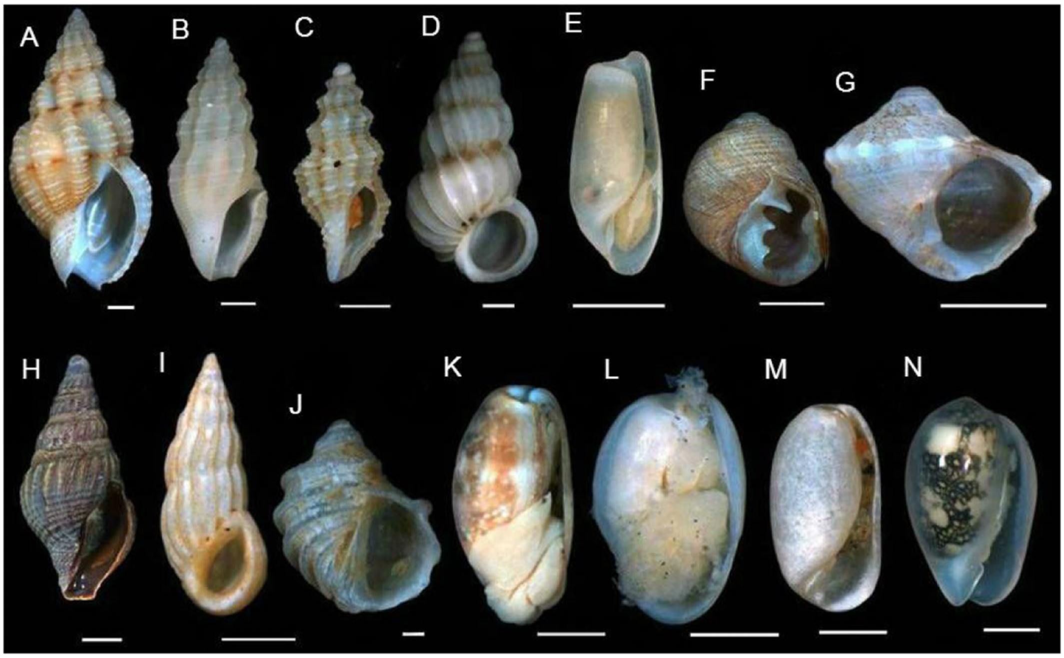

Figure 5. Gastropod species collected in *Sargassum* sp. beds from the São Sebastião Channel, Caraguatatuba and Ubatuba. Nassariidae: *Nassarius albus* (A). Mangellidae: *Tenaturris fulgens* (B) and *Glyphoturris rugirima* (C). Epitoniidae: *Epitonium* cf. *worsfoldi* (D). Retusidae: *Pyrunculus caelatus* (E). Ellobiidae: *Pedipes mirabilis* (F). Modulidae: *Modulus modulus* (G). Pseudomelatomidae: *Crassispira* cf. *fuscescens* (H). Rissoinidae: *Schwartziella bryerea* (I). Planaxidae: *Fossarus ambiguus* (J). Bullidae: *Bulla occidentalis* (K). Haminoeidae: *Haminoea antillarum* (L). Cylichnidae: *Cylichna discus* (M). Marginellidae: *Volvarina* sp. (N). **Scale bars: 1000um for A-K; 500um for L-N.**

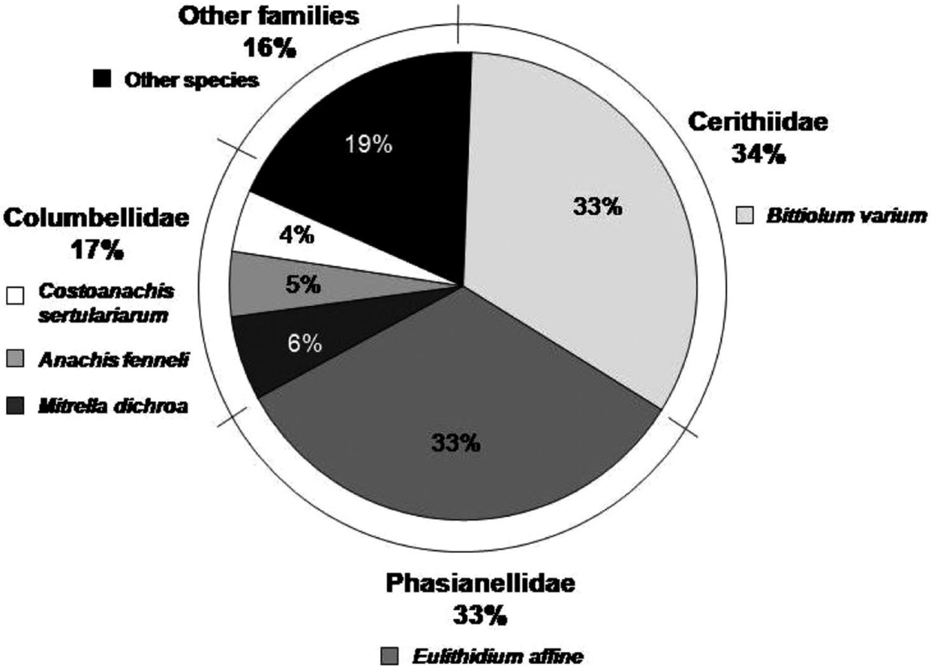

Figure 6. The most representative species and families, in terms of relative abundance of collected individuals.

(n=600) (Columbellidae). Apart from these abundant species, 57 species are responsible for 19% of the total number of individuals (Figure 6). Some of them were well collected, as *Caecum ryssotitum* de Folin, 1867, *Caecum brasilicum* de Folin, 1874 and *Alvania auberiana* (d'Orbigny, 1842), with 323, 294 and 302 individuals, respectively. Noteworthy is also the occurrence of *Costoanachis sparsa* (Reeve, 1859), *Anachis obesa* (Adams, 1845), *Fissurella rosea* (Gmelin, 1791), *Turbonilla multicostata* (C. B. Adams, 1850), *Rissoella ornata* Simone, 1995, *Alaba incerta* (d'Orbigny, 1841) and *Amphithalamus glabrus* Simone, 1996, each one represented by 100 to 200 specimens. Regarding the more rare species, 26 presented less than 10 specimens; for some species, most animals found are juveniles, as for *Cerithium atratum* (Born, 1778), *F. rosea*, *T. multicostata*, *Stramonita brasiliensis* Claremont & D. G. Reid, 2011, *Calliostoma* sp. and *Bulla occidentalis* A. Adams, 1850.

Discussion

Expressive values for both number of species and individuals were found for the Gastropoda assemblages studied herein. Similar records had already been found for phytal assemblages of other algae species and from other localities (Montouchet 1979, Schézy & Paula 2000, Chemello & Milazzo 2002, Jacobucci & Leite 2002, Jacobucci et al. 2006, Almeida 2007, Leite et al. 2009, Veras 2011). Many families identified in this work, including the most abundant ones (Cerithiidae, Phasianellidae and Columbellidae) have recurrent records in general phytal studies already developed in Brazil (Montouchet 1979, Jacobucci et al. 2006, Almeida 2007, Leite et al. 2009, Veras 2011).

The two most abundant species, *B. varium* and *E. affine*, exhibit similar feeding habits: they graze algae surface and feed on the perifiton settled on the fronds (Marcus & Marcus 1960, Montfrans et al.1982). The following most abundant species, the columbelllids *M. dichroa* and *A. fenneli*, on the other hand, are both carnivorous species (Radwin 1977). The Pyramidellidae and the Eulimidae, with eight and four species, respectively, are known as parasites of other invertebrates (Warén 1983, Wise 1996). This diversity in the feeding habits is notorious throughout all the species, and indicates that the *Sargassum* sp. beds are a highly heterogeneous environment, which provides a great variety of food sources for its associated species. This should be expected, since *Sargassum* species are already known as having a high structural complexity (Széchy & Paula 2000).

Among the least abundant species (< 50 specimens), some of them are known to occur in phytal habitats, *e.g. Columbella mercatoria* (Linnaeus, 1758), *Schwartziella bryerea* (Montagu, 1803), *Finella dubia* (d'Orbigny, 1840), *Seila adamsii* (H. C. Lea, 1845), *Assiminea succinea* (Pfeiffer, 1840), *Nototriphora decorata* (C. B. Adams, 1850) and *Glyphoturris rugirima* (Dall, 1889) (Rios 2009). On the other hand, a few species found are typical from other habitats like rocky shores or soft bottoms, *e.g. Echinolittorina lineolata* (d'Orbigny, 1840), *S. brasiliensis*, *Calliostoma* sp., *Melanella eburnea* (Mühlfeld, 1824) and *Tegula viridula* (Gmelin, 1791). In this last case, the occurrence of most species in the *Sargassum* sp. beds can be considered as fortuitous, whilst in the former case, those species can be characterized as rare, even though they can be considered typical in this habitat. In both cases, and also for many of the more numerous species, it is notable the presence of juvenile forms. This may be an indicator that the seaweed beds are a favorable environment for the development of these gastropods, due to the many benefits provided by the algae, which can act as a nursery for many species.

The gastropod assemblages stand out, therefore, as an important component of the associated fauna of the *Sargassum* sp. beds in São Sebastião Channel, northern coast of São Paulo. However, studies describing the composition and dynamics of these phytal assemblages are still scarce, especially the ones developed in Brazil. A higher and more detailed knowledge of these assemblages are an important step for a better understanding and conservation of these environments.

Acknowledgements

We wish to thank FAPESP, for the financing support of the senior author (Proc. 2012/09374-8); G. B. Jacobucci, M. L. L. de Moraes and S. G. L. Siqueira for performing the collections, as well as the technicians from CEBIMar – USP for the help and support during the collecting process; P. V. F. Corrêa for the edition of the map; and A. D. Pimenta, J. H. Leal, L. Souza, M. Fernandes, R. Figueira and S. F. B. de Lima for the help during the identification process.

References

ABBOTT, R.T. 1974. American Seashells. 2 ed. Index, New York.

ABSALÃO, R.S. & PIMENTA, A.D. 1999. *Turbonilla* (Gastropoda: Pyramidellidae) species described by Katharine Jeannette Bush: scanning electron microscope studies of the type material in the Academy of Natural Sciences of Philadelphia. Proc. Acad. Nat. Sci. Philadelphia 149:77-91.

ABSALÃO, R.S. & PIMENTA, A.D. 2005. Moluscos marinhos da APA do Arquipélago de Santana, Macaé, RJ: chave ilustrada para identificação das espécies do substrato inconsolidado. Ciência Moderna, Rio de Janeiro.

ABSALÃO, R.S., PIMENTA, A.D. & CAETANO, C.H.S. 2005. Turridae (Mollusca, Neogastropoda, Conoidea) coletados no litoral sudeste do Brasil, Programa Revizee "Score" Central. Biociências 13(1):19-47.

ALMEIDA, S.M. 2007. Malacofauna associada ao fital de *Sargassum* spp. no Pontal do Cupe, Ipojuca, PE. Dissertação de Mestrado, Universidade Federal de Pernambuco, Pernambuco.

BANDEL, K. 1996. Phylogeny of the Caecidae (Caenogastropoda). Mitt. Geol. - Palaeontol. Inst. Univ. Hamb. 79:53-15.

BUSH, K.J. 1899. Descriptions of new species of *Turbonilla* of the Western Atlantic fauna, with notes on those previously known. Proc. Acad. Nat. Sci. Philadelphia 51(1):145-177.

CHEMELLO, R. & MILAZZO, M. 2002. Effect of algal architecture on associated fauna: some evidence from phytal molluscs. Mar. biol. 140:981-990, http://dx.doi.org/10.1007/s00227-002-0777-x

CLAREMONT, M., WILLIAMS, S.T., BARRACLOUGH, T.G. & REID, D.G. 2011. The geographic scale of speciation in a marine snail with high dispersal potential. J. biogeogr. 38:1016-1032, http://dx.doi.org/10.1111/j.1365-2699.2011.02482.x

DORNELLAS, A.P.S. 2012. Description of a new species of *Calliostoma* (Gastropoda, Calliostomatidae) from Southeastern Brazil. ZooKeys. 224:89-106, http://dx.doi.org/10.3897/zookeys.224.3684

FALLON, P.J. 2011. Descriptions and illustrations of some new and poorly known turrids (Turridae) of the Tropical northwestern Atlantic.Part 2. Genus *Crassispira* Swainson, 1840 subgenera *Monilispira* Bartsch and Rehderm, 1939 and Dallspira Bartsch, 1950. Nautilus 125(1):15-28.

FERNANDES, M.R., PIMENTA, A.D. & LEAL, J.H. 2013. Taxonomic review of Triphorinae (Gastropoda: Triphoridae) from the Vitória-Trindade Seamount Chain, southeastern Brazil. Nautilus 127(1):1-18.

GOMES, R.S. & ABSALÃO, R.S. 1996. Lista comentada e ilustrada dos Caecidae (Mollusca, Prosobranchia, Mesograstropoda) da operação oceanográfica GEOMAR XII. Rev. Bras. Zool. 13(2):513-531, http://dx.doi.org/10.1590/S0101-81751996000200019

HOUBRICK, R.S. 1977. Reevaluation and new description of the genus *Bittium* (Cerithiidae). Veliger 20:101-106.

HOUBRICK, R.S. 1980. Observations on the anatomy and life history of *Modulus modulus* (Prosobranchia: Modulidae). Malacologia 20(1):117-142.

HOUBRICK, R.S. 1987. Anatomy of *Alaba* and *Litiopa* (Prosobranchia: Litiopidae); Systematic Implications. Nautilus 101(1): 9-18.

HOUBRICK, R.S. 1990. Anatomy, reproductive biology and systematic position of *Fossarus ambiguus* (Linné) (Fossariinae: Planaxidae; Prosobranchia). Açoreana 1990:59-73.

HOUBRICK, R.S. 1993. Phylogenetic relationships and generic review of the Bittiinae (Prosobranchia: Cerithioidea). Malacologia 35(2): 261-313.

JACOBUCCI, G.B., GÜTH, A.Z., TURRA, A., MAGALHÃES, C.A., DENADAI, R., CHAVES, A.M.R. & SOUZA, E.C. 2006. Levantamento de Mollusca, Crustacea e Echinodermata associados a *Sargassum* spp. na Ilha de Queimada Pequena, Estação Ecológica dos Tupiniquins, litoral sul do estado de São Paulo, Brasil.

JACOBUCCI, G.B. & LEITE, F.P.P. 2002. Distribuição vertical e flutuação sazonal da macrofauna vágil associada a *Sargassum cymosum* C. Agardh, na praia do Lázaro, Ubatuba, São Paulo, Brasil. Rev. Bras. Zool. 19(1):87–100, http://dx.doi.org/10.1590/S0101-81752002000500004

LEITE, F.P.P., TAMBOURGI, M.R.S. & CUNHA, C.M. 2009. Gastropods associated with the green seaweed *Caulerpa racemosa*, on two beaches of the Nothern coast of the State of São Paulo, Brazil. Strombus 16(1-2):1–10.

MALAQUIAS, M.A.E. & REID, D.G. 2008. Systematic revision of the living species of Bullidae (Mollusca: Gastropoda: Cephalaspidea), with a molecular phylogenetic analysis. Zool. j. Linn. Soc. 153:453–543, http://dx.doi.org/10.1111/j.1096-3642.2008.00369.x

MARCUS, E. 1970. Opisthobranchs from Northern Brazil. Bull. mar. sci. 20(4):922–951.

MARCUS, E. & MARCUS, E. 1960. Studies on *Tricolia affinis cruenta*. Bol. Fac. Fil. C. Let. Univ. São Paulo, Zoologia. 23:171–198.

MARCUS, E. & MARCUS, E. 1962. Studies on Columbellidae. Bol. Fac. Fil. C. Let. Univ. São Paulo, Zoologia 24:335–401.

MARCUS, E. & MARCUS, E. 1964. On *Cerithium atratum* (Born, 1778) (Gastropoda: Prosobranchia). Bull. mar. sci. 14(3):494–510.

MARCUS, E. & MARCUS, E. 1965. On Brazilian supratidal and estuarine snails. Bol. Fac. Fil. C. Let. Univ. São Paulo, Zoologia. 25:19–82.

MATTHEWS, H.R. 1968. Notas sobre a família Nassariidae no nordeste brasileiro (Mollusca: Gastropoda). Arq. Estac. Biol. Mar. Univ. Fed. Ceara. 8(2):141–143.

MONTFRANS, J.V., ORTH, R.J. & VAY, S.A. 1982. Preliminary studies of grazing by *Bittium varium* on eelgrass periphyton. Aquat, bot. 14:75–89, http://dx.doi.org/10.1016/0304-3770(82)90087-0

MONTOUCHET, P.C. 1979. Sur La communauté dês animaux vagiles associés à Sargassum cymosum C. Agardh, à Ubatuba, Etat de São Paulo, Brésil. Stud Neotrop Fauna Environ. 14:33–64, http://dx.doi.org/10.1080/01650527909360546

MELLO, R.D.L.S. 1986. A família Caecidae Gray, 1850 no nordeste do Brasil. Cad. omega, Ser. cienc. aquat. 2:145–166

MELLO, R.L.S. 1990. Gastropoda: Opisthobranchia: Pyramidellidae Gray, 1840 da América do Sul, litoral nordeste do Brasil. Caatinga 7:38–43.

MONTOUCHET, P.C. 1972. Three new species of Scissurellidae (Gastropoda, Prosobranchia) from the coast of Brazil. Bol. Inst. Oceanogr. 21:1-13, http://dx.doi.org/10.1590/S0373-55241972000100001

PEREIRA, P.H.C., BIASI, P.C. & JACOBUCCI, G.B. 2010. Dinâmica populacional e distribuição espacial de *Tricolia affinis* (Mollusca: Gastropoda) associados a *Sargassum* spp. no litoral norte de São Paulo. Rev. bras. zoocienc. 12(1):7–16.

PIMENTA, A.D. 2012. Four new species and two new records of Odostomiinae (Gastropoda: Pyramidellidae) from Brazil. Zoologia 29(5):439–450

PIMENTA, A.D. & ABSALÃO, R.S. 2004. Review of the genera *Eulimastoma* Bartsch, 1916 and *Egila* Dall & Bartsch, 1904 (Mollusca, Gastropoda, Pyramidellidae) from Brazil. Zoosystema 26(2):157–173.

PIMENTA, A.D., ABSALÃO, R.S. & MIYAJI, C. 2009. A taxonomic review of the genera *Boonea*, *Chrysallida*, *Parthenina*, *Ivara*, *Fargoa*, *Mumiola*, *Odostomella* and *Trabecula* (Gastropoda, Pyramidellidae, Odostomiinae) from Brazil. Zootaxa 2049:39–66.

PIMENTA, A.D., SANTOS, F.N. & ABSALÃO, R.S. 2008. Review of the Genera *Ividia*, *Folinella*, *Oscilla*, *Pseudoscilla*, *Tryptichus* and *Peristichia* (Gastropoda, Pyramidellidae) from Brazil, with descriptions of four new Species. Veliger 50(3):171–184.

QUEIROZ, V., SOUZA, L.S., PIMENTA, A.D. & CUNHA, C.M. 2013. New host records of *Melanella* (Caenogastropoda: Eulimidae) from the Brazilian coast. Marine Biodiversity Records 6:1–5.

QUINN, J.F. 1992. New species of *Calliostoma* Swainson, 1840 (Gastropoda: Trochidae), and notes on some poorly known species from the Western Atlantic Ocean. Nautilus 106(3):77–114.

RADWIN, G.E. 1968. New taxa of Western Atlantic Columbellidae (Gastropoda, Prosobranchia). Proc. Biol. Soc. Wash. 81:143–150.

RADWIN, G.E. 1977. The family Columbellidae in the Western Atlantic. Veliger 19(4):403–417.

REYNOSO-GRANADOS, T., MONSALVO-SPENCER, P., SERVIERE-ZARAGOZA, E. & PRÓO, S.A.G. 2007. Larval and early juvenile development of the volcano keyhole limpet, *Fissurella volcano*. J. shellfish. res. 26(1):65–70.

RIGHI, G. 1965. Sôbre algumas Fissurellidae Brasileiras. An. Acad. Bras. Cienc. 37(3):539–550.

RIOS, E.C. 1985. Seashells of Brazil. Museu Oceanográfico da FURG, Rio Grande.

RIOS, E.C. 2009. Compendium of Brazilian Seashells. Evangraf, Rio Grande.

ROBERTSON, R. 1958. The family Phasianellidae in the Western Atlantic. Johnsonia 3(37):245–283.

ROBERTSON, R. 1993. The new tropical Western Atlantic species of *Epitonium*, with notes on similar global species and natural history. Nautilus 107(3):81–93.

RÓLAN, E. & ESPINOSA, J. 1995. The family Cerithiopsidae (Mollusca: Gastropoda) in Cuba 3. The genus *Cerithiopsis* s. l., species with brown shells. Iberus 13(2):129–147.

RÓLAN, E. & FERNANDES, F. 1990. The Genus *Seila* A. Adams, 1861 (Mollusca, Gastropoda, Cerithiopsidae) in the Atlantic Ocean. Apex 5(3/4):17–30.

SASAKI, T. 1998. Comparative anatomy and phylogeny of the recent Archaeogastropoda (Mollusca: Gastropoda). Bulletin/The Univ. museum, the Univ. of Tokyo 38:1–15.

SIMONE, L.R.L. 1995. A new *Amphithalamus* Carpenter, 1864 species (Gastropoda, Rissoidae, Barleeidae) from the Brazilian coast. J. conchol. 35:329–333.

SIMONE, L.R.L. 1995. *Rissoella ornata*, a new species of Rissoellidae (Mollusca: Gastropoda: Rissoelloidea) from the southeastern coast of Brazil. Proc. Biol. Soc. Wash. 108(4):560-567.

SIMONE, L.R.L. 2001. Phylogenetic analyses of Cerithioidea (Mollusca, Caenogastropoda) based on comparative morphology. Arq. Zool. 36(2):147–263, http://dx.doi.org/10.11606/issn.2176-7793.v36i2p147-263

SPENCER, R.S. & CAMPBELL, L.D. 1987. The fauna and paleoecology of the late Pleistocene marine sediments of southeastern Virginia. Bull. am. paleontol. 92(327):1-106.

SZÉCHY, M.T.M. & PAULA, E.J. 2000. Padrões estruturais quantitativos de bancos de *Sargassum* Phaeophyta, Fucales) do litoral dos estados do Rio de Janeiro e São Paulo, Brasil. Rev. Bras. Bot. 23(2):121–132, http://dx.doi.org/10.1590/S0100-84042000000200002

VERAS, D.R.A. 2011. Moluscos associados à macroalga *Pterocladiella caerulescens* (Rhodophyta, Pterocladiaceae) na zona entremarés da praia da Pedra Rachada, Paracuru, Ceará, Nordeste do Brasil. Dissertação de Mestrado, Universidade Federal do Ceará, Ceará.

WARÉN, A. 1983. A generic revision of the family Eulimidae (Gastropoda, Prosobranchia). J. molluscan stud. Suppl. 13. 49:1–96, http://dx.doi.org/10.1093/mollus/49.Supplement_13.1

WILLIAMS, S.T. 2007. Origins and diversification of Indo-West Pacific marine fauna: evolutionary history and biogeography of turban shells (Gastropoda, Turbinidae). Biol, J, Linnean Soc. 92:573–592, http://dx.doi.org/10.1111/j.1095-8312.2007.00854.x

WILLIAMS, S.T., KARUBE, S. & OZAWA, T. 2008. Molecular systematic of Vetigastropoda: Trochidae, Turbinidae and Trochoidea redefined. Zool. scr. 37(5):483–506, http://dx.doi.org/10.1111/j.1463-6409.2008.00341.x

WISE, J.B. 1996. Morphology and phylogenetic relationships of certain pyramidellid taxa (Heterobranchia). Malacologia 37(2):443–511.

Received 23/07/2014
Revised 08/10/2014
Accepted 09/10/2014

Biota Neotropica 14(4): e20140018, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Zooplankton communities as eutrophication bioindicators in tropical reservoirs

Antonio José Gazonato Neto[1,2]***, Lidiane Cristina da Silva***[1]***, Angelo Augusto Saggio***[1] ***& Odete Rocha***[1]

[1] *Departamento de Ecologia e Biologia Evolutiva, Universidade Federal de São Carlos, Via Washington Luiz Km 235, CEP 13565-905, São Carlos, SP, Brazil.*
[2] *Corresponding author: Antonio José Gazonato Neto, e-mail: neto_gazonato@hotmail.com*

GAZONATO NETO, A.J., SILVA, L.C., SAGGIO, A.A., ROCHA, O **Zooplankton communities as eutrophication bioindicators in tropical reservoirs.** Biota Neotropica. 14(4): e20140018. http://dx.doi.org/10.1590/1676-06032014001814

Abstract: Eutrophication is a process characterized by an increase in the aquatic system productivity, which causes profound changes in the structure of its communities. Owing to the high environmental sensitivity of planktonic species, the study of their communities can indicate the deterioration of the environment. The Jaguari and Jacareí reservoirs are part of the Cantareira System, supplying water to São Paulo inhabitants and that has been affected by several forms of continuous human interference. Here we analyze some properties of the zooplankton community as bioindicators of eutrophication and water quality change. *In situ* physical and chemical measurements were carried out, water was collected for analysis and quantitative zooplankton samples were taken at eight sites in the two reservoirs, in both seasons, dry and rainy. Species were identified and their numerical abundances and biomasses were determined and used to estimate two biological indices. The overall trophic state and zooplankton structure, the Calanoida/Cyclopoida ratio and the *k*-dominance curves were associated with the disturbance levels, mainly represented by nutrient river inputs and by water level fluctuations. The Jaguari Reservoir was more eutrophicated than the Jacareí Reservoir, as evidenced by the obtained indices values. The zooplankton community properties used as indicators of the reservoir trophic state were useful monitoring tools.
Keywords: *zooplankton, ABC curves, Calanoida/Cyclopoida ratio, Cantareira System, environmental impact.*

GAZONATO NETO, A.J., SILVA, L.C., SAGGIO, A.A., ROCHA, O **Comunidades zooplanctônicas como bioindicadoras de eutrofização em reservatórios tropicais.** Biota Neotropica. 14(4): e20140018. http://dx.doi.org/10.1590/1676-06032014001814

Resumo: A eutrofização é um processo caracterizado pelo aumento da produtividade do sistema aquático, o que provoca profundas alterações na estrutura de suas comunidades. Devido à alta sensibilidade ambiental das espécies planctônicas, o estudo de suas comunidades pode indicar a deterioração do ambiente. Os reservatórios Jaguari e Jacareí são parte do Sistema Cantareira, que fornece água para os habitantes de São Paulo e que tem sido afetado por diversas formas de contínua interferência humana. Neste trabalho vamos analisar algumas propriedades da comunidade zooplanctônica como bioindicadoras de eutrofização e alteração da qualidade da água. Foram realizadas medições *in situ* de variáveis físicas e químicas, amostras de água foram coletadas para análises e amostras quantitativas de zooplâncton foram coletadas em oito localidades compreendendo os dois reservatórios, em duas estações, seca e chuvosa. As espécies foram identificadas e suas abundâncias numéricas e biomassas foram determinadas e utilizadas para estimar dois índices biológicos. O estado trófico e a estrututa do zooplâncton, a relação Calanoida / Cyclopoida e as curvas de k-dominância foram associados com os níveis de perturbação, representada principalmente pela entrada de nutrientes transportados pelo rio e pelas flutuações no nível da água. O Reservatório Jaguari se encontrava mais eutrofizado do que o Reservatório Jacareí, como evidenciado pelos índices obtidos. As propriedades da comunidade zooplanctônica utilizadas como indicadoras do estado trófico dos reservatórios foram úteis como ferramentas de monitoramento.
Palavras-chave: *Zooplankton, curvas ABC, razão Calanoida/Cyclopoida, Sistema Cantareira, impacto ambiental.*

Introduction

Eutrophication is a detrimental process that can occur in aquatic ecosystems characterized by the enrichment of nutrients, mainly nitrogen and phosphorus, leading to increased productivity of the system (Serafim-Júnior 2010). This process causes changes in communities that may threaten the conservation of aquatic species and, because it is generally associated with some type of pollution, also poses risks to all living beings that directly or indirectly make use of the contaminated water or consume the organisms.

Such an alteration in the trophic state of a water body usually causes profound changes in the structure of plankton communities (Matsumura-Tundisi & Tundisi 2005), which is the reason why the interpretation of biological events in these populations and qualitative and quantitative analysis of their structures allows the degree of deterioration of the water body as a whole to be assessed (Pinto-Coelho et al. 2005, Silva 2011).

Characteristically, the zooplankton community is composed of highly sensitive organisms that respond to a large number of environmental changes in relatively short periods of time. Moreover, because this community is more developed in lentic aquatic systems, studies of its structure and population dynamics can be very useful tools in the analysis of the environmental disturbances to which these water bodies are subjected (Sampaio et al. 2002, Eskinazi-Sant'anna 2013).

An increase in zooplankton biomass has been related by many authors to a rising level of eutrophication, since, to a large extent, a higher trophic state will lead to increased resource availability, which, in turn, leads to growth in the biomass of zooplankton populations (Serafim-Júnior et al. 2010, Bonecker et al. 2007).

Besides recording biomass as a quantitative parameter, another community property used to indicate the trophic condition of the water body is the set of ratios between component populations of the zooplankton (rotifers, copepods and cladocerans) given that these ratios are also affected by eutrophication (Sampaio et al. 2002, Sendacz et al. 2006, Bini et al. 2007).

Studies performed by Gannon & Stemberger (1978) and Tundisi (1988) have associated lower proportions of calanoid to cyclopoid copepods and cladocerans with eutrophic environments. One generalization usually made in relation to zooplankton size structure and trophic state of water bodies is that species with larger bodies such as Calanoida (predominantly herbivores), occur primarily in oligotrophic environments, where there is a predominance of nanophytoplankton (Hillbricht-Ilkowska 1977, Echevarria et al. 1990), whereas the Cyclopoida occur at higher density in meso-eutrophic environments, owing to their ability to handle larger food particles (Pace 1986, Santos-Wisniewski & Rocha 2007). Water quality in tropical reservoirs can also be indicated by using specific species of cyclopoid as indicators (Silva, 2011).

The aim of this study was to relate the zooplankton communities structure with the trophic state and chemical and physical water properties of the Jaguari and Jacareí reservoirs, through the analysis of spatial and temporal changes in numerical abundance and biomass of the community as a whole and in the proportion of bioindicator groups.

Material and Methods

1. *Study area*

The Jaguari and Jacareí reservoirs, located at 22°92'33.78" S and 46°41'74.94" W (Figure 1), are interconnected and part of Cantareira System, considered one of the largest water-supply systems in the world. In 2008, this system supplied a major portion of the population of the São Paulo Metropolitan Region, the most populous urban area in Brazil, with approximately 8.8 million people. The Jaguari-Jacareí system provides 45% of the water in the Cantareira System, used entirely for the purpose of supplying water (ISA 2007).

Changes in the land use and occupation of the surrounding area, essentially rural in the 1970s, but now occupied by residential developments and leisure activities reflected in the deterioration of the water quality in some of the main tributaries of the basin. The environmental monitoring of the Cantareira system detected two eutrophic sites on the Jaguari River and a hypereutrophic site on the Jacareí River, both with trend towards increasing eutrophication over time (ISA 2007). Despite a great increase in organic pollution in the Jacareí River, the Jacareí Reservoir has remained oligotrophic at most points, owing possibly to the dilution caused by the large volume of water stored in this reservoir and by the low residence time of the water.

2. *Sampling and Data Analysis*

In situ physical and chemical measurements, water samples for analysis and quantitative zooplankton samples were taken at eight points in the two reservoirs (Figure 1), three in the Jaguari and five in the Jacareí Reservoir. The geographical location of these points was determined with a Garmin GPS, model 130 SOUNDER. Samples were collected in two seasons and contrasting water levels, due to the operation of the reservoirs (outflow control), one in August 2012 (dry season and high water level) and another in March 2013 (rainy season and low water level). All measurements and samplings were carried out in the interval between 9 a.m. and 4 p.m.

The transparency of the water column checked by readings of the Secchi Disk and depth measurements were performed. The extent of the euphotic zone was calculated by multiplying the Secchi depth reading by the factor 3.0. The pH, electrical conductivity ($\mu S\ cm^{-1}$), dissolved oxygen concentration ($mg\ L^{-1}$) and temperature of the water (°C) were measured with a HORIBA U-10 multisensor. Data were collected every 0.5 or 1.0 m according to the sampling point depth.

Data on rainfall and air temperature were retrieved from the website of the Brazilian National Institute of Meteorology (INMET - http://www.inmet.gov.br), based on readings at the meteorological station of Monte Verde, MG, the closest to the reservoirs.

The spectrophotometric methods used for the analysis of nutrients were those described by Golterman et al. (1978) and Mackereth et al. (1978).

The trophic state was assessed in terms of the index proposed by Carlson (1977) and modified by Lamparelli (2004), based on the variables: water transparency measured by Secchi disk readings (S), chlorophyll *a* concentration (Chl), total phosphorus (P) and dissolved inorganic phosphate (PO_4), using the formula $TSI = TSI(S) + 2\,[TSI(P) + TSI(PO_4) + TSI(Chl)] / 7$.

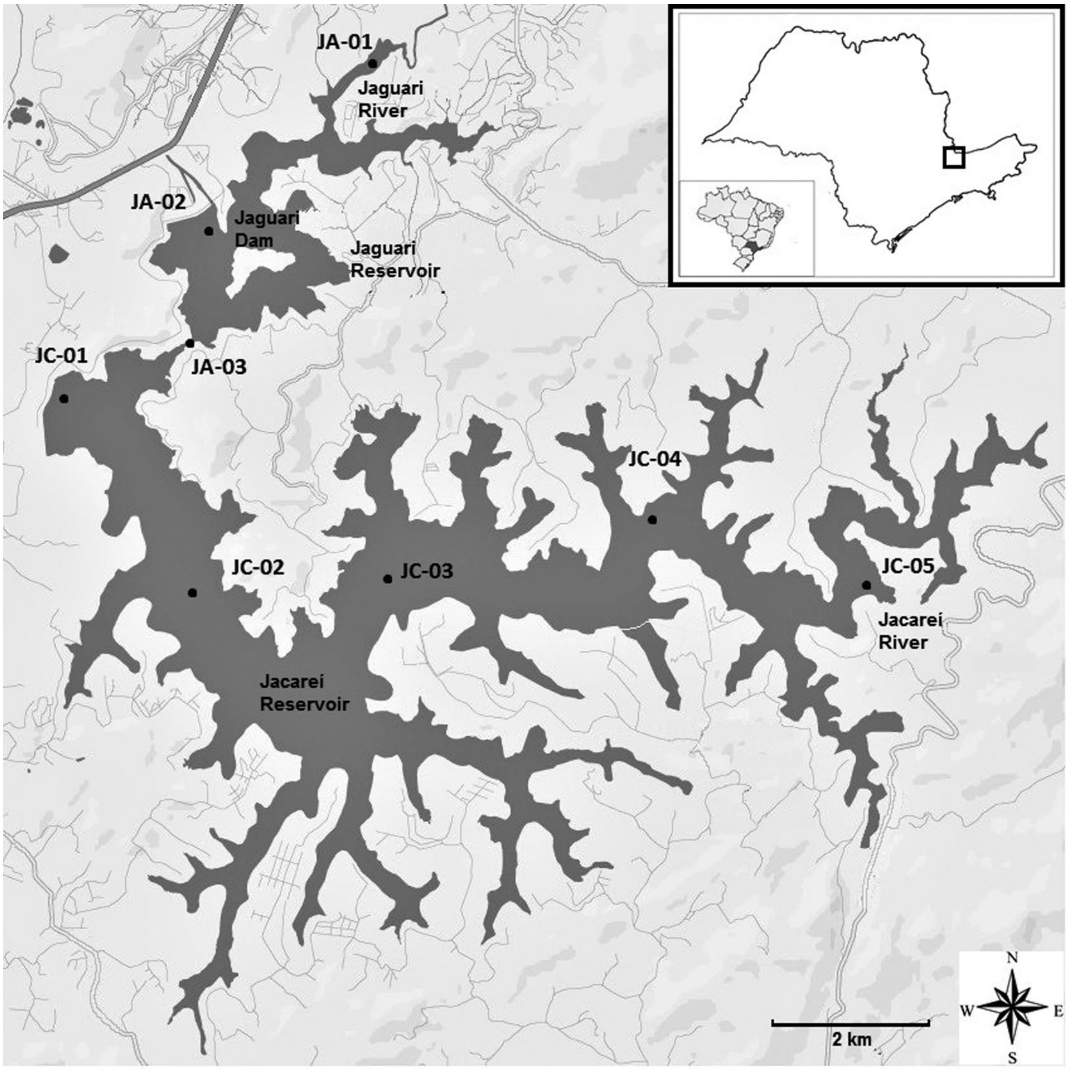

Figure 1. Maps of Jaguari and Jacareí Reservoirs and inset their location in the state of São Paulo, showing the eight sampling sites in the reservoirs. Geographic coordinates: 22°92'33.78''S and 46°41'74.94'' W (Modified from: Google Earth, 2013). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

Chlorophyll concentrations were determined by extraction with 90% acetone, as described in Golterman et al. (1978). Calculations were carried out as indicated by Nush et al. (1980).

Semi-quantitative samples of zooplankton were collected using plankton net of 68 μm mesh aperture, by vertical hauls. The collected volume of water was calculated by multiplying the area of the net mouth by the trawl depth. After sampling, the material was preserved in 4% formaldehyde solution.

The zooplankton were identified to genus or species level under a Zeiss® microscope with camera lucida and magnification up to 1,000 times, and had their sizes measured by a computerized image acquisition system. For taxonomic identification, dissections were performed, slides mounted and the following keys and specialized bibliography were used: Edmondson 1959, Koste 1978, Reid 1985, Nogrady et al. 1993, Elmoor-Loureiro 1997, Nogrady & Segers 2002, Segers & Shiel 2003, Silva & Matsumura-Tundisi 2005.

To determine the numerical abundance of each taxon, samples were analyzed in a gridded acrylic plate under a stereoscopic Leica® MZ6 microscope at 50 times magnification. Counts were performed on subsamples of variable size, according to species abundance, and for the least abundant species the count was performed on the whole sample. For the Rotifera species and for Copepoda nauplii, subsamples of 1 mL were counted in a Sedgewick-Rafter chamber under an optical microscope, at up to 1,000 times magnification. Once identified and counted, population densities were calculated and expressed as number of individuals per cubic meter of water (ind.m^{-3}).

Body size measurements (about 20 individuals of each species or genus per sample) were made under an optical microscope with an ocular micrometer and together with corresponding population density data, were used to estimate the biomass, expressed in μg of dry weight per cubic meter (μg dw.m^{3}).

Biomasses of Cladocera and Copepoda were calculated with the standard linear equation for the double logarithmic regression proposed by Bottrell et al. (1976), which relates the body length (mm) of individuals in a given taxonomic group (Cladocera and Copepoda) to their dry weight (μg).

The following equations were used: $\ln W = 1.7512 + 2.6530 \ln L$ for cladocerans and $\ln W = 1.9526 + 2.3990 \ln L$ for copepods.

The biomass of each group (Cladocera or Copepoda) was calculated as the sum of the biomass of individual populations. Copepoda was subdivided into two sub-groups, *viz.* the sub-orders Calanoida and Cyclopoida.

The biomass of Rotifera species was determined by the technique described by Ruttner-Kolisko (1977), in which the biovolume is calculated by specific formulas for the geometrical shape closest to the shape of each species or developmental phase.

Two indices were used as biological indicators of the trophic state of the reservoir or disturbances in particular compartments of the reservoirs.

The first was the ratio CA/CY (Calanoida/Cyclopoida) between the numerical densities of populations belonging to the sub-orders Calanoida and Cyclopoida, which was assessed as a possible bioindicator of the trophic state in the various portions of the reservoirs.

The second index was the shape of the ABC curves (Warwick, 1986) representing the accumulated numerical abundance and biomass of all populations present in a given community, which can be an indicator of environmental perturbation. The W parameter of the ABC curves was obtained from the expression $W = \Sigma (Bi-Ai) / [50 (S-1)]$, where Bi is the biomass value of each sequence of species (i) on the ABC curve, Ai is the abundance of each sequence of species (i) on the ABC curve and S is the number of species. This index allows the degree of disturbance of these environments to be expressed quantitatively. Positive values indicate an undisturbed environment; negative values suggest disturbed communities and values near zero indicate moderate disorders: the value of W can range from -1 to 1.

To compare species diversity between the sampled sites in the Jaguari and Jacareí reservoirs, the following indices were calculated: Richness (number of taxa recorded), Shannon-Wiener diversity index (H'), Dominance index (D') and Evenness or Pielou Equitability index (J).

The beta diversity, that informs the heterogeneity of the sampled stations relative to the species richness, was estimated from the β-1 index of Harrison et al. (1992).

The Canonical Correspondence Analysis (CCA) was employed to seek correlations between the environmental variables and the density and biomass of zooplankton groups, through the CANOCO 3:12 program (Ter Braak & Šmilauer 2002). During the analysis, the significance of correlation between environmental and biotic parameters was tested by a Monte Carlo test with 999 random permutations, and $p \leq 0.5$ as the criterion of significance.

Results

In August 2012, the rainfall values (mm) were the lowest in that year, since from mid July until the first sampling date (August) there was very little precipitation (1 mm) and given that in the three months before this sampling the total precipitation in the reservoirs was 363 mm. The second sampling, conducted at the beginning of March 2013, reflected the large amount of rain that had fallen since October 2012, with a rainfall of 938 mm recorded in the three months preceding the data gathering, of which 335 mm was from the previous month. The lowest air temperatures (°C) in the year 2012 were recorded in the period between May and October with an average of 14°C in the previous three months to the first collection. From the end of October until March 2013, the average temperature in the three months before the second sampling was higher, being 20°C.

According to data provided by the water authority, SABESP, the maximum operational volume of both reservoirs working in a coupled mode is 1047.9 hm^3. In August 2012 (low rainfall and high water level), the volume of this operating system reached 73.81% of the maximum capacity, while in March 2013 (high rainfall and low water level) it was 59.19%. The average flow rate for the dry period was 31.5 m^3/s and, for the rainy season, 24.9 m^3/s, resulting in residence times of 284 and 288 days, respectively.

Table 1 presents the values of physical and chemical variables measured at various points in the Jaguari and Jacareí reservoirs. It was found that seven of the eight sampling sites had lower trophic state indices in the dry than in the rainy season. At the first sampling, seven of the eight points were characterized as oligotrophic (TSI ≤ 44) and only one point, located in the Jaguari reservoir, was mesotrophic (TSI range = 44 to 54). In the second sampling, however, five sites were

Table 1. Values of Trophic State Index (TSI) of Carlson, modified by Lamparelli, 2004, chlorophyll *a*, total phosphorus and total nitrogen concentrations, pH, electrical conductivity, dissolved oxygen, water temperature, depth of the water column and the Secchi disk with their respective standard deviations, recorded at the sampling sites in Jaguari (JA) and Jacareí (JC) Reservoirs, in August 2012 (dry) and March 2013 (rainy season). The numbers following the abbreviations JC and JA refer to the first (1) and second (2) sampling.

Environ. Variables – Site / Sampling	Measurement Unit	JA/1	JC/1	JA/2	JC/2
TSI	-	42.7 ± 7.04	33.0 ± 4.47	60.7 ± 6.55	38.4 ± 3.07
Chl a	μg/L	3.1 ± 0.33	3.4 ± 0,52	22.8 ± 15.73	3.1 ± 2.00
Total P	μg/L	32 ± 17.78	28 ± 11.60	135 ± 42.01	25 ± 4.02
Total N	μg/L	548 ± 77.19	491 ± 82.00	463 ± 262.11	545 ± 45.58
pH	-	6.5 ± 0.75	6.9 ± 0.83	6.9 ± 1.49	6.4 ± 0.90
Elec.Cond.	μS.cm-1	28.2 ± 1.18	27.4 ± 0.70	22.4 ± 1.25	22.1 ± 0.50
DO	mg.L-1	8.0 ± 1.29	8.2 ± 1.26	6.7 ± 3,47	7.4 ± 1.71
Temp.	°C	18.2 ± 1.53	19.4 ± 0.77	23.6 ± 2.27	25.1 ± 0.98
Depth	m	10.0 ± 5.92	16.8 ± 5.74	13.8 ± 11.52	16.5 ± 6.71
Secchi	m	2.8 ± 1.11	3.8 ± 0.12	0.5 ± 0.18	2.5 ± 0.38

classified as oligotrophic, all located in the Jacareí reservoir, while among the three located in the Jaguari reservoir, one site was mesotrophic and two were eutrophic (TSI range = 54 to 74).

It was observed that in the dry period, the amplitude of variation in the nutrient concentrations in the reservoirs was lower than in the rainy season. In the latter period, there were higher peaks of phosphorus, chlorophyll *a* and total nitrogen concentrations in the Jaguari Reservoir. Also in this reservoir there was a fall in Secchi Disk depth readings in the second sampling.

The dissolved oxygen concentrations in the water recorded in the dry period ranged between 7.1 and 9.1 mg L^{-1}, while in the rainy season the range was lower, from 5.6 to 8.7 mg $L^{-1.}$ The electrical conductivity of the water ranged between 26.7 and 30.4 $\mu S.cm^{-1}$ in the dry season and between 21 and 23.5 $\mu S.cm^{-1}$ in the rainy. In the rainy season the average temperature was higher at all points, while the pH decreased at six points, relative to the dry season.

Total densities of zooplankton and also those of each group are shown in Figures 2a and 2b, for the dry and rainy periods, respectively. In general, densities were higher in samples collected in August 2012, with the exception of site JA-01, in which density was also high in March 2013, owing the large numbers of cyclopoid copepods. It was also observed that rotifers were numerically dominant at seven of the eight sites in the samples collected during the dry season, while in the rainy season this occurred at only three points and numbers were generally lower.

Figures 2c and 2d present the biomass values for total zooplankton and for each component group. It can be observed that in the dry season (Figure 2c), the total biomass of zooplankton was higher at sites JA-01 and JA-02, but lower at point JC-03. In the samples taken during the rainy season

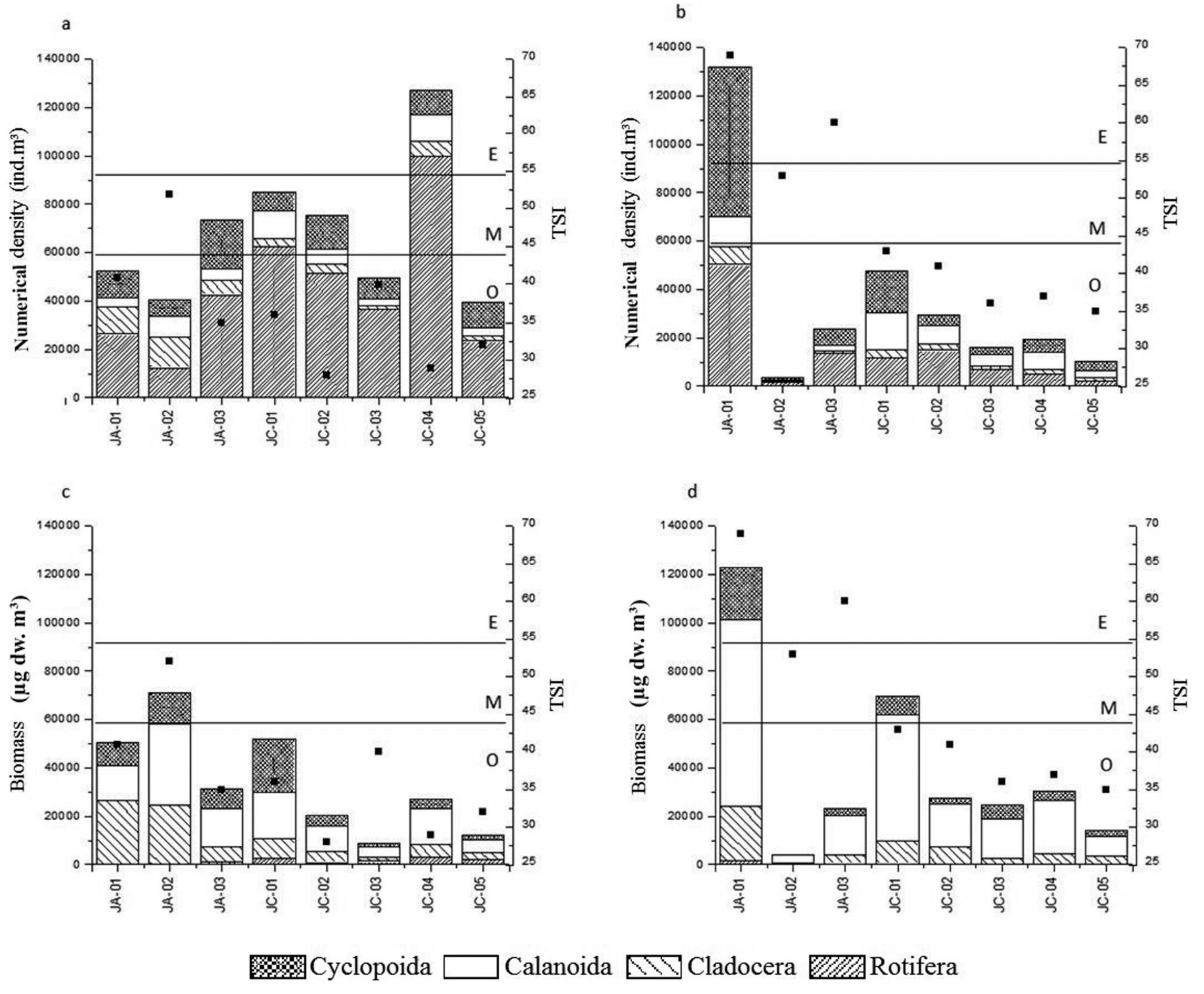

Figure 2. Values of total numerical density (ind.m^{-3}) and total biomass (µg dw. m^3) of the main components of the zooplankton community groups and values of trophic state index at the sampling sites in the Jaguari and Jacareí reservoirs, SP, during Aug 2012 (dry season) and Mar 2013 (rainy season). a) Density in August 2012, b) Density in March 2013, c) Biomass in August 2012, d) Biomass in March 2013 (O = oligotrophic, M = mesotrophic, E = eutrophic). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

Table 2. Values of the components of diversity (species richness and evenness) and the Shannon-Wiener Diversity and Dominance Indices for zooplankton species in the Jaguari and Jacareí reservoirs during Aug 2012 (dry season) and Mar 2013 (rainy season). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

1st sampling	JA-01	JA-02	JA-03	JC-01	JC-02	JC-03	JC-04	JC-05
Richness	13	13	18	19	21	18	21	20
Dominance	0.62	0.39	0.24	0.16	0.16	0.20	0.17	0.18
Shannon-Wiener	0.95	1.56	1.91	2.15	2.06	1.81	1.97	2.06
Evenness	0.37	0.60	0.66	0.73	0.68	0.63	0.65	0.69
2nd sampling	**JA-01**	**JA-02**	**JA-03**	**JC-01**	**JC-02**	**JC-03**	**JC-04**	**JC-05**
Richness	18	5	12	16	13	11	18	20
Dominance	0.14	0.38	0.24	0.13	0.40	0.14	0.12	0.14
Shannon-Wiener	2.43	1.11	1.78	2.39	1.51	2.15	2.47	2.46
Evenness	0.84	0.69	0.71	0.86	0.59	0.90	0.85	0.82

(Figure 2d), the total biomass was high at site JA-01, close to the influx of the Jaguari river.

The highest biomass of cladocerans in the samples collected in August 2012 (low rainfall) occurred near the Jaguari river entry-point (JA-01 and JA-02), while in March 2013 (high rainfall), the biomass of this group was high only at JA-01. In the sampling carried out in March 2013, Calanoid copepods reached a higher biomass than in August 2012 at almost all sites and the highest biomass among all the taxonomic groups (Calanoida, Cyclopoida, Cladocera and Rotifera). Biomasses of all groups were highest at the most eutrophic point, JA -01. Unlike the numerical density, the biomass of Rotifera was the lowest of all groups of zooplankton at all sites in both seasons.

During the dry season, the lowest richness in Jaguari Reservoir was recorded in the upstream part of the Jaguari reservoir (JA-01, JA-02), with a total of 13 species, while at the other sampling sites richness varied between 18 and 21 species; dominance index values were 0.62 and 0.39 at JA-01 and JA-02, while at the remaining sites these ranged from 0.16 to 0.24. The equitability index at JA-01 was 0.37, the lowest value recorded, while at the other sites it ranged from 0.60 to 0.73. The Shannon-Wiener index for the zooplankton community was 0.95 at JA-01 and 1.56 at JA-02, while at other sites it varied from 1.81 to 2.15 (Table 2).

The heterogeneity value obtained through the beta diversity index was 15%, which reveals great similarity of the zooplankton diversity among the Jaguari and Jacarei reservoirs, especially among the Copepoda and the Cladocera; however, some differences were observed in the Rotifera taxonomic composition: seven species occurred only in the Jacareí reservoir (*Ascomorpha ecaudis*, *Asplanchna sieboldi*, *Keratella americana*, *Keratella lenzi*, *Conochillus dossuarius*, *Trichocerca similis* and *Conochillus coenobasis*), whereas the remainder occurred in both reservoirs, except for *Trichocerca Capuccina*, which occurred only in the Jaguari reservoir.

During the dry season, copepods of the order Cyclopoida were dominant at most sites, with values of the ratio CA/CY lower than 1.0. At the few sites where the dominance of the order Calanoida was observed, the numerical densities of both groups were similar resulting in values of the ratio close to 1.0 (Table 3).

In the rainy season, when a lower water level is maintained in the reservoir, the lowest values of the Calanoida / Cyclopoida ratio (close to 0.0) were obtained at the sites with the highest trophic state index in the Jaguari reservoir, indicating a decrease in the abundance of Calanoida copepods at these sites. At the remaining sites ratios near 1.0 were recorded; however, there was dominance of Calanoida Copepoda in some parts of the Jacareí reservoir, especially at JC-02, where the value of CA/CY was 1.94 (Table 3).

For zooplankton sampled in August 2012 (Figure 3) it is observed that, although the two ABC curves are close, the numerical abundance curve is located above the biomass curve at all sampling sites, indicating slightly disturbed environments, with intermediate conditions. For the sampling conducted in March 2013 (Figure 4), the biomass curve is located above the numerical abundance curve at most sites, indicating undisturbed environments, with the exception of JA-01 and JA-03, where the abundance curve practically covers the biomass curve ($w < 0.09$), suggesting that these are slightly disturbed habitats. In the dry season, it was found that all values of the W index were negative, ranging from -0.14 to -0.031, while in the rainy season, all values were positive and ranged from 0.01 to 0.3 (Figures 3 and 4).

In the CCA conducted relating the numerical density and the abiotic variables (Figure 5a) it was observed that the first two axes explained 77.9% of the data variability. There is a positive correlation between TSI, chlorophyll *a*, temperature and total phosphorus with the zooplankton groups Copepoda and Cladocera and also with the rainy period. On the other hand the numerical densities of Rotifera were positively correlated with the values of dissolved oxygen and total nitrogen and also with the dry period.

Regarding the CCA analysis applied to the biomass and environmental variables values (Figure 5b), the first two axes had an explicability of 53.6%. A positive correlation between the Copepoda biomass and the variables TSI, chlorophyll *a*,

Table 3. Calanoid:cyclopoid copepods density ratio (CA/CY) in zooplankton communities sampled in August 2012 (dry) and March 2013 (rainy season) in Jaguari (JA) and Jacareí (JC) reservoirs. The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

CA/CY RATIO	JA-01	JA-02	JA-03	JC-01	JC-02	JC-03	JC-04	JC-05
1st samp.	0.35	1.16	0.24	1.27	0.44	0.36	1.05	0.28
2nd samp.	0.20	0.38	0.30	0.85	1.94	1.38	1.36	0.79

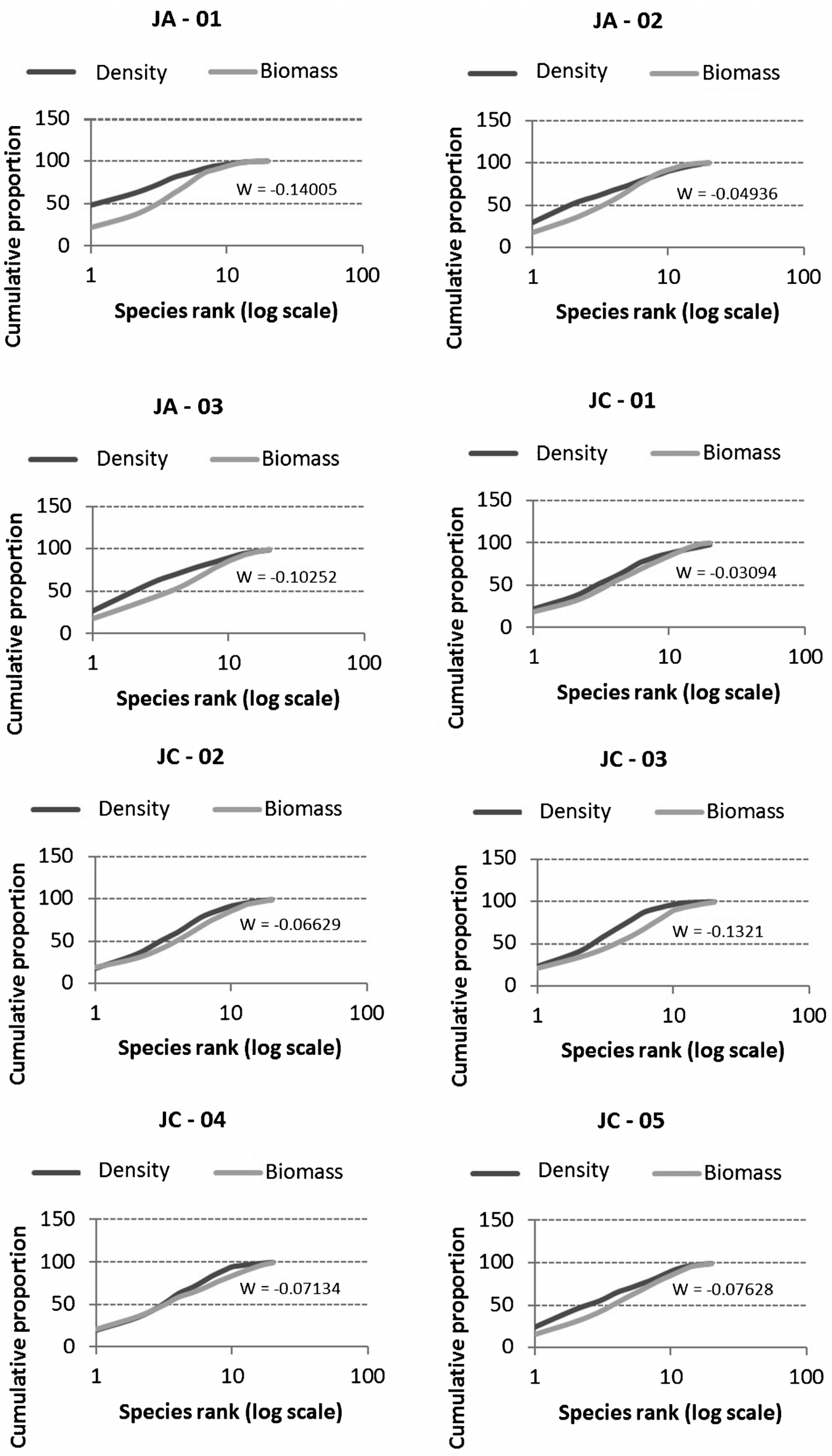

Figure 3. ABC curves comparing cumulative biomass and numerical abundance of all zooplankton taxa and their respective W index values for the zooplankton community at the various sampling sites in the Jaguari (JA) and Jacareí (JC) reservoirs during the dry season (August 2012). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

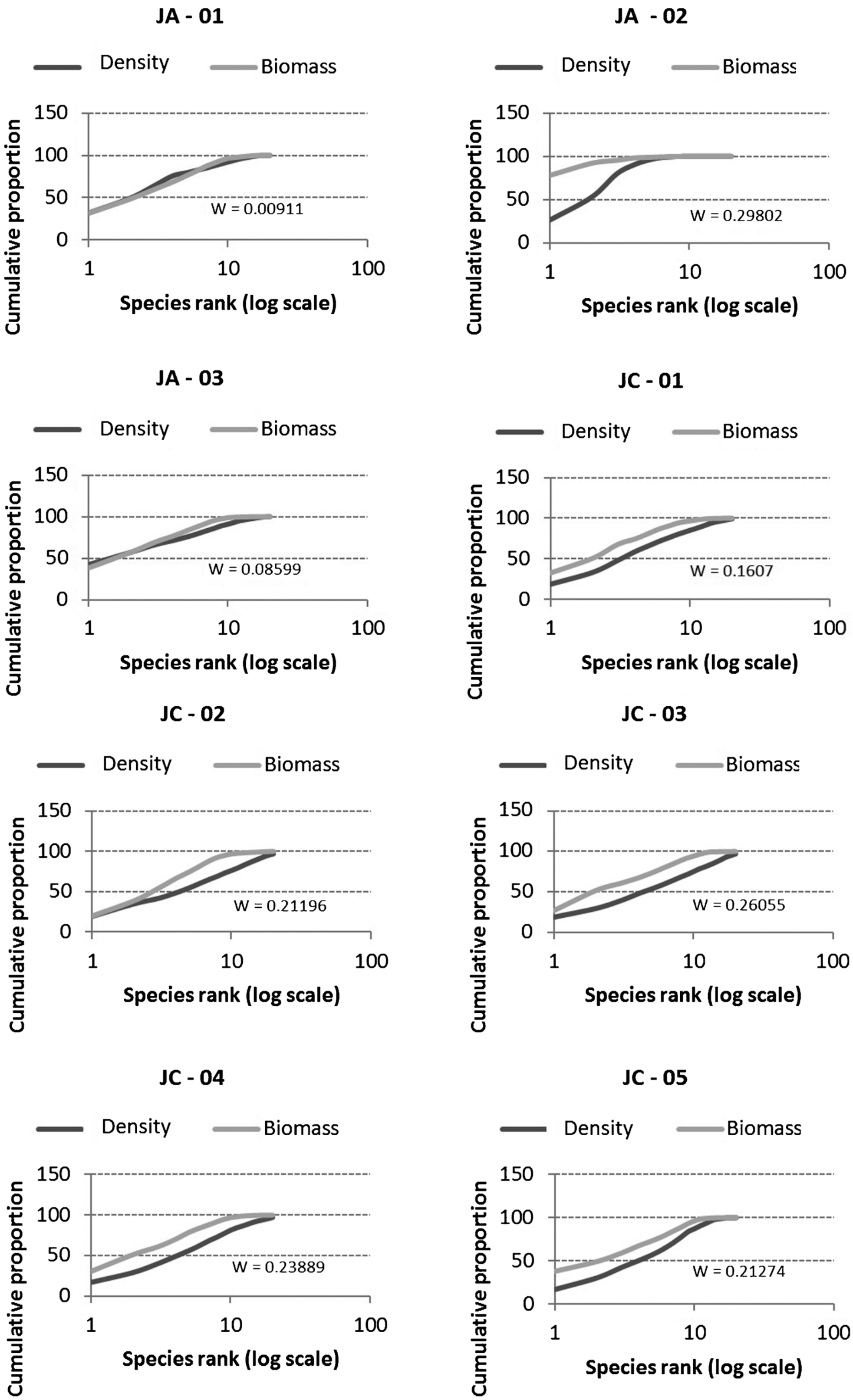

Figure 4. ABC curves comparing cumulative biomass and numerical abundance of all zooplankton taxa and their respective W index values for the zooplankton community at the various sampling sites in the Jaguari (JA) and Jacareí (JC) reservoirs during the rainy season (March 2013). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

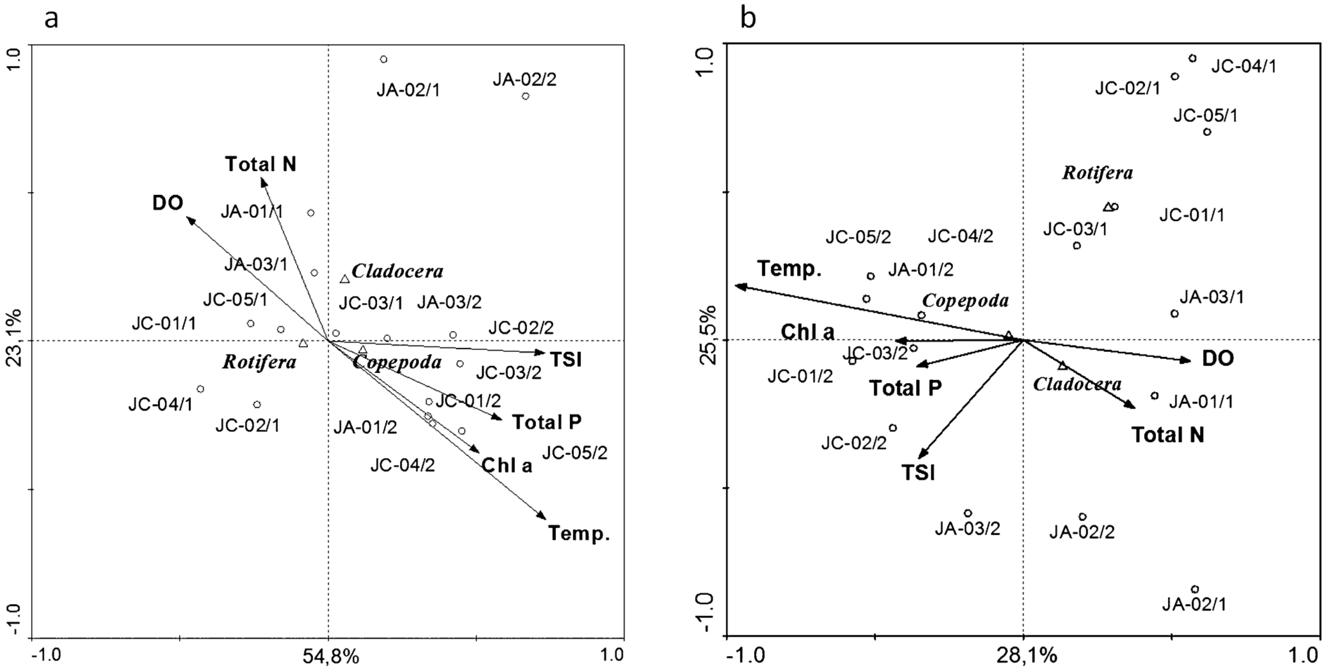

Figure 5. Canonical Correspondence Analysis applied to abiotic variables and a) numerical density and b) total biomass of zooplankton groups in the Jaguari (JA) and Jacareí (JC) reservoirs during the dry (August 2012) and rainy (March 2013) seasons (/1 – dry season; /2 – rainy season). The numbers following the abbreviations JC and JA refer to the numbering of the sampling sites.

total phosphorus and temperature was found. The biomasses of the Rotifera and Cladocera groups were correlated with the concentrations of total nitrogen and dissolved oxygen.

Discussion

Many Brazilian reservoirs undergo large annual fluctuations in the water level, partially determined by climatic forces but mainly by the operation of the dam. This was the case in Barra Bonita reservoir, the uppermost in the reservoir cascade along the Tietê River basin (Matsumura-Tundisi & Tundisi 2005). Its water level is fully controlled in order to regulate the levels in the downstream reservoirs, as well as the amount of hydroeletricity produced, one of the main zooplankton communities modifiers (Bini et al. 2007). A similar situation was observed in the Jaguari and Jacareí reservoirs in the present study, where, during the dry season, the reservoirs levels were high, reaching 73.81% of their maximum capacity, whereas in the rainy season they were only 59.19% full. Thus, the water level was more related to the changes in the amount of water extracted for the public supply than to the natural inputs from the catchment basin.

The increasing trophic state of Jaguari Reservoir (RJA) in the rainy season was evidenced by the increase in the concentration of chlorophyll *a* at two of the three sites sampled and the significant increase in the concentration of total phosphorus, due to the continuous inflow of the Jaguari River, which receives domestic untreated sewage and thus represents the main point source of pollution and disturbance in this reservoir (ISA 2007); the increase of eutrophication in the rainy period, as well the strong relationship between this increase with the total phosphorus and chlorophyll *a* concentrations was evidenced by both CCA analyses conducted. On the basis of these variables, this reservoir was classified as eutrophic in the rainy period.

At the sites located in the Jacareí reservoir (RJC), the values of TSI were relatively similar between the two sampling dates and RJC was classified as oligotrophic at all points. Although this reservoir receives the organically polluted waters of the Jacareí River, its much larger volume of water (compared to RJA) results in great dilution of the nutrients transported by the river and also carried in runoff from the disturbed catchment basin (ISA 2007).

The decrease in the water transparency (Secchi disk) in the rainy season is another indication of the increase in the trophic state of Jaguari Reservoir. However, the high inorganic turbidity of water in tropical reservoirs can, in some periods and depending on the activities occurring in the basin, affect the reliability of this measure of the trophic state, which should not be used alone (Mercante & Tucci-Moura 1999).

Zooplankton densities in the reservoirs were lower at seven of the eight sites sampled during the rainy season, possibly due to dilution by the greater volume of water and partially by the removal of populations by the downstream outflow (water extraction system operation). The only site at which a high density of zooplankton was found was near the entrance of the Jaguari river, probably reflecting the higher trophic conditions suggested by the high phosphorus and chlorophyll concentrations (TSI value = 69). The fall in zooplankton at the end of the rainy season has also been observed in other reservoirs, as in the Guarapiranga reservoir, by Sendacz et al. (2006), and the Barra Bonita reservoir, by Tundisi et al. (2008).

For the Jaguari and Jacareí reservoirs the highest concentrations of nutrients were observed during periods of high water level. Tundisi et al. (2008) indicated that, in the Barra Bonita reservoir, the highest concentration of nutrients occurs at the beginning of the rainfall, due to entrainment of soil particles from runoff and via tributaries; however, after some time, a diluting effect may occurs because of the increased volume of water, reducing the concentration of nutrients. This may explain why, despite the high rates of TSI during the rainy season, caused by the importing of nutrients, zooplankton communities have low densities, possibly due to dilution caused by excess rainfall.

A direct relationship was found between the values of zooplankton biomass and trophic levels in the reservoirs in both periods and at almost all sampling sites, except at JC-03 and JC-05 during the dry season, at which the high density of nauplii, possibly due to a reproductive peak, resulted in a lower copepod population biomass, and at JA-02 during the rainy season, which had low chlorophyll concentrations, suggesting that low food availability may have been a limiting factor for community growth, despite the high concentration of nitrogen, an indicator of the presence of sewage carried in the Jaguari river inflow. This close relationship between the values of biomass and TSI was also observed by Bonecker et al. (2007) in three reservoirs in Paraná State.

In the samplings carried out during the dry season, at seven of the eight points, there was a numerical dominance of rotifers, a relationship that is noticeably established by the CCA, not only by the numerical density, but also by the Rotifera biomass, which was strongly related to the dry period too. The dominance of rotifers at most sites is possibly a consequence of an unstable environment, which enhance r-strategists growth (Matsumura-Tundisi & Tundisi 2005). The higher biomass in both periods was associated with Copepoda Calanoida, except at the main river entrance points JA-01 and JC-01, a feature expected for oligotrophic water bodies, as reported by Pinto-Coelho et al. (2005), who concluded that the Calanoida are good indicators of oligotrophy.

In contrast, in the meso-eutrophic Guarapiranga Reservoir Sendacz et al. (2006) reported that the Cyclopoida were the main contributors to the biomass in the reservoir during the dry period, a fact commonly observed in other eutrophic Brazilian reservoirs, like Barra Bonita, SP (Santos-Wisniewski & Rocha 2007).

Under the more eutrophic conditions of sites JA-01 and JA-02 during the dry season and JA-01 during the rainy season, the highest cladoceran biomasses were observed, a response similar to that reported by Bonecker et al. (2007) and Serafim-Júnior et al. (2010) that observed an increase in Cladocera biomass and abundance at points with highest trophic state condition. This strong relationship between the Cladocera and the most eutrophic period and variables, like total phosphorus and chlorophyll *a*, is evidenced by the CCA.

The values of the four diversity related indices reflected the disturbance caused by the Jaguari River nutrient input on the zooplankton community at the sites located in the upper portion of the reservoir, especially during the dry season, indicating the imbalance in the community concerned. In the Jacareí reservoir, on the other hand, there are lower levels of dominance and higher values of evenness and Shannon-Wiener index, indicating a less disturbed body of water, possibly due to the greater volume of water in this reservoir .The values found for the richness of species in the zooplankton communities of the Jaguari and Jacareí reservoirs were low compared to those reported by Silva (2011) whereas the evenness of species populations found in this study was high compared to those obtained by the same author.

The taxonomic differences observed for Rotifera between the reservoirs is possibly due to the greater spatial heterogeneity observed in the Jacareí reservoir, which may bear a higher number of species, especially rotifers, that have a short life cycle, fast adaptation to environmental variations and higher turnover rates, which makes them a more representative group in freshwater environments and good indicators of the trophic level in these environments (Serafim-Júnior et al. 2010, Bini et al. 2007). Besides these characteristics the lowest trophic level of the Jacareí reservoir allows greater taxonomic diversity.

The zooplankton community structure did change with the changes of trophic conditions over the reservoirs. Relative numbers and biomass of Calanoids decreased and those of Cyclopoids increased at sites under more eutrophic conditions, thus resulting in lower values of Calanoida-Cyclopoida ratios. This pattern has been reported before for other Brazilian reservoirs (Tundisi 1988, Santos-Wisniewski & Rocha 2007, Sendacz et al. 2006) and elsewhere for both, tropical, and subtropical water bodies (Pace 1986, Caramujo & Boavida 2000), namely that the presence of calanoid copepods relates to a low trophic level in the habitat, while cyclopoid copepods are favored in the more productive areas of higher trophic state. The higher proportion of calanoids in oligotrophic waters is due to the herbivorous-filter feeding habit of most species belonging to this group, especially in adulthood; and such feeding is based on nano-phytoplankton, which is replaced by micro-phytoplankton in environments of higher trophic state. In eutrophic environments, with the fall in the population density of Calanoida, we observe the dominance of Cyclopoida, which are mostly carnivorous and prey on smaller species of Rotifera and Cladocera, usually more abundant at higher levels of nutrients (Matsumura-Tundisi & Tundisi 1976, Nogueira 2001).

The k-dominance curves for the zooplankton community in the different compartments of the Jaguari and Jacareí reservoirs indicated that during the dry season this environment was disturbed or polluted, since the numerical density curve was raised above the biomass curve, especially at sites located in the Jaguari reservoir, possibly because the low rainfall augmented the constant supply of nutrients from the Jaguari river. For the zooplankton sampled in the rainy season, the raising of the biomass curve over the density at most sites, indicates that the environment was undisturbed, which is probably due to the dilution caused by the rains and the dam operation. A similar result was observed by Arantes-Júnior (2011) in his study of the zooplankton community in the Madeira river in various hydrological cycles, where the numerical curves were raised in most samples collected during periods of low water and flooding (with lower depths, low light and high concentrations of suspended solids). However, during periods of high depth and rates of flow due to high rainfall, the biomass curves overlapped, indicating lower disturbance than in other periods.

In the rainy season, however, the *k*-dominance curves obtained for the zooplankton at the Jaguari river entrance and at the downstream compartment (sites JA-01 and JA-03) show an overlapping of the lines, indicating moderate perturbation, resulting from the constant supply of nutrients coming from the river Jaguari and consequent eutrophication, corroborated by the corresponding trophic indices.

Regarding the values of W, it was found that in the dry period this parameter was negative, suggesting a disturbed environment, while in the rainy season, the positive values of W indicate that the environment was undisturbed, or, in the case of JA-01 and JA-03, in an intermediate condition (Warwick

1986). Sonoda (2011) also applied these parameters to microcrustaceans in the Tropeiros lake and found that near the littoral zone the numerical curve was above the biomass curve and the value of W negative, indicating a community in a disturbed habitat. For the limnetic region, the biomass curve was higher than the numeric curve and W was positive, indicating that the community environment was undisturbed. The author explains that the region near the land suffers greater outside influence and, being a shallower region, it may be affected more by turbulence, due to sediment suspension, besides other factors.

In the case of Jaguari and Jacareí reservoirs, the main disturbances were due to the combined effects of two factors: eutrophication and controlled changes in the water level due to variations in the water extraction.

In conclusion, it can be seen that biological indices can be used to assess the effects of various environmental disorders, which alter the number and biomass of the zooplankton in a similar manner.

Acknowledgments

We thank CAPES (Coordination for the Improvement of Higher Education Personnel) for the grant to the first author and SABESP (Sanitation and Water Supply Company of São Paulo State) for research financial support and local infrastructure.

References

ARANTES-JUNIOR, J.D. 2011. Estudo limnológico de um trecho do médio Rio Madeira (região de Porto Velho - RO), com ênfase na comunidade zooplanctônica. Tese de doutorado, Universidade Federal de São Carlos, São Carlos.

BINI, L.M., VIEIRA, L.C.G., MACHADO, J. & VELHO, L.F.M. 2007. Concordance of Species Composition Patterns among Microcrustaceans, Rotifers and Testate Amoebae in a Shallow Pond. Hydrobiologia 92(1):9–22, http://dx.doi.org/10.1002/iroh.200610865

BONECKER, C.C., NAGAE, M.Y., BLETLLER, M.C.M., VELHO, L.F.M. & LANSAC-TÔHA, F.A. 2007. Zooplankton biomass in tropical reservoirs in southern Brazil. Hydrobiologia 579(1):115–123, http://dx.doi.org/10.1007/s10750-006-0391-x

BOTTRELL, H.H., DUNCAN, A., GLIWICZ, Z., GRYGIEREK, E., HERZIG, A., HILLBRICHT-ILKOWSKA, A., KURASAWA, H., LARSSON, P. & WEGLENSKA, T.A. 1976. Review of some problems in zooplankton production studies. Norw. J. Zoo 24:419–456.

CARAMUJO, M.J. & BOAVIDA, M.J. 2000. The crustaceans communities of River Tagus Reservoirs, zooplankton structure as reservoir trophic state indicator. Limnetica 18:37–56.

CARLSON, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr 22(2):361–369, http://dx.doi.org/10.4319/lo.1977.22.2.0361

ECHEVARRIA, F., CARRILO, F.J., SANCHEZ-CASTILLO, P., CRUZ-PIZARRO, L. & RODRIGUES, J. 1990. The size-abundance distribution and taxonomic composition of plankton in a oligotrophic, high mountain lake (La Caldera, Sierra Nevada, Spain). J. Plankton Res 12(2):415–422, http://dx.doi.org/10.1093/plankt/12.2.415

EDMONDSON, W.T. 1959. Freshwater Biology. 2 ed. John Wiley & Sons Inc, New York.

ELMOOR-LOUREIRO, L.M. 1997. Manual de identificação de Cladóceros límnicos do Brasil. Ed. Universa, Brasília.

ESKINAZI-SANTANNA, E.M., MENEZES, R., COSTA, I.S., ARAÚJO, M., PANOSSO, R. & ATTAYDE, J.L. 2013. Zooplankton assemblages in eutrophic reservoirs of the Brazilian semi-arid. Braz. J. Biol 73(1):37–52, http://dx.doi.org/10.1590/S1519-69842013000100006

GANNON, J.E. & STEMBERGER, R. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. T. Am. Microsc. Soc 97:16–35, http://dx.doi.org/10.2307/3225681

GOLTERMAN, H.L., CLYMO, R.S. & OHNSTAD, M.A.M. 1978. Methods for physical and chemical analysis of freshwaters. 2 ed. Blackwell Scientific Publications, Oxford.

HARRISON, S., ROSS, S.J. & LAWTON, J.H. 1992. Beta diversity on geographic gradients in Britain. J. Anim. Ecol 62:151–158, http://dx.doi.org/10.2307/5518

HILLBRICHT–ILKOWSKA, A. 1977. Trophic relations and energy flow in pelagic plankton. Pol. Ecol. Stud.

INMET – Instituto Nacional de Meteorologia. http://www.inmet.gov.br (accessed in 01/07/2013)

ISA – INSTITUTO SÓCIO AMBIENTAL. 2007. Um olhar sobre o maior manancial de água da Região Metropolitana de São Paulo – Resultados do diagnóstico socioambiental participativo do Sistema Cantareira. São Paulo.

KOSTE, W. 1978. Rotatoria die radertiere mitteleuropas, Übeiordnung Monogononta. Berlim: Gebriider Bernträger.

LAMPARELLI, M.C. 2004. Grau de trofia em corpos d'água do Estado de São Paulo: avaliação dos métodos de monitoramento. Tese de doutorado, Universidade de São Paulo, São Paulo.

MACKERETH, F.J.H., HERON, J. & TALLING, J.F. 1978. Water analysis: some revised methods for limnologists. 2 ed. Freshwater Biological Association, Michigan.

MATSUMURA-TUNDISI, T. & TUNDISI, J.G. 1976. Plankton studies in a lacustrine environment. Oecologia 25(3):265–270, http://dx.doi.org/10.1007/BF00345103

MATSUMURA-TUNDISI, T. & TUNDISI, J.G. 2005. Plankton richness in a eutrophic reservoir (Barra Bonita Reservoir, SP, Brazil). Hydrobiologia 542(1):367–378, http://dx.doi.org/10.1007/s10750-004-9461-0

MERCANTE, C.T.J. & TUCCI-MOURA, A. 1999. Comparação entre os índices de Carlson e de Carlson modificado aplicados a dois ambientes aquáticos subtropicais, São Paulo, SP. Acta Limnol. Bras. 11(1):1–14.

NOGRADY, T. & SEGERS, H. 2002. The Asplanchnidae, Gastropodidae, Lindiidae, Microcodinidae, Synchaetidae, Trochosphaeridae. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. Backhuys Publishers BV, DordrechtThe Netherlands.

NOGRADY, T., WALLACE, R.L. & SNELL, T.W. 1993. Rotifera: biology, ecology and systematic. In Guides to the identification of the microinvertebrates of the continental waters of the world (DUMONT, H.J.F., ed.). Netherlands: SPB Academic Publishing, v.1, p.1–142.

NOGUEIRA, M.G. 2001. Zooplankton composition, dominance and abundance as indicators of environmental compartmentalization in Jurumirim Reservoir (Paranapanema River), São Paulo, Brasil. Hydrobiologia 455(1–3):1–18, http://dx.doi.org/10.1023/A:1011946708757

NUSH, E.A. 1980. Comparison of different methods for chlorophyll and phaeopigments determination. Hydrobiologia 14:14–36.

PACE, M.L. 1986. An empirical analysis of zooplankton community size structure across lake trophic gradients. Limnol. Oceanogr 31(1):45–55, http://dx.doi.org/10.4319/lo.1986.31.1.0045

PINTO-COELHO, R.M., BEZERRA-NETO, J.F. & MORAIS-JR, C.A. 2005. Effects of eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. Braz. J. Biol 65(2):325–338.

REID, J.W. 1985. Chave de identificação para as espécies continentais sulamericanas de vida livre da Ordem Cyclopoida (Crustacea, Copepoda). Universidade de São Paulo, São Paulo.

RUTTNER-KOLISKO, A. 1977. Suggestions for biomass calculation of plankton rotifers. Arch. Hydrobiol 8(7):1–76.

SABESP – Companhia de Saneamento Básico do Estado de São Paulo. http://www.sabesp.com.br (accessed in 01/07/2013)

SAMPAIO, E.V., MATSUMURA-TUNDISI, T. & TUNDISI, J.G. 2002. Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brasil. Braz. J. Biol 62(3):525–545, http://dx.doi.org/10.1590/S1519-69842002000300018

SANTOS-WISNIEWSKI, M.J. & ROCHA, O. 2007. Spatial distribution and secondary production of Copepoda in a tropical reservoir: Barra Bonita, SP, Brazil. Braz. J. Biol. 67(2):223–233, http://dx.doi.org/10.1590/S1519-69842007000200007

SEGERS, H. & SHIEL, R.J. 2003. Microfaunal diversity in a biodiversity hotspot: new rotifers from Southwestern Australia. Zool. Stud 42(4):516–521.

SENDACZ, S., CALEFFI, S. & SANTOS-SOARES, J. 2006. Zooplankton biomass of reservoirs in different trophic conditions in the State of São Paulo, Brasil. Braz. J. Biol 66(1b):337–350, http://dx.doi.org/10.1590/S1519-69842006000200016

SERAFIM-JÚNIOR, M., PERBICHE-NEVES, G., DE BRITO,L., GHIDINI, A.R. & CASANOVA, S.M. 2010. Variação espaço-temporal de Rotifera em um reservatório eutrofizado no sul do Brasil. Iheringia Ser. Zool 100(3):233–241.

SILVA, W.M. 2011. Potential use of Cyclopoida (Crustacea, Copepoda) as trophic state indicators in tropical reservoirs. Oecologia 15(3):511–521, http://dx.doi.org/10.4257/oeco.2011.1503.06

SILVA, W.M. & MATSUMURA-TUNDISI, T. 2005. Taxonomy, ecology, and geographical distribution of the species of the genus *Thermocyclops Kiefer*, 1927 (Copepoda, Cyclopoida) in São Paulo state, Brazil, with description of a new species. Braz. J. Biol 65(3):521–531.

SONODA, S.L. 2011. Transposição e fragmentação do Rio Piumhi (Bacia do rio São Francisco, MG): Variáveis Limnológicas e Microcrustáceos zooplanctônicos da Lagoa dos Tropeiros. Tese de doutorado, Universidade Federal de São Carlos, São Carlos.

TER BRAAK, C.J.F. & ŠMILAUER, P. 2002. Canoco reference manual and CanoDraw for Windows user's guide: software for canonical community ordination. Microcomputer Power, Ithaca, New York.

TUNDISI, J.G. 1988. Limnologia e manejo de represas. Universidade de São Paulo, São Paulo.

TUNDISI, J.G., MATSUMURA-TUNDISI, T. & ABE, D.S. 2008. The ecological dynamics of Barra Bonita (Tietê River, SP, Brazil) reservoir: implications for its biodiversity. Braz. J. Biol 68(4):1079–1098, http://dx.doi.org/10.1590/S1519-69842008000500015

WARWICK, R.M. 1986. A new method for detecting pollution effects on marine macrobenthic communities. Mar. Biol 92(4):557–562, http://dx.doi.org/10.1007/BF00392515

Received 04/02/2014
Revised 07/11/2014
Accepted 19/11/2014

Biota Neotropica 14(4): e20130079, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Five new species of Ectobiidae (Blattodea) collected in the Reserva Ducke, Amazonas, Brazil

Sonia Maria Lopes[1,3]***, Edivar Heeren de Oliveira***[1] ***& Vitor Tarli***[2]

[1]*Departamento de Entomologia do Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.*
[2]*Instituto Nacional de Pesquisas da Amazonia, Manaus, AM, Brazil.*
[3]*Corresponding author: Sonia Maria Lopes, e-mail: sonialfraga@gmail.com*

LOPES, S.M., OLIVEIRA, E.H., TARLI, V. **Five new species of Ectobiidae (Blattodea) collected in the Reserva Ducke, Amazonas, Brazil.** Biota Neotropica. 14(4): e20130079. http://dx.doi.org/10.1590/1676-06032014007913

Abstract: Herein we describe five new species of the Ectobiidae subfamilies Pseudophyllodromiinae (*Amazonina spiculata* sp. nov., *Amazonina spinostylata* sp. nov**.**, *Cariblatta duckeniana* sp. nov., *Cariblatta manauensis* sp. nov.) and Nyctiborinae (*Nyctibora nigra* sp. nov.), collected in the Reserva Ducke, Manaus, state of Amazonas. The specimens were collected from litter, fallen logs, branches, and foliage. We illustrate the male genitalia of the new species.
Keywords: *Blattaria, Nyctiborinae, Pseudophyllodromiinae, Taxonomy, Leaf litter.*

LOPES, S.M., OLIVEIRA, E.H., TARLI, V. **Cinco espécies novas de Ectobiidae (Blattodea) coletados na Reserva Ducke, Amazonas, Brasil.** Biota Neotropica. 14(4): e20130079. http://dx.doi.org/10.1590/1676-06032014007913

Resumo: Neste trabalho são descritas cinco novas espécies das subfamílias Pseudophyllodromiinae (*Amazonina spiculata* sp. nov., *Amazonina spinostylata* sp. nov**.**, *Cariblatta duckeniana* sp. nov., *Cariblatta manauensis* sp. nov.) and Nyctiborinae (*Nyctibora nigra* sp. nov.) coletadas na Reserva Ducke, Manaus (Estado do Amazonas). Os espécimens foram coletados em folhiço, troncos caídos, ramos e folhagens. Foram ilustradas as genitálias dos machos das novas espécies.
Palavras-chave: *Blattaria, Nyctiborinae, Pseudophyllodromiinae, Taxonomia, Folhiços.*

Introduction

The specimens of Blattodea presented herein were collected in the Reserva Ducke, Manaus, state of Amazonas, and belong to the family Ectobiidae. Most ectobiid species are small in size compared to blaberids and many blattids. They are usually long-legged and very fast-moving (Rentz 2014). Forest ecosystems, such as the area within the Ducke Reserve, have structurally complex habitats where cockroaches are relatively diverse. These habitats offer many niches for roach populations, including living and dead leaves, branches, cracks and spaces in the bark, twigs, hollows, etc. (Bell et al. 2007). In temperate climates, cockroaches play a minor role in soil biology because their populations are not very dense (Eisenbeis & Wichard 1985). Similarly, in tropical forests, ants, mites and springtails are dominant, and cockroaches are only occasionally mentioned in this context (Fittkau & Klinge 1973).

In this contribution we describe and illustrate the male genitalia of five new species of Ectobiidae collected in the Reserva Ducke, Manaus, state of Amazonas. Four of the new species belong to the subfamily Pseudophyllodromiinae and one to Nyctiborinae. The Ectobiidae were studied by Khambhampati (1996), based on 31 species of cockroaches and their mitochondrial DNA and RNA concluded that Ectobiidae is a sister group of Blaberidae. This conclusion was supported by Maekawa & Matsumoto (1999) after analyzing 18 species of orthopteroid insects, including three species of Asian cockroaches belonging to the families Blaberidae, Ectobiidae and Blattidae, based on COII, and added that Blattidae is a sister-group of the Blaberidae and Ectobiidae.

In the checklist provided by Beccaloni (2014), among Pseudophyllodromiinae, the genus *Amazonina* Hebard, 1929 comprises 17 species, of which 15 are Neotropical and 14 of these are described from Brazil, in the Amazon region; and the genus *Cariblatta* Hebard, 1916 comprises 82 Neotropical species, of which 45 are listed for South America, with 42 species in Brazil and seven restricted to the Amazon region. The present study adds two species to each of these genera. The subfamily Nyctiborinae comprises 32 species, of which 29 are Neotropical, including 22 from Brazil with 15 recorded in the Amazon region; an additional species of *Nyctibora* from the Amazon is added herein.

The diversity of Blattodea is little known. Rocha e Silva Albuquerque (1974) studied members of *Amazonina* in the Amazon region; Lopes & Oliveira (2002a) added one species to the genus, and Lopes (2008) presented a new record of the genus for southeastern Brazil Rocha e Silva Albuquerque &

Lopes (1975) recorded six species for the Amazon region. Lopes & Oliveira (2009) recorded two species of *Nyctibora*, and Vélez-Bravo (2013) recorded six additional species of this genus in the Amazon region. Lopes & Oliveira (2002b, 2004 and 2005) reported new locality records for members of both genera.

Materials and Methods

This study was conducted in the dense ombrophilous forest of the Reserva Ducke. The Reserva Ducke is located at km 26 of highway AM-010 (Manaus-Itacoatiara) between 03°00'02" and 03°08'00" S and 59°58'00" W. The regional climate is type Afi according to the Köppen classification. The mean annual temperature is 25°C, and the minimum mean monthly temperature never falls below 18°C. The mean annual rainfall is 2000 mm, with a rainy season from November to May, with most rainfall in March and April; and a dry season from June to October, with September typically the driest month (Sampaio et al. 2005).

The vegetation is typical terra-firme tropical humid forest, which can be differentiated into plateau forest, with predominantly clay soils or dystrophic yellow-alic latosol; forest slope along the transition between the plateau and the valley, with predominantly quartz-sand soils; and campinarana forest or valley, with predominantly sandy soils (Ribeiro et al. 1999).

The collecting focused on adults found in the leaf litter, and on twigs, fallen logs and foliage. We collected during the early evening hours, using a plastic container with 50 ml of 70% ethanol, to euthanize the specimens. The specimens were placed in plastic containers with 70% ethanol and 8 ml glycerin in a proportion of 80:20, and were labeled as to collector, date, time of collection and plot number. They were then taken to the laboratory, sorted and pinned. The species were identified at the Museu Nacional of Rio de Janeiro, with the aid of identification keys and comparison with previously identified material. For observation of the genital plates, we separated the tail from the abdomen, using traditional dissection techniques described by Lopes & Oliveira (2000). After analysis, the plates and genital parts were stored in microtubes containing glycerin, and stored next to their respective specimens, a technique developed by Gurney et al. (1964). The terminology of the genitalia and the taxonomic classification are based on Roth (2003).

We collected a total of 777 specimens of Ectobiidae, of which 359 belong to subfamily Pseudophyllodromiinae, 409 to Blattellinae, 7 to Anaplectinae and 2 to Nyctiborinae. The 5 new species described are represented by 132 specimens belonging to the subfamilies Pseudophyllodromiinae and Nyctiborinae. The remaining 227 individuals are other, known species of Pseudophyllodromiinae.

The material studied in this paper was deposited in the collection of the Instituto Nacional de Pesquisas da Amazônia, INPA and in the collection of the Entomology Department of the Museu Nacional, UFRJ/MN.

Results

Amazonina spiculata sp. nov.

General coloration dark brown (Figure 6a). Head and interocular space with scattered dark-brown marks, eye black (Figure 1a); antennae and palps pale, golden-tomentose; pronotum indistinctly hyaline; central disk pale brown with dark-brown dots and strokes (Figure 1b); tegmina with sparse dark-brown dots; legs with insertion area of tibial spines dark brown; pulvilli whitish. Wings with dilated apices of radial veins brown.

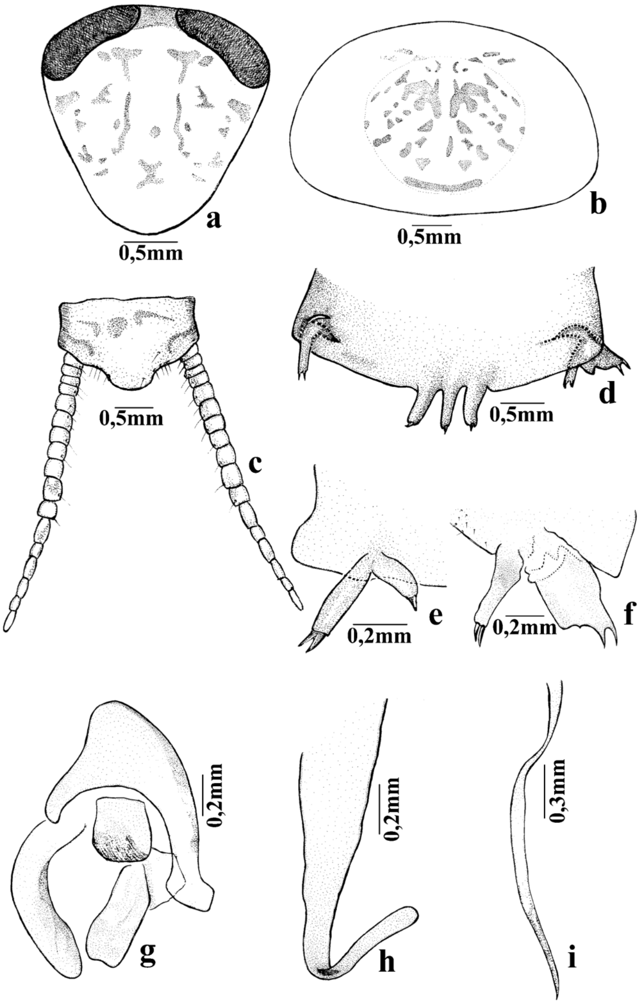

Figure 1. *Amazonina spiculata* sp. nov., male holotype. a. Head, ventral view; b. pronotum, dorsal view; c. Supranal plate, dorsal view; d. Subgenital plate, ventral view; e. Detail of the lateral base of the subgenital plate with a spiniform structure, left side, ventral view; f. Detail of the lateral base of the subgenital plate with a spiniform structure, right side, ventral view; g. Left phallomere, dorsal view; h. Right phallomere, dorsal view; i. Median sclerite, dorsal view.

Dimensions of Holotype ♂. Total length: 15.4 mm; length of pronotum: 2.8 mm; width of pronotum: 3.8 mm; length of tegmen: 13.4 mm; width of tegmen: 3.2 mm.

Head subtriangular, vertex slightly exposed beneath pronotum in dorsal view; interocular space narrow, approximately one-third of distance between antennal bases. Antennae long, reaching beyond apex of abdomen; maxillary palps with third and fourth articles similar in size and larger than the dilated fifth article.

Thorax with pronotum subtrapezoidal, lateral flaps rounded and slightly deflexed. Legs spiny; fore femur with ventrocephalic margin bearing row of 12 spines that gradually decrease in size toward the apex, plus two large apical spines; ventrocaudal margin with four well-spaced spines in median-apical region, one apical spine; middle and hind femora each with five or six large, well-spaced spines, including one apical spine, similarly arranged on ventral surfaces; genicular spine present; pulvilli present on all tarsomeres, claws symmetrical and specialized; arolium small. Tegmina long, reaching beyond apex of cerci; marginal field narrow. Scapular field elongate, with oblique veins; discoidal field with longitudinal venular arrangement; basal branches arranged almost obliquely; anal field narrow, with 6 or 7 axillary veins. Wings, costal field with apices of branches of radial vein dilated; apical triangle present, small; anal field folded as a fan.

Abdomen. Supranal plate narrow, slightly indented medially between cerci (Figure 1c). Cerci long, tapering toward apex. Subgenital plate wide, with 2 elongated styles and a median projection between them, and tapered expansion on each lateral edge (Figures 1d, 1e, 1f). Left phallomere shaped as an inverted U with arms subequal in size and shape (Figure 1g). Right phallomere hooked, with elongate and widened apex (Figure 1h). Median sclerite comma-shaped, tapering toward apex (Figure 1i).

Material examined. Holotype: ♂, Brazil, Amazonas, Manaus, Reserva Ducke, V.D. Tarli & V. Linard cols.; Paratypes: 1 ♂, 12/VII/2011; 1 ♂, 30/VI/2010; 6 ♂ and 6 ♀, 8–14/XI/2010; 17 ♂ and 5 ♀, 30/XI–5/XII/2010; 10 ♂ and 1 ♀, 11–12/VII/2011; 5 ♂ and 4 ♀, 24–27/V/2011; 4 ♂ and 3 ♀, 10–14/V/2011 (INPA); 1 ♂ and 1 ♀, 30/XI–5/XII/2010 (MNRJ). All paratypes from same locality as holotype.

Etymology. The species name refers to the shape of the apex of the style.

Discussion. This species is similar to *A. goiana* (Rocha e Silva-Albuquerque, 1974) in the lateral configuration of the base of the subgenital plate (Figure 1d). It differs in the configuration of the styles and the genitalia (Figures 1g, 1h, 1i).

Amazonina spinostylata sp. nov.

General coloration light brown (Fig. 6b) Head with distinct dark-brown marks on the labrum, genae, and between insertion of antennae; dark-brown transverse stripe on interocular space (Figure 2a), antennae light-golden tomentose; pronotum hyaline, central disk milky light brown with dark-brown nuances (Figure 2b). Tegmina dark brown, hyaline, with sparse dark-brown dots. Legs pale, basal portion of most femoral and tibial spines dark brown; pulvilli whitish.

Dimensions of Holotype ♂. Total length: 14.2 mm; Length of pronotum: 2.5 mm; width of pronotum: 2.9 mm; length of tegmen: 11.9 mm; width of tegmen: 3.0 mm.

Head triangular, vertex exposed beneath pronotum in dorsal view. Interocular space ample, about half of space between bases of antennae; antennae long, reaching beyond apex of abdomen; maxillary palpi with third and fourth articles subequal in length and larger than the remaining articles, fifth article dilated.

Thorax with pronotum subtrapezoidal, with rounded, slightly deflexed lateral flaps; central disk conspicuous. Legs spiny; fore femora, ventrocephalic margin with 4 spines, decreasing in size toward apex, plus 2 larger apical spines; ventrocaudal margin with robust median spine plus 3 spines on apical third and one apical; middle and hind femora with 4 to 6 well-spaced spines and one apical spine, similarly arranged on both ventral surfaces. Genicular spine present. Pulvilli tiny, present on all tarsomeres; claws symmetrical and specialized. Tegmina long, reaching beyond apex of cercus; marginal field narrow, approximately one-third length of tegmina; scapular field long, with oblique venules; discoidal field with longitudinal veins, radiating in such a way that basal branches appear oblique; anal field short and narrow, with four or five axillary veins.

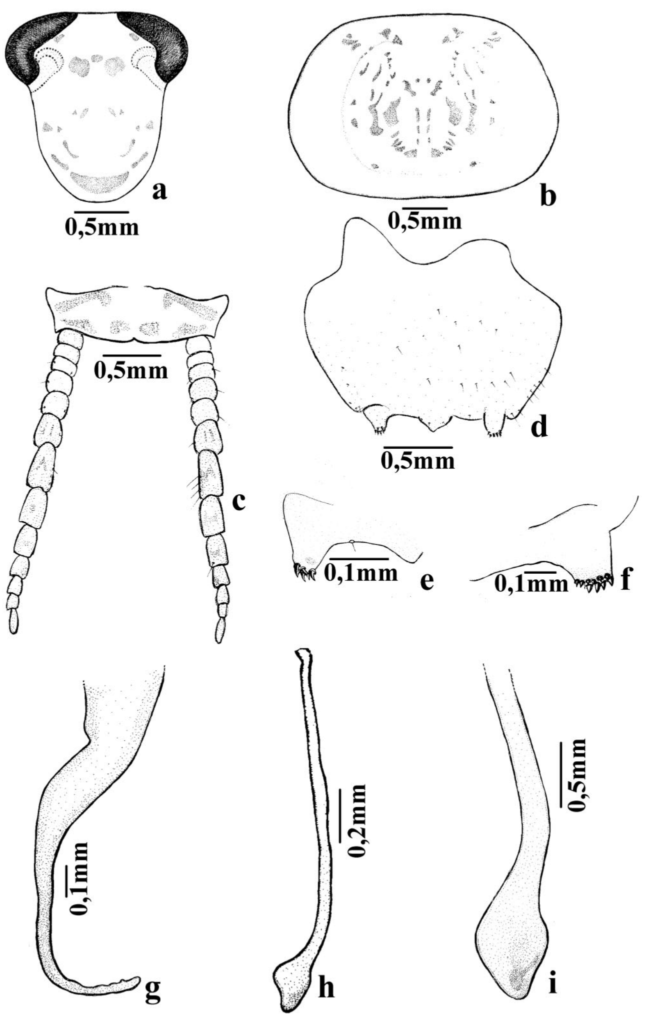

Figure 2. *Amazonina spinostylata* sp. nov., male holotype. a. Head, ventral view; b. Pronotum, dorsal view; c. Supranal plate, dorsal view; d. Subgenital plate, ventral view; e. Detail of the rounded left style with spiniform structures on apex, ventral view. f. Detail of the rounded right style with spiniform structures on apex, ventral view; g. Right phallomere, dorsal view; h. Median sclerite, dorsal view; i. Detail of apically spoon-shaped median sclerite, dorsal view.

Abdomen. Supranal plate narrow, with slight median indentation; cerci long and tapering toward apex (Figure 2c); subgenital plate symmetrical, with conspicuous triangular projection medially (Figure 2d); styles short, round, with spiny projections on apex (Figures 2e, 2f); right phallomere slender, hook-shaped, with slight projections apically (Figure 2g); median sclerite slender and spoon-shaped apically (Figures 2h, 2i).

Material examined. Holotype ♂, Brazil, Amazonas, Manaus, Reserva Ducke, 24–27/V/2012, V.D. Tarli & V. Linard; Paratypes: 1 ♂, 10–14/V/2011; 14 ♂, 30/XI–5/XII/2010; 8 ♂, 24–27/V/2011; 7 ♂, 10–14/V/2011 (INPA); 1 ♂, 1 ♀, 10–14/V/2011 (MNRJ). All paratypes from same locality as holotype.

Etymology. The species is named for the shape of the styles.

Discussion. This species is similar to *A. nodipenis* (Hebard, 1926) in the configuration of the subgenital plate (Figure 2d) and styles (Figures 2e, 2f), differing in its general coloration (Figure 6b) and genitalia (Figures 2g, 2h, 2i).

Cariblatta duckeniana sp. nov.

General coloration brown (Fig. 6c). Head dark brown with vertex yellowish brown, interocular space dark brown (Figure 3a); eye black; antennae with seven light-brown basal antennomeres. Pronotum with central disk dark brown, lateral flaps hyaline (Figure 3b). Legs dark brown with whitish pulvilli. Tegmina bicolored, marginal field and outer stripe narrow and scapular field hyaline; anal and discoidal fields and inner stripe of scapular field dark brown.

Dimensions of Holotype ♂. Total length: 11.2 mm; length of pronotum: 1.92 mm; width of pronotum: 2.8 mm; length of tegmen: 10.3 mm; width of tegmen: 2.6 mm.

Head subtriangular, vertex exposed beneath pronotum in dorsal view; interocular space narrow, approximately 1/4 space between antennal insertions; antennae long and tomentose, reaching beyond apex of abdomen; maxillary palpi tomentose, third article longer than fourth, fifth article dilated.

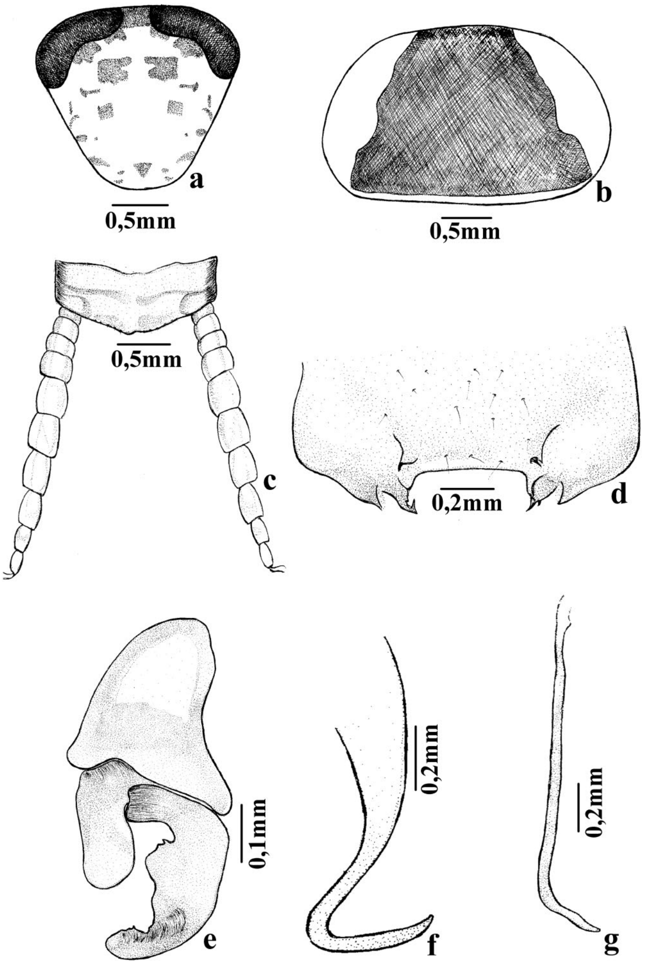

Figure 3. *Cariblatta duckeniana* sp. nov. male holotype. a. Head, ventral view; b. Pronotum, dorsal view; c. Supranal plate, dorsal view; d. Subgenital plate, ventral view; e. Left phallomere, dorsal view; f. Right phallomere, dorsal view; g. Median sclerite, dorsal view.

Thorax with pronotum subtrapezoidal, transverse, convex, with lateral flaps rounded and slightly deflexed; legs spiny. Fore femora with ventrocephalic margin bearing 12 spines that decrease in size toward apex, plus 2 larger apical spines; ventrocaudal margin with three spines on apical third, plus one apical spine. Middle and hind femora with 6 to 7 well-spaced spines up to apex, one apical spine, spines similar on both ventral surfaces. Middle and hind femora each with genicular spine; pulvilli present on all tarsomeres; claws symmetrical, specialized, with ventral denticles. Arolium present, small. Tegmina lanceolate, long, reaching beyond apex of cerci, marginal field narrow and long, reaching to midlength of tegmina; scapular field with oblique venules; discoidal field with longitudinal veins; anal field short, with four axillary veins. Wings with costal field having apices of branches of radial vein dilated; apical triangle present, small; anal field ample and folded as a fan.

Abdomen. Supranal plate narrow, with slight median indentation between cerci; cerci long, slightly dilated (Figure 3c); subgenital plate wide, base straight between styles; two projections present near base of plate, tapering toward apex, styles differentiated, bearing apical spine (Figure 3d); left phallomere shaped as inverted U with 2 arms differing in shape and size (Figure 3e); right phallomere hook-shaped, with pre-apical notch (Figure 3f); median sclerite long and slender at apex (Figure 3g).

Material examined. Holotype: ♂, Brazil, Amazonas, Manaus, Reserva Ducke, 10–14/V/2011, V.D. Tarli & V. Linardi cols.; paratypes: 1 ♂, 30/XI–5/XII/2010; 2 ♀, 24–27/V/2011 (INPA); 1 ♀. All paratypes from same locality as holotype. No material deposited in Museu Nacional, UFRJ.

Etymology. The name of the species is derived from the type locality, the Reserva Ducke.

Discussion. This species can be distinguished from all other members of the genus by the shape of the subgenital plate (Figure 3d), differing in the general coloration (Figure 6c) and genitalia (Figures 3e, 3f, 3g).

Cariblatta manauensis sp. nov.

General coloration dark brown (Figure 6d); frons with dark-brown transverse stripe between bases of antennae; interocular space with slightly darker stripe; antennae yellowish dark brown, golden-tomentose (Figure 4a); pronotum hyaline with central disk milky with dark-brown marks, strokes and dots (Figure 4b). Legs with base of tibial spines and apex of tarsal articles dark brown. Tegmina hyaline with light brownish-orange veins and dark-brown transverse veins in median and apical regions of discoidal field.

Dimensions of Holotype ♂. Total length: 13.9 mm; length of pronotum: 2.6 mm; width of pronotum: 3.1 mm; length of tegmen: 11.7 mm; width of tegmen: 3.1 mm.

Head subtriangular, wide, vertex slightly exposed beneath pronotum in dorsal view; interocular space narrow, approximately 1/4 distance between bases of antennae; antennae long and tomentose, reaching beyond apex of abdomen; maxillary palps with third article longest, fifth article dilated.

Thorax with pronotum convex, subtriangular, lateral flaps and apex rounded. Legs spiny, fore femora with ventrocephalic margin armed with 16 spines, 6 decreasing in length toward apex, plus 2 apical spines; ventrocaudal margin with 2 spines on apical third, plus 1 apical spine; middle and hind femora with 4 or 5 spaced spines and 1 apical spine; spines similar on both

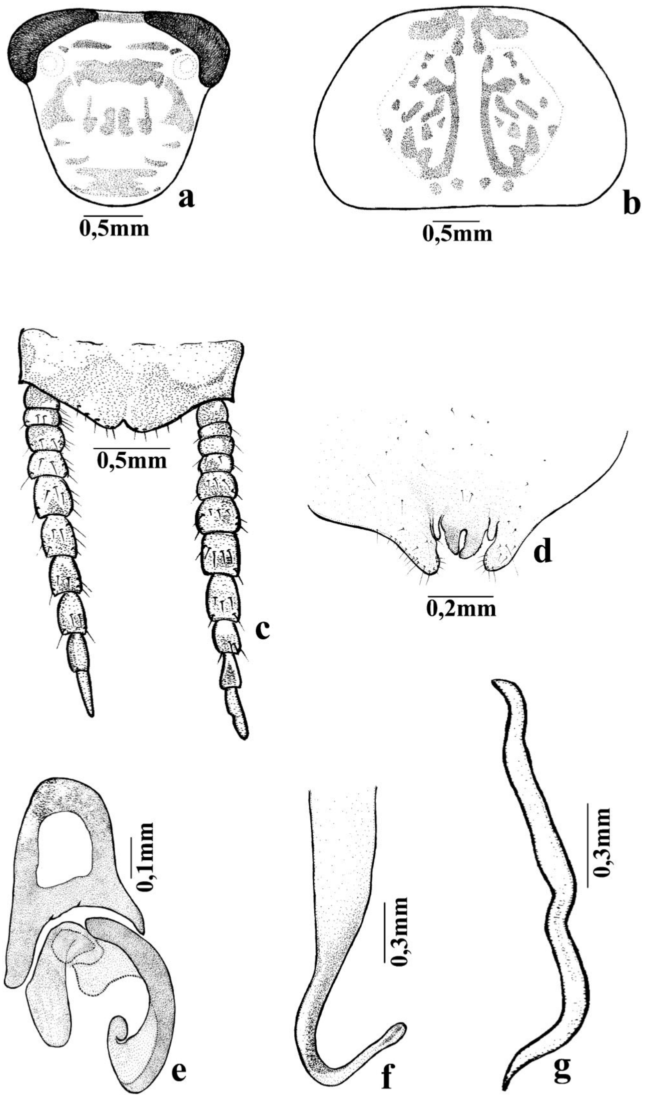

Figure 4. *Cariblatta manauensis* sp. nov. male holotype. a. Head, ventral view; b. Pronotum, dorsal view; c. Supranal plate, dorsal view; d. Subgenital plate, ventral view; e. Left phallomere, dorsal view; f. Right phallomere, dorsal view; g. Median sclerite, dorsal view.

ventral surfaces; pulvilli on all tarsomeres; claws symmetrical and specialized, with ventral denticles; arolia present. Tegmen lanceolate, marginal field narrow and deflexed; scapular field elongate, with oblique venules; discoidal field with veins arranged longitudinally; anal field short, with 6 to 7 axillary veins. Wings, costal field with apices of branches of radial vein dilated; apical triangle present, small; anal field ample and folded as a fan.

Abdomen. Supranal plate narrow, with distinct median indentation between cerci (Figure 4c); subgenital plate ventrally narrowing toward apex, with rounded extensions with median styliform notch, serrated internally, and with two smaller rounded styles (Figure 4d); left phallomere shaped as an inverted U with two arms differing in shape and size (Figure 4e); right phallomere hook-shaped with conspicuous pre-apical notch, apex elongate and round (Figure 4f); median sclerite long, its apex slender (Figure 4g).

Material examined. Holotype: ♂, Brazil, Amazonas, Manaus, Reserva Ducke, 8–14/X/2010, V.D. Tarli & V. Linard cols.; paratypes: 1 ♂ and 5 ♀, 8–14/XI/2010; 1 ♂ and 7 ♀, 30/XI–5/XII/2010; 2 ♀, 11–12/VII/2011; 2 ♀, 24–27/V/2011; 4 ♀, 10–14/V/2011 (INPA); 1 ♀, 30/XI-5/XII/2010 (MNRJ). All paratypes from same locality as holotype.

Etymology. The specific name refers to the name of the city, Manaus, where the material was collected.

Discussion. This species is similar to *C. vera* (Rocha e Silva-Albuquerque & Lopes, 1975) differing in the configuration of the subgenital plate (Figure 4d).

Nyctibora nigra sp. nov.

General coloration dark brown, with yellowish dark-brown tomentosity (Figure 6e). Head brown (Figure 5a), eyes almost black; tip of clypeus light brown; palps and antennae golden-tomentose with light-brown tips; ocelli whitish yellow; pronotum black (Figure 5b); legs dark, golden-tomentose with dark-brown spines; pulvilli whitish.

Dimension of Holotype ♂. Total length: 27.2 mm; length of pronotum: 6.9 mm; width of pronotum: 9.8 mm; length of tegmen: 24.2 mm; width of tegmen: 8.4 mm.

Head subtriangular; vertex slightly exposed beneath pronotum in dorsal view; interocular space ample, measuring

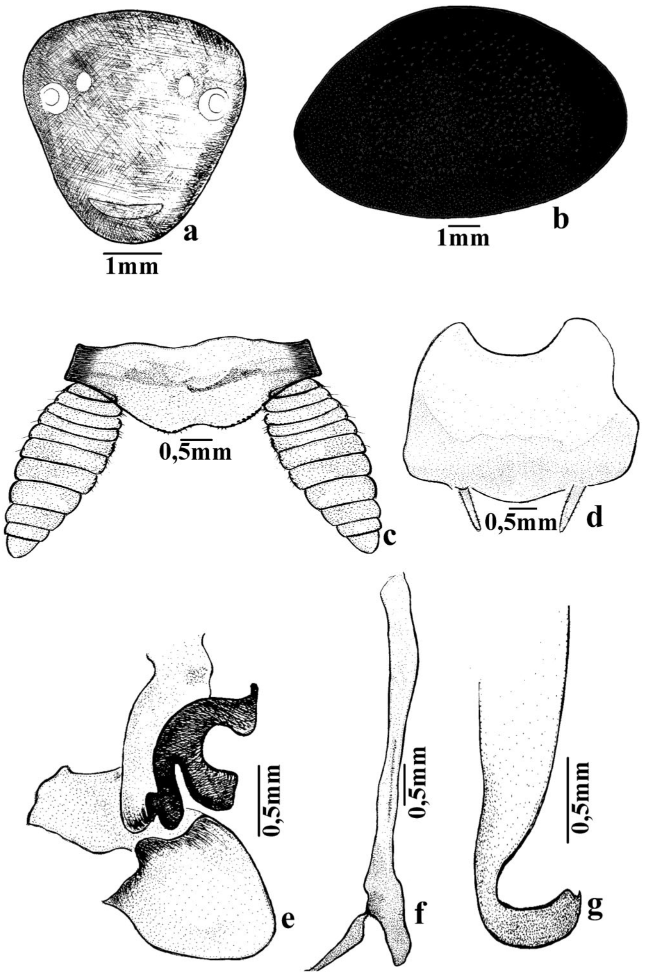

Figure 5. *Nyctibora nigra* sp. nov. male holotype. a. Head, ventral view; b. Pronotum, dorsal view; c. Supranal plate, dorsal view; d. Subgenital plate, ventral view; e. Right phallomere, dorsal view; f. Median sclerite, dorsal view; g. Left phallomere, dorsal view.

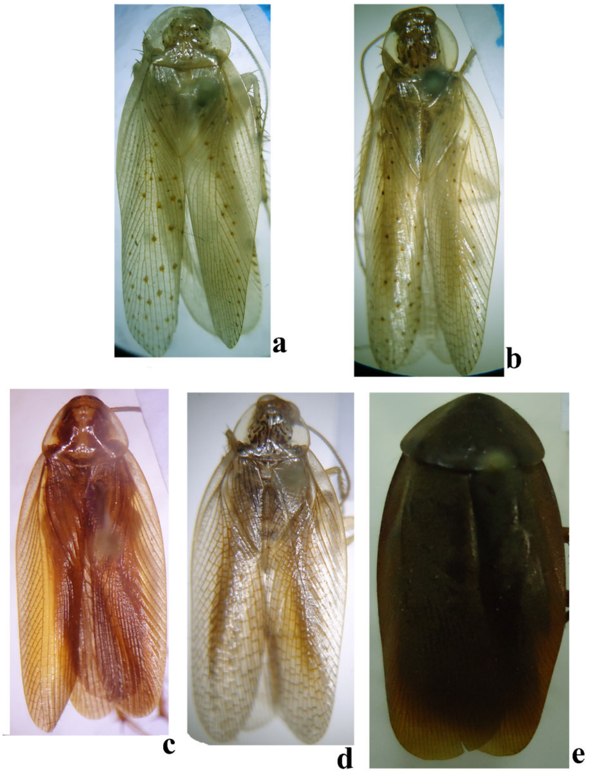

Figure 6. Habitus. a. *Amazonina spiculata* sp. nov., male holotype; b. *Amazonina spinostylata* sp. nov. male holotype; c. *Cariblatta duckeniana* sp. nov. male holotype; d. *Cariblatta manauensis* sp. nov. male holotype; e. *Nyctibora nigra* sp. nov. male holotype.

about half distance between bases of antennae; ocelli conspicuous; antennae long, reaching beyond apex of cerci; maxillary palps with four articles, each dilated at apex, and fifth article dilated and longer than remaining articles.

Thorax with pronotum elliptical, transverse and convex. Legs robust and tomentose; fore femora with ventrocephalic margin bearing small spines up to apex, pre-apical spine longest, and 2 larger apical spines; ventrocaudal margin with spines up to apex, with 1 spine on apical third, plus apical spine. Middle and hind femora with 6 to 9 robust, well-spaced spines, 1 apical spine; spines similar on both ventral surfaces; middle and hind femora each with genicular spine. Claws symmetrical, not specialized; arolia present; pulvilli present on all tarsomeres. Tegmina tomentose and developed, reaching beyond apex of cerci; marginal field narrow and elongate; scapular field with oblique venules; discoidal field ample, with longitudinal venules; anal field ample, with 11 axillary veins. Wings developed; apical triangle absent; anal field folded as a fan.

Abdomen. Supranal plate narrow proximally, distal half wider; inconspicuous indentation medially between cerci; cerci short, wide, tapering toward apex (Figure 5c); subgenital plate wide, short and asymmetrical, with apex slightly rounded and inconspicuous at the base between the styles, styles similar in shape and size (Figure 5d); right phallomere with laminar arms and sclerotized medially (Figure 5e); median sclerite long, wide at base, with slender medial-apical projection (Figure 5f); left phallomere hook-shaped (Figure 5g).

Material examined. Holotype: ♂, Brazil, Amazonas, Manaus, Reserva Ducke, 24–27/V/2011, V.D. Tarli & V. Linard cols.; paratype: 1 ♀, same locality as holotype, 8–14/XI/2010 (INPA). No material deposited in Museu Nacional/UFRJ.

Etymology. The species epithet refers to the general coloration.

Discussion. This species differs from other members of the genus in size, coloration (Figure 6e), and the configuration of the genital plates (Figures 5e-g).

Acknowledgments

We are grateful to Prof. Solange Garrido for translation the text and to Dr. Janet W. Reid for edited the text in English.

References

BECCALONI, G.W. 2014. *Cockroach Species File Online*. Version 5.0/5.0. World Wide Web electronic publication. <http://Cockroach.SpeciesFile.org> [accessed 29 July 2014].

BELL, W.J., ROTH, L.M. & NALEPA, C.A. 2007. Cockroaches: Ecology, Behavior, and Natural History. The Johns Hopkins University Press. Baltimore, Maryland. 230p.

EISENBEIS, G. & WICHARD, W. 1985. Atlas on the Biology of Soil Arthropods. Springer-Verlag, Berlin. 437p.

FITTKAU, E.J. & KLINGE, H. 1973. On biomass and trophic structure of the central Amazonian rain forest ecosystem. Biotropica 5:2–14, http://dx.doi.org/10.2307/2989676

GURNEY, A.B., KRAMER, J P. & STEYSKAL, G.C. 1964. Some Techniques for the Preparation, Study and Storage in Microvials of Insect Genitalia. Ann. Entomol. Soc. Am. 57: 240–242.

KAMBHAMPATI, S. 1996. Phylogenetic relationship among cockroach families inferred from mitochondrial 12S rRNA gene sequence. Syst. Entomol. 21: 89–98.

LOPES, S.M. 2008. Espécie nova de *Amazonina* e novo status para *A. sooretamensis* (Blattaria: Blattellidae: Pseudophyllodromiinae). Rev. Bras. Zool. 25(3): 499–501, http://dx.doi.org/10.1590/S0101-81752008000300015

LOPES, S.M. & OLIVEIRA, E.H. 2000. Espécie nova de *Blaberus* Serville, 1831 do Estado de São Paulo, Brasil (Blaberidae, Blaberinae). Bol. Mus. Nac., Nova Sér., Zool. 415: 1–4.

LOPES, S.M. & OLIVEIRA, E.H. 2002a. Espécie nova de *Amazonina* de Minas Gerais, Brasil (Blattaria, Blattellidae). Iheringia, Sér. Zool. 92(2): 5–8, http://dx.doi.org/10.1590/S0073-47212002000200001

LOPES, S.M. & OLIVEIRA, E.H. 2002b. Espécies novas de *Cariblatta* Hebard, 1916 (Dictyoptera, Blattaria) de Mato Grosso, Brasil. Bol. Mus. Nac., Nova Sér., Zool. 480: 1–8.

LOPES, S.M. & OLIVEIRA, E.H. 2004. Duas espécies novas de *Cariblatta* Hebard, 1916 (Blattaria, Blattellidae) do Estado do Acre (Brasil) coletadas em ninhos de vespas (Hymenoptera, Sphecidae). Arq. Mus. Nac. 62(2): 173–177.

LOPES, S.M. & OLIVEIRA, E.H. 2005. Espécie nova de *Cariblatta* Hebard, 1916 (Blattaria, Blattellidae) do Estado do Mato Grosso, Brasil. Arq. Mus. Nac. 63: 639–641.

LOPES, S.M. & OLIVEIRA, E.H. 2009. Espécies e registros novos de *Nyctibora* Burmeister, 1838 do Brasil e considerações sobre o gênero (Blattaria: Blattellidae). Lundiana 9(1): 49–51.

MAEKAWA, K. & MATSUMOTO, T. 1999. Molecular phylogeny of cockroaches (Blattaria) based on mitochondrial COII gene sequences. Syst. Entomol. 25: 511–519, http://dx.doi.org/10.1046/j.1365-3113.2000.00128.x

RENTZ, D.C.. 2014. A guide to the cockroaches of Australia. CSIRO Publishing, Collingwood. 318p.

RIBEIRO, J.E.L.S., HOPKINS, M.J.G., VICENTINI, A., SOTHERS, C.A., COSTA, M.A.S., BRITO, J.M., SOUZA, M.A.D., MARTINS, L.H.P., LOHMANN, L.G., ASSUNÇÃO, P.A.C.L., PEREIRA, E.C., SILVA, C.F., MESQUITA, M.R. & PROCÓPIO, L.C. 1999. Flora da Reserva Ducke: Guia de identificação das plantas vasculares de uma floresta de terra-firme na Amazônia Central. Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas. 816p.

ROCHA E SILVA ALBUQUERQUE, I. 1974. Revisão do gênero *Amazonina* Hebard, 1929 (Epilampridae, Blattellinae). Acta Amazonica 4(2): 55–67.

ROCHA E SILVA ALBUQUERQUE, I. & LOPES, S.M. 1975. Revisão de *Cariblatta* Hebard, 1916 no Brasil (Dictyoptera, Epilampridae, Blattellinae). Rev. Bras. Biol. 35(2): 273–396.

ROTH, L.M. 2003. Systematics and phylogeny of cockroaches (Dictyoptera: Blattaria). Oriental Insects 3: 1–186.

SAMPAIO, P. de T.B., BARBOSA, A.P., VIEIRA, G., SPIONELLO, W.R. & BUENO, F.M.S. 2005. Biomassa da rebrota de copas de pau-rosa (*Aniba rosaeodora* Ducke em plantios sob combra parcial em floresta primária. Acta Amazonica 35(4): 491–494.

VÉLEZ-BRAVO, A. 2013. Checklist of Colombian cockroaches (Dictyoptera, Blattaria). Biota Colombiana 9(1): 21–38.

Received 03/12/2013
Revised 13/10/2014
Accepted 15/10/2014

Biota Neotropica 14(4): e20140129, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

inventory

Diversity of small land mammals in a subtropical Atlantic forest in the western region of the state of Santa Catarina, southern Brazil

Renan Maestri[1,2,4], Daniel Galiano[3], Bruno Busnello Kubiak[3] & Jorge Reppold Marinho[1]

[1] *Programa de Pós-Graduação em Ecologia, Universidade Regional Integrada do Alto Uruguai e das Missões, Erechim, RS, Brazil.*
[2] *Programa de Pós-Graduação em Ecologia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.*
[3] *Programa de Pós-Graduação em Biologia Animal, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.*
[4] *Corresponding author: Renan Maestri, e-mail: renanmaestri@gmail.com*

MAESTRI, R., GALIANO, D., KUBIAK, B.B., MARINHO, J.R. **Diversity of small land mammals in a subtropical Atlantic forest in the western region of the state of Santa Catarina, southern Brazil.** Biota Neotropica. 14(4): e20140129. http://dx.doi.org/10.1590/1676-06032014012914

Abstract: Small land mammals possess features that significantly influence the dynamics of ecosystems and participate in various levels of the food web. In the Brazilian Atlantic Forest the richness of these animals is high, which makes them even more ecologically and numerically relevant in this environment. In this context, we investigated the species composition of small mammals in an unexplored area of southern Brazil, and compared the species composition of this area with other Atlantic Forest regions in order to understand how this community is related to others. The study area was located in an interior Atlantic forest formation, at a transition region between deciduous and Araucaria forests. Small mammals were captured at five collection points using pitfall traps. We compared the species composition found in our studied area with the composition of other 11 studies in different regions by a cluster analysis, and we investigated the presence of spatial autocorrelation between communities with a Mantel test. We recorded 779 individuals from 21 species of small rodents (15 species) and marsupials (six species) during the 13 months of the collection period. This richness was high compared to other studies conducted in the Atlantic Forest formations near to coastline and in interior forest formations. This may be a result of the conditions provided by this transition area (deciduous and Araucaria forests), where could be found elements of the both forests formations, which probably allows the establishment of small mammal species from both forest types. Despite differences in sampling effort of the studies, our results suggest that the interior forest formations may harbor a number of species comparable to the formations near the coast. The species composition of this area was similar to those found in other interior forest formations with the same phytophysiognomy characteristics and at nearby regions, and it was less similar to the distant formations located in southeastern and northeastern Brazil and nearby to the coastline. This can be a result of both the spatial autocorrelation (i.e. more nearby communities tend to have more similar species composition) and the differences of forest characteristics among regions.

Keywords: *Richness, species composition, Uruguay River, Rodentia, Didelphimorphia.*

MAESTRI, R., GALIANO, D., KUBIAK, B.B., MARINHO, J.R. **Diversidade de pequenos mamíferos terrestres em floresta Atlântica subtropical na região oeste do estado de Santa Catarina, sul do Brasil.** Biota Neotropica. 14(4): e20140129. http://dx.doi.org/10.1590/1676-06032014012914

Resumo: Pequenos mamíferos terrestres possuem características que influenciam significativamente a dinâmica dos ecossistemas, participando em vários níveis da teia trófica. Na floresta Atlântica brasileira a riqueza desses animais é alta, o que os torna ainda mais ecológica e numericamente relevantes neste ambiente. Neste contexto, nós investigamos a composição de espécies de pequenos mamíferos em uma área não estudada, e comparamos a composição de espécies desta área com outras regiões de floresta Atlântica de modo a entender como esta comunidade de pequenos mamíferos é relacionada a outras. A área de estudo está localizada em uma formação de floresta Atlântica de interior, em uma transição entre floresta decidual e floresta com Araucária. Os pequenos mamíferos foram capturados em cinco pontos de coleta por meio do método de armadilhas de interceptação e queda. Nós comparamos a composição de espécies encontrada em nosso estudo com a de outros 11 estudos realizados em diferentes regiões através de uma análise de agrupamento, e nós investigamos a presença de autocorrelação espacial entre comunidades por meio de um teste de Mantel. Nós registramos 779 indivíduos de 21 espécies de pequenos roedores (15 espécies) e marsupiais (seis espécies) durante um período de 13 meses de coleta. A riqueza é alta comparada com outros estudos em formações de floresta Atlântica próximas do litoral e formações de interior. Isso pode ser o resultado das condições fornecidas por esta área de transição (floresta decidual e floresta com Araucária), onde podem ser encontrados elementos das duas formações florestais, o que provavelmente permite o estabelecimento de espécies de pequenos mamíferos dos dois tipos de floresta. Apesar das diferenças no esforço amostral entre os estudos, esses resultados são uma boa indicação de que as formações de floresta Atlântica de interior podem abrigar um número de espécies comparáveis a de formações próximas da costa. A composição de espécies desta área é mais similar a de outras formações Atlânticas de interior com as mesmas características florestais e de regiões espacialmente próximas, e é menos similar as formações localizadas no sudeste e no nordeste do Brasil, e de regiões próximas da costa. Isso pode ser o resultado de autocorrelação espacial (i.e. comunidades mais próximas tendem a ter uma composição de espécies mais similar) e das diferenças nas características florestais entre as regiões.

Palavras-chave: *Riqueza, composição de espécies, Rio Uruguai, Rodentia, Didelphimorphia.*

Introduction

Small terrestrial mammals (both rodents and marsupials), characterized here as those that weigh less than 1 kg in average (Fonseca et al. 1996), are important numerically and possess features that significantly influence the dynamics of ecosystems (Pardini & Umetsu 2006). They are important predators of insects, consume fruits, disperse seeds (Carvalho et al. 1999) and fungal spores (Pyare & Longland 2001) as well as participate in the cycle of various zoonoses that affect man (Bonecker et al. 2009, Pinto et al. 2009). In addition to knowing the species composition of any community, it is important to understand how these species are distributed in space in comparison to other communities of different regions. Such information can assist us when devising of strategies for the conservation of the sampled sites and increasing our understanding of the ecological relationships between species (Begon et al. 2007).

The Atlantic Forest is one of the richest and most threatened biomes in the world. Efforts to understand and outline strategies to conserve biodiversity must be urgent (Myers et al. 2000). The richness of small land mammals, as with most animal groups, is remarkable in this region (Galindo-Leal & Câmara 2003). There are approximately 100 species of small marsupials and rodents spread throughout the biome (Bonvicino et al. 2002, Pardini & Umetsu 2006, Pinto et al. 2009, Paglia et al. 2012). Despite the increasing number of studies in this biome, some regions remain poorly sampled. For example, only a few studies of small mammal species have been carried out in the western state of Santa Catarina, where this study was conducted. In this region, the information available is results from fauna surveys (Studies of Environmental Impact) at hydroelectric plants (Cherem et al. 2008, Cherem et al. 2012).

In this context, the aims of our study was (1) to evaluate the species composition of small mammals present in a poorly sampled region in a transition between deciduous and Araucaria forests in southern Brazil; and (2) to compare the species composition of this area with other Atlantic Forest regions in order to understand how this community of small mammals is related to others. Additionally, we discuss the conservation potential of our study area based on the small mammal richness in relation to other studies.

Material and Methods

1. Study area

The study was conducted in a fragment of Atlantic Forest in a transition region between deciduous and Araucaria forests. The fragment is located in the western region of the state of Santa Catarina in southern Brazil (Figure 1). The ground has a large slope; the altitude ranges from 388 to 600 meters above sea level. The total area of this fragment reaches approximately 400 hectares. About 300 hectares are of native vegetation, permeated by 100 hectares of a eucalyptus plantation. The surrounding area of the fragment is dominated by eucalyptus monocultures, forestry and housing. The area inside the

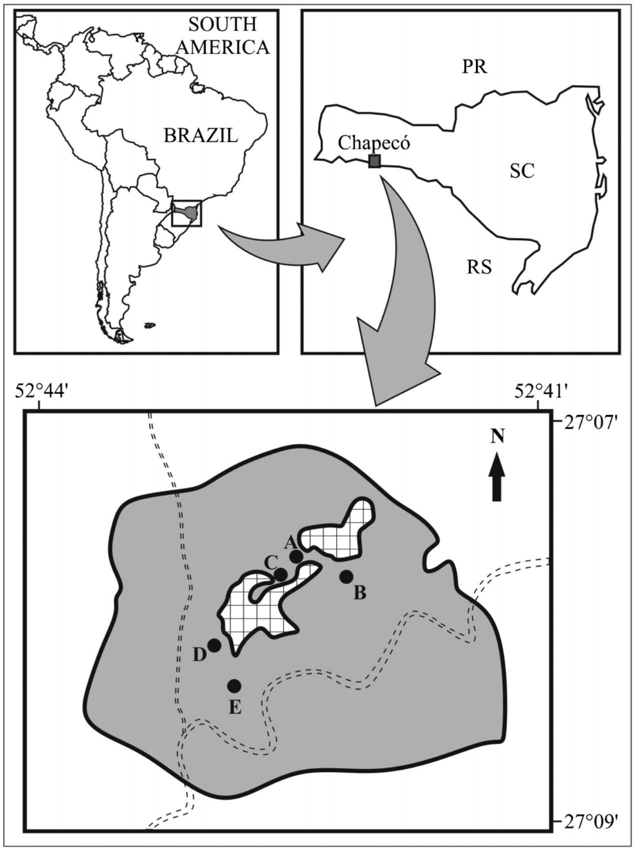

Figure 1. Sketch of the study area and its location in the context of the state of Santa Catarina and Brazil. The black dots represent the places where the traps to catch small mammals were located. The grey area represents the native vegetation (i.e. the transition between deciduous and Araucaria forest). The area in squares represents eucalyptus plantations. Dashed lines denote rivers; the vertical one is an unnamed river; and the horizontal one is the Passo dos Índios River. Acronyms: PR, Paraná state; SC, Santa Catarina state; RS, Rio Grande do Sul state.

http://dx.doi.org/10.1590/1676-06032014012914

fragment was greatly affected by logging (approximately 10 years before our sample). The native forest is in regeneration, but moderate disturbances caused mainly by hunting has continued. The climate classified as Köeppen type Cfb, mesothermic humid, with an average annual temperature of approximately 18° to 19° C and an average annual rainfall of approximately 1,800 mm (Peel et al. 2007). Rainfall is equally distributed over the year. A warm season and a cold season are present, which gives the seasonal character of the forest. The subtropical climate favors the onset of the following two main types of vegetation: the deciduous forest commonly associated with the valley and the rivers, and the Araucaria forest occurring in higher places. The studied area was located at a transition region between these two physiognomies (Silva-Filho & Pugues 2008). The Deciduous forest owes its name to foliar seasonality of the dominant arboreal elements, whose percentage of leaf fall is 50% or more in the colder months. Currently, the original vegetation has been reduced to a few fragments, usually located in steep terrain (Silva-Filho & Pugues 2008). The Araucaria forest, typical in areas with high rainfall, presents a mixture of floras from different regions. One of its most remarkable features is the presence of Araucaria pine (*Araucaria angustifolia* (Bert.) O. Ktze.) (Netto et al. 2012). In the studied area, near the Chapecó River, the original forest was composed mainly of deciduous forest elements (e.g. *Apuleia leiocarpa* (Vogel) J.F.Macbr; *Parapiptadenia rigida* (Benth) Brenan; *Cedrela fissilis* Vell.), with the presence of some typical examples of Araucaria forest (e.g. *Araucaria angustifolia*; *Ocotea porosa* (Ness) Baroso; *Luehea divaricata* Mart. et. Zucc.) (Silva-Filho & Pugues 2008, Netto et al. 2012).

2. *Data collection*

Small mammals were captured using only pitfall traps (see Ribeiro-Júnior et al. 2011 and Cechin & Martins 2000 for discussion concerning this choice). These traps were distributed at five sampling points (A to E) (Figure 1). The maximum distance between the external points (A-E) was 1,180 meters; the inside points (A-B, A-C, B-C, C-D, D-E) were nearly 400 m apart. Each sample point consisted of 10 buckets with 100-liter capacities that were buried in the ground and arranged in a Y-shape. The distance between the buckets was 10 meters. A drift fence (plastic screen), with approximately 50 cm high, placed over the middle of each bucket, connected one bucket to another. The traps were left open for 10 consecutive days over the following 13 months: August 2011 (pilot field) and from October 2011 to September 2012. The overall sampling effort was 6,500 trap-nights. The sample points were revised daily during the sample period.

All of the individuals captured were collected for the preparation of their skin and skull and are deposited in the collection of the Museu Regional do Alto Uruguai (MURAU) of the Universidade Regional Integrada do Alto Uruguai e das Missões (URI) with the numbers MURAU301 to MURAU1061. This collection excluded specimens of the genus *Didelphis* Linnaeus 1758, and one individual of *Guerlinguetus* sp. that was visualized and did not fall in the pitfall. The animals were captured with the consent of environmental agencies (ICMBio), under the permanent and personal license number 15224-2 (J.R.M.).

3. *Data Analysis*

The richness, relative abundance and frequency of occurrence of the species in this study were quantified in totality (i.e. a sum of all the five sampling points). In the case of the genus *Didelphis*, individuals caught for a second time in less than two days at the same sample point were not considered in the abundance calculation for suspected of being the same individual. We choose this criterion as a method to estimate the abundance of *Didelphis*, because the individuals were not marked. A species accumulation curve was generated with 1,000 randomizations in the order of the samples.

We compared the species composition found in our studied area to the composition of other regions present in the Atlantic Forest biome (Table 1). All of the analyzed studies had survey durations greater than eight months. To do this comparison, a cluster analysis was carried out using the Jaccard coefficient of similarity and a UPGMA algorithm of clustering. To avoid bias, we did not consider in the analysis individuals classified at the taxonomic level of genus or exotic species. We analyzed the consistency of the similarity by a bootstrap analysis with 1,000 permutations, which gives a value (ranging from 0 to 100) stating the percentage of replicates where each node is

Table 1. List from the 13 small mammal surveys used to compose the cluster analysis. The number of species shown does not include those classified at the taxonomic level of genus or exotic species, this is the reason for some studies (including this one) show here fewer species. Acronyms: BA, Bahia state; ES, Espírito Santo state; RJ, Rio de Janeiro state; SP, São Paulo state; SC, Santa Catarina state; RS, Rio Grande do Sul state. Formation: CAF: Coastal Atlantic Forest (maximum of 80 km of the coast); IAF: Interior Atlantic Forest (minimum of 180 km from the coast).

Locality	Formation	Geographic coordinates	Number of species	Reference
Una (BA)	CAF	39°11'W; 15°12'S	15	Pardini 2004
Viana (ES)	CAF	40°29'W; 20°23'S	19	Pinto et al. 2009
Itatiaia (RJ)	CAF	44°34'W; 22°29'S	29	Geise et al. 2004
Cotia (SP)	CAF	46°55'W; 26°36'S	21	Pardini & Umetsu 2006
Florianópolis (SC)	CAF	48°31'W; 27°43'S	10	Graipel et al. 2006
Cambará do Sul (RS)	CAF	50°06'W; 28°58'S	6	Dalmagro & Vieira 2005
Três Barras (SC)	IAF	50°18'W; 26°07'S	8	Cherem & Perez 1996
São Domingos (SC)	IAF	53°33'W; 26°40'S	11	Cherem et al. 2008
Xanxerê (SC)	IAF	52°24'W; 26°36'S	15	Cherem et al. 2012
Mato Castelhano (RS)	IAF	52°11'W; 28°17'S	10	Galiano et al. 2013; Galiano 2010
Erechim (RS)	IAF	52°16'W; 27°38'S	9	Kessel 2011; Kubiak 2010; Kubiak et al. 2009
Chapecó (SC)	IAF	52°42'W; 27°08'S	19	Present study

supported. All of these analyses were performed using PAST software (Hammer et al. 2001). We ran a Mantel test to correlate the matrix of distance in the composition (based on Jaccard) with a matrix of geographic distance. The last matrix was calculated based on the degrees of latitude and longitude (see Table 1) using Euclidean distance. The Mantel test was made in order to determine if spatial autocorrelation was present among the communities. This analysis was developed in the R program for statistical computing (R Core Team, 2014) with the vegan package (Oksanen et al. 2013).

Results

We recorded 779 individuals belonging to 21 small mammal species. Of these, 15 species were rodents and six were marsupials (Table 2). The species accumulation curve showed a tendency for stabilization (Figure 2).

The cluster analysis revealed two distinguished groups with a consistent similarity index (Figure 3). One group was comprised of the formations of southeastern and northeastern Brazil (SE/NE group), where all the locations are less than 80 km of the coast (CAF – Coastal Atlantic Forest) and had distinct forest features from each other. The second group included all of the studies in southern Brazil (SR group), and presents both interior forest formations (IAF – Interior Atlantic Forest, at least 180 km from the coast) and CAF formations. The composition of small mammal species in our study area was more similar to that found in the Erechim and Mato Castelhano municipalities (approximately 100 and 200 km from our study site, respectively). Erechim presents a forest formation very similar to ours, composed by a transition region between semideciduous and Araucaria forests (Budke et al. 2010). Mato Castelhano has a typical mixed ombrophilous forest dominated by *Araucaria angustifolia* (Bertol.) Kuntze (Araucaria forest) (Galiano et al. 2013). Regarding the others locations, IAF, Xanxerê and São Domingos have the same forest characteristics found in this study, a deciduous forest associated with elements from the Araucaria forest (Silva-Filho & Pugues 2008, Netto et al. 2012), and Três Barras was originally composed by Araucaria forests, which currently are found only in small fragments (Cherem & Perez 1996). Still, within the southern group the more extern studies in the cluster occurred in a strict Araucaria forest at Cambará do Sul (Dalmagro & Vieira 2005) and in a Dense Submontane forest at

Table 2. Number of individuals captured and the frequency of occurrence of the 21 species recorded in the period of August 2011 (pilot field) and from October 2011 to September 2012 in Chapecó, Santa Catarina in southern Brazil. The equitability and dominance indices are displayed at the end of table. *This species is undergoing taxonomic revision and its epithet may be changed.

Species	Number of individuals	Frequency of occurrence (%)
Order Rodentia		
Family Cricetidae		
Oligoryzomys flavescens (Waterhouse, 1837)	374	48.01
Akodon montensis Thomas, 1913	188	24.13
Sooretamys angouya (G. Fisher, 1814)	49	6.29
Oligoryzomys nigripes (Olfers, 1818)	40	5.13
Thaptomys nigrita (Lichtenstein, 1829)	35	4.49
Abrawayaomys ruschii Cunha and Cruz, 1979	3	0.38
Brucepattersonius iheringi (Thomas, 1896)	3	0.38
*Juliomys pictipes** (Osgood, 1933)	3	0.38
Necromys lasiurus (Lund, 1841)	1	0.12
Nectomys squamipes (Brants, 1827)	1	0.12
Oxymycterus judex Thomas, 1909	1	0.12
Euryoryzomys russatus (Wagner, 1848)	1	0.12
Family Echimyidae		
Euryzygomatomys spinosus (G. Fisher, 1814)	2	0.25
Family Sciuridae		
Guerlinguetus sp.	1	0.12
Family Muridae		
Mus musculus Linnaeus, 1758	9	1.15
Order Didelphimorphia		
Family Didelphidae		
Didelphis aurita (Wied-Neuwied, 1826)	35	4.49
Monodelphis americana (Müller, 1776)	13	1.66
Gracilinanus microtarsus (Wagner, 1842)	10	1.28
Didelphis albiventris Lund, 1840	5	0.64
Monodelphis dimidiata (Hensel, 1872)	5	0.64
Marmosa paraguayana (Tate, 1931)	1	0.12
Richness		**21**
Individuals		**779**
Dominance		**0.30**
Equitability		**0.55**

http://dx.doi.org/10.1590/1676-06032014012914

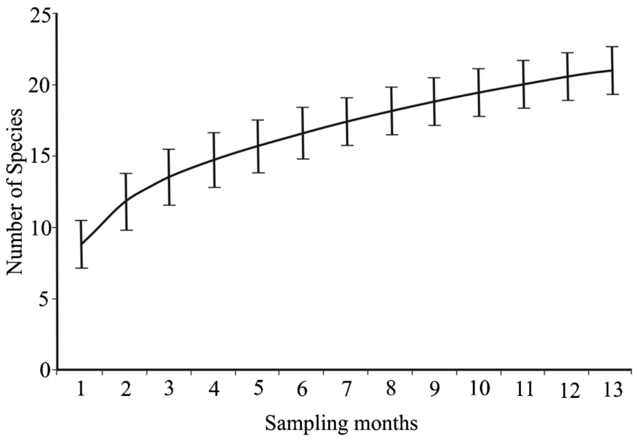

Figure 2. Species accumulation curve. Calculated based on data obtained in the period of August 2011 (pilot field) and from October 2011 to September 2012 in Chapecó, Santa Catarina in southern Brazil. The black line represents the mean, and the bars are the standard deviations generated by 1,000 randomizations. The numbers 1-13 correspond to the sampling months.

Florianópolis (Graipel et al. 2006). These last two localities are very close to the coastline. We found a geographically structured pattern of variation in species composition among the localities with the Mantel test (r= 0.66; *p*= 0.003); we observed that spatially closer populations are more similar in species composition, especially within the southern group, and more distant populations are more dissimilar (Figure 4).

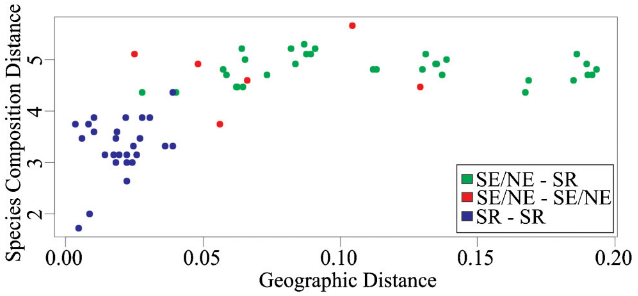

Figure 4. Scatterplot of the pairwise species composition distance against the pairwise geographic distance between localities. The species composition distance was calculated with Jaccard distance, and the geographic distance was calculated by Euclidean Distance. Mantel r = 0.66. SR: Southern; SE/NE: Southeastern/Northeastern.

Discussion

The number of species found in this study (n=21) is similar to other studies carried out in the Atlantic forest and approaches to. Pardini & Umetsu (2006) reported one of the largest numbers of species in the biome (n=23) in Cotia (São Paulo state) by a study using both pitfall traps as cages. Cotia is mostly covered by vegetation classified as dense mountain ombrophilous forest (Metzger et al. 2006). When compared to studies from the nearby areas of the deciduous and Araucaria forests, our results show a substantially greater number of species (Galiano et al. 2013 n=6, Kubiak et al. 2009 n=7; Cherem et al. 2012 n=20, Cherem et al. 2008 n=12, Dalmagro & Vieira, 2005 n=6). This large number of species could be a

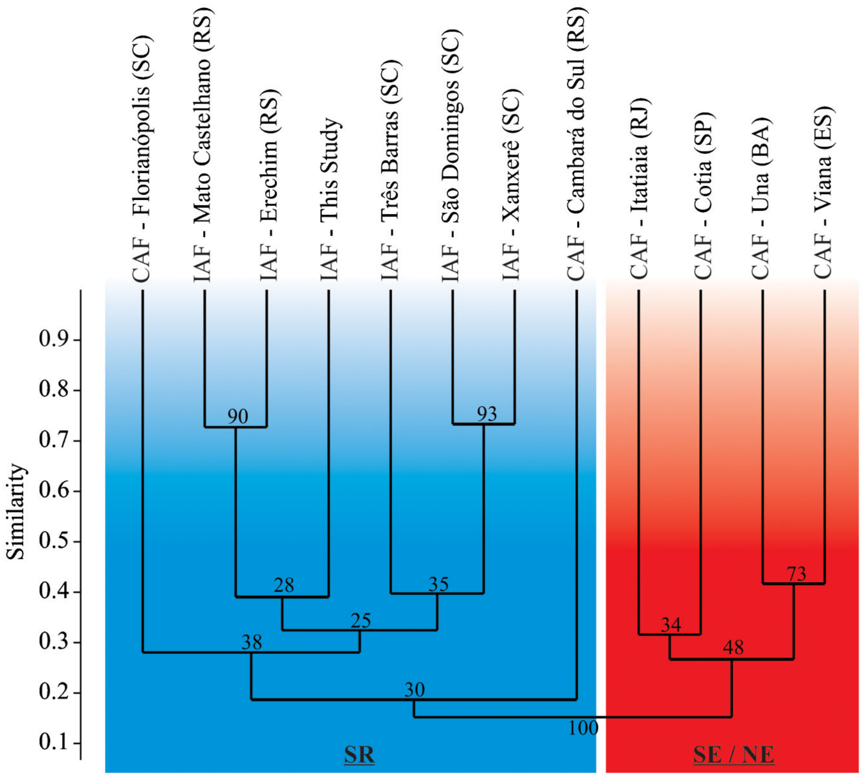

Figure 3. A cluster analysis showing the similarity in small mammal species composition among Atlantic forest localities. The tree was constructed based on Jaccard distance and a UPGMA algorithm. Numbers inside the tree represent the percentage of consistency of the similarity calculated by 1,000 bootstraps. SR: Southern; SE/NE: Southeastern/Northeastern.

result of the conditions provided by the transition region between the both forest formations (as also found by Cherem et al. 2012 in the same forest characteristics). In addition, the high diversity we found is an indication that the interior forest formations may harbor a number of species comparable to those forests nearby the coast, and this might be a result of the presence of different physiognomies at the interior forests.

Despite the high richness found in the area, the fragment sampled is small compared to other sampled areas in the biome (Galiano et al. 2013, Pardini & Umetsu 2006, Geise et al. 2004, Grelle 2003). In addition, the sample area is not protected under a conservation unit. Pardini & Umetsu (2006) provided a summary of 20 surveys of small mammals in Atlantic Forest fragments representing an area greater than 700 ha; however, only two of these studies (Bonvicino et al. 1997 and Pardini & Umetsu 2006) found richness equal to or greater than that reported here. In a study near the Paranapiacaba ecological *continuum*, Leiner & Silva (2012) caught 20 species of small non-volant mammals in one of the largest regions of Atlantic forest (due to the presence of four conservation units). In one of the few surveys conducted in the western region of the state of Santa Catarina, Cherem et al. (2012) recorded 20 species of small non-flying mammals; of these, three were exotic and 17 were native. This last study was also conducted in a non-protected area in a transition region between deciduous and Araucaria forest. Moreover, Cherem et al. (2012) used only cage traps, and their sampling effort was about 3,300 trap/nights, while our sampling effort was much bigger, totaling 6,500 trap/nights. It is important to denote that regions where high richness is associated with high anthropogenic threats, as in the present study, are clearly prioritized for biodiversity conservation, and protection efforts in such areas should be more urgent (Myers et al. 2000). The richness found in the area and the presence of rare and specialized species, such as *Abrawayaomys ruschii* and *Juliomys pictipes* are good indicators of the quality of this fragment in maintaining biodiversity.

The analysis of species composition revealed that forest formations in the Atlantic Forest biome in SR Brazil contain a unique set of species different from those found in SE/NE regions. This is most likely the result of geographic distance (Figure 4) and less clearly the result of the different types of physiognomies. All SE/NE areas are near to the coastline, while southern regions are composed by interior and coastal forests. Inside the southern region, there is one clearly closed cluster composed of interior forest formations that share similar species compositions. This group is composed of communities found in areas with characteristics of Deciduous, Semideciduous and Araucaria forests. The more dissimilar areas within the southern group are the two located near the coastline; one is a Dense Submontane forest (Graipel et al. 2006), and the other is an Araucaria forest (Dalmagro & Vieira 2005). Therefore, the species composition found in our study is more influenced by the nearby communities and physiognomy characteristics of the Deciduous and Araucaria forests, than by distant regions.

Finally, the accumulation curve showed a tendency to stabilization. It is possible that species not yet registered would occur if sampling had continued. This fact, combined with all the data mentioned above, indicates the importance of this fragment in the maintenance of ecosystem diversity, and it is concerning that this area is not legally protected. It is important that more studies be conducted in nearby areas, and also in other interior Atlantic forest formations, in order to track the species diversity in other fragments, which will permit a more accurately assessment of the regional richness and species composition.

Acknowledgements

We thank Martin Maurer, Joana Boschetti and Elaine M. L. Gonsales for help in the field and AURORA Industry for authorization and support for our fieldwork. We thank Rodrigo Fornel, Thales R. O. de Freitas and Carlos Benhur Kasper for reading the manuscript and for valuable suggestions on an early version. We thank the Coordination for the Improvement of Higher Level Personnel (CAPES) for granting a scholarship to the first author and the National Counsel of Technological and Scientific Development (CNPq) for the scholarships granted to the second and third authors.

References

BEGON, M., TOWNSEND, C.R. & HARPER, J.L. 2007. Ecologia: de indivíduos a ecossistemas. 4 ed. Porto Alegre, Artmed.

BONECKER, S.T., PORTUGAL, L.G., COSTA-NETO, S.F. & GENTILE, R. 2009. A long term study of small mammal populations in a Brazilian agricultural landscape. Mammalian Biology, 74:467-477.

BONVICINO, C.R., LANGGUTH, A., LINDBERGH, S.M. & PAULA, A.C. 1997. An elevational gradient study of small mammals at Caparaó National Park, Southeastern Brazil. Mammalia, 61:547-560.

BONVICINO, C.R., LINDBERGH, S.M. & MAROJA, L.S. 2002. Small non-flying mammals from conserved and altered areas of Atlantic forest and cerrado: comments on their potential use for monitoring environment. Brazilian Journal of Biology, 62(4B):765-774, http://dx.doi.org/10.1590/S1519-69842002000500005

BUDKE, J.C., ALBERTI, M.S., ZANARDI, C., BARATTO, C. & ZANIN, E.M. Bamboo dieback and tree regeneration responses in a subtropical forest of South America. Forest Ecology and Management, 260:1345-1349, http://dx.doi.org/10.1016/j.foreco.2010.07.028

CARVALHO, F.M.V., PINHEIRO, P.S., FERNANDEZ, A.S. & NESSIMIAN, J.L. 1999. Diet of small mammals in Atlantic Forest fragments in southeastern Brazil. Revista Brasileira de Zoociências, 1:91-101.

CECHIN, S.Z. & MARTINS, M. 2000. Eficiência de armadilhas de queda (pitfall traps) em amostragens de anfíbios e répteis no Brasil. Revista brasileira de zoologia, 17(3):729-740, http://dx.doi.org/10.1590/S0101-81752000000300017

CHEREM, J.J. & PEREZ, D.M. 1996. Mamíferos terrestres de floresta de araucária no município de Três Barras, Santa Catarina, Brasil. Biotemas, 9(2):29-46.

CHEREM, J.J., ALTHOFF, S.L. & REINICKE, R.C. 2008. Mamíferos. In A fauna das áreas de influência da Usina Hidrelétrica Quebra-Queixo (Cherem, J. J. & Kammers, M. org). Habilis Editora, Erechim, Brasil, p.89-102.

CHEREM, J.J., ALTHOFF, S.L. & TESTONI, A.F. 2012. Mamíferos. In Fisiografia, Flora e Fauna do Rio Irani. (Cherem, J.J. & Samoria, V. org). ETS, Florianópolis, p. 137-159.

DALMAGRO, A.D., & VIEIRA, E.M. 2005. Patterns of habitat utilization of small rodents in an area of Araucaria forest in Southern Brazil. Austral Ecology, 30:353-362, http://dx.doi.org/10.1111/j.1442-9993.2005.01447.x

FONSECA, G.A.B, HERMANN, G., LEITE, Y.L.R., MITTERMEIER, R.A., RYLANDS, A.B. & PATTON, J.L. 1996. Lista anotada dos mamíferos do Brasil. Occasional Papers in Conservation Biology 4. Conservation Internacional, Belo Horizonte, Brazil.

GALIANO, D. 2010. Dinâmica populacional e efeitos de variáveis ambientais sobre a fauna de pequenos mamíferos em um fragmento de floresta com araucária no sul do Brasil. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS.

GALIANO, D., KUBIAK, B.B., MARINHO, J.R. & FREITAS, T.R.O. 2013. Population dynamics of *Akodon montensis* and *Oligoryzomys nigripes* in an Araucaria forest of southern Brazil. Mammalia, 77(2):173-179, http://dx.doi.org/10.1515/mammalia-2011-0128

GALINDO-LEAL, C.,CÂMARA, I.G. (Eds.) 2003. The Atlantic Forest of South America: Biodiversity status, Threats and Outlook. CABS and Island Press, Washington.

GEISE, L., PEREIRA, L.G., BOSSI, D.E.P. & BERGALLO, H.G. 2004. Pattern of elevational distribution and richness of non volant mammals in Itatiaia National Park and its surroundings, in southeastern Brazil. Brazilian Journal of Biology, 64(3B):599-612, http://dx.doi.org/10.1590/S1519-69842004000400007

GRAIPEL, M.E., CHEREM, J.J., MONTEIRO-FILHO, E.L.A. & GLOCK, L. 2006. Dinâmica populacional de marsupiais e roedores no parque municipal da lagoa do Peri, ilha de Santa Catarina, sul do Brasil. Mastozoologia Neotropical, 13(1):31-49.

GRELLE, C.E.V. 2003. Forest structure and vertical stratification of small mammals in a secondary Atlantic forest, southeastern, Brazil. Studies on Neotropical Fauna and Environment, 38:81-85, http://dx.doi.org/10.1076/snfe.38.2.81.15926

HAMMER, O., HARPER, D.A.T. & RYAN, P.D. 2001. PAST: Paleontological Statistics software package for education and data analysis. Paleontologica Eletronica, 4(11). 99p.

KUBIAK, B.B., ESTEVAN, C., GALIANO, D. & MARINHO, J.R. 2009. Comparação da fauna de pequenos mamíferos entre uma área de Floresta Estacional Semidecidual e reflorestamento de *Pinus* sp. Perspectiva (Erexim), 33:155-164.

KUBIAK, B.B. 2010. Efeito de borda sobre *Akodon montensis* Thomas, 1913, e *Oligoryzomys flavescens* Waterhouse, 1837 em um fragmento de floresta ombrófila mista. Trabalho de Conclusão de Curso, Universidade Regional do Alto Uruguai e das Missões, ErechimRS.

LEINER, N.O. & SILVA, W.R. 2012. Non-volant small mammals at an Atlantic forest area situated nearby a limestone quarry (Limeiraquarry), state of São Paulo, Brazil. Biota Neotrop. 12(4): http://www.biotaneotropica.org.br/v12n4/en/abstract?inventory+bn02312042012 (ultimo acesso em: 15/10/2013)

METZGER, J.P., ALVES, L.F., GOULART, W., TEIXEIRA, A.M.G., SIMÕES, S.J.C. & CATHARINO, E.L.M. 2006. Uma área de relevante interesse biológico, porém pouco conhecida: a Reserva Florestal do Morro Grande. Biota Neotrop. 6(2), http://www.biotaneotropica.org.br/v6n2/pt/abstract?article+bn00206022006 (ultimo acesso em 11/08/2014).

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature, 403(6772):853 – 858, http://dx.doi.org/10.1038/35002501

NETTO, R.S., SALMORIA, V. & SANT'ANNA, F.S. 2012. Vegetação. In Fisiografia, Flora e Fauna do Rio Irani. (Cherem, J.J. & Samoria, V. org). ETS, Florianópolis, p.28–32.

OKSANEN, J., BLANCHET, F.G., KINDT, R., LEGENDRE, P., MINCHIN, P.R., O'HARA, R.B., SIMPSON, G.L., SOLYMUS, P., STEVENS, M.H.H. & WAGNER, H. 2013. Vegan: Community Ecology Package. R package version 2.0-7.

PAGLIA, A.P., FONSECA, G.A.B., RYLANDS, A.B., HERRMANN, G., AGUIAR, L.M.S., CHIARELLO, A.G., LEITE, Y.L.R., COSTA, L.P., SICILIANO, S., KIERULFF, M.C.M., MENDES, S.L., TAVARES, V.C., MITTERMEIER, R.A. & PATTON, J.L. 2012. Annotated checklist of Brazilian mammals. 2 ed. Occasional Papers in Conservation Biology n.6, Conservation International, Arlington 76p.

PARDINI, R. & UMETSU, F. 2006. Pequenos mamíferos não-voadores da Reserva Florestal do Morro Grande – distribuição das espécies e da diversidade em uma área de Mata Atlântica. Biota Neotrop. 6(2) http://www.biotaneotropica.org.br/v6n2/pt/abstract?article+bn00606022006 (ultimo acesso em 15/10/2013), http://dx.doi.org/10.1590/S1676-06032006000200007

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

PINTO, I.S., LOSS, A.C.C., FALQUETO, A. & LEITE, Y.L.R. 2009. Pequenos mamíferos não voadores em fragmentos de Mata Atlântica e áreas agrícolas em Viana, Espírito Santo, Brasil. Biota Neotrop. 9(3):355-360 http://www.biotaneotropica.org.br/v9n3/en/abstract?inventory+bn03109032009 (ultimo acesso em: 15/10/2013), http://dx.doi.org/10.1590/S1676-06032009000300030

PYARE, S. & LONGLAND, W.S. 2001. Patterns of ectomycorrhizal-fungi consumption by small mammals in remnant old-growth forests of the Sierra Nevada. Journal of Mammalogy, 82:681-689, http://dx.doi.org/10.1644/1545-1542(2001)082<0681:POEFCB>2.0.CO;2

R Development Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0 .http://www.R-project.org/.

RIBEIRO-JÚNIOR, M.A., ROSSI, R.V., MIRANDA, C.L. & ÁVILA-PIRES, T.C.S. 2011. Influence of pitfall trap size and design on herpetofauna and small mammal studies in a Neotropical forest. Zoologia, 28(1):80-91, http://dx.doi.org/10.1590/S1984-46702011000100012

SILVA-FILHO, F.A. & PUGUES, S. 2008. Vegetação. In A fauna das áreas de influência da Usina Hidrelétrica Quebra-Queixo (Cherem, J.J. & Kammers, M. org). Habilis Editora, ErechimBrasil, p.44-56.

Received 15/10/2013
Accepted 24/11/2014

Biota Neotropica 14(4): e20140036, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

First record of *Corbicula largillierti* (Philippi 1844) in the Paraíba River Basin and potential implications from water diversion of the São Francisco River

Evaldo de Lira Azevêdo[1,3], *José Etham de Lucena Barbosa*, *Teofânia H. D. A. Vidigal*[2], *Marcos Callisto*[2] &

Joseline Molozzi[1]

[1] *Departamento de Biologia, Programa de Pós-graduação em Ecologia e Conservação, Universidade Estadual da Paraíba, Campina Grande, PB, Brazil.*
[2] *Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil.*
[3] *Corresponding author: Evaldo de Lira Azevêdo, e-mail: evaldoazevedo@yahoo.com.br*

AZEVÊDO, E.L., BARBOSA, J.E.L, VIDIGAL, T.H.D.A, CALLISTO, M., MOLOZZI, J. **First record of *Corbicula largillierti* (Philippi 1844) in the Paraíba River Basin and potential implications from water diversion of the São Francisco River.** Biota Neotropica. 14(4): e20140036. http://dx.doi.org/10.1590/1676-0603003614

Abstract: *Corbicula largillierti* is a native mollusk from China. In Brazil, this species was first recorded in the Pantanal of Mato Grosso. This short communication reports the occurrence of *C. largillierti* for the first time in the Paraíba river basin (Brazilian semi-arid), and also considers the risk of introduction of other molluscs invaders in this basin due to the diversion of water from the São Francisco River. Densities of individuals ranged from 33 to 65 ind.m^{-2} (maximum values of 484 ind.m^{-2}) in coarse sediment (gravel, 2-4 mm). The diversion of waters from the São Francisco river can lead to the introduction of new species, enhancing ecological problems in the Paraiba river basin.

Keywords: *Invasive species, Semi-arid, Molluscs, Corbiculidae.*

AZEVÊDO, E.L., BARBOSA, J.E.L, VIDIGAL, T.H.D.A, CALLISTO, M., MOLOZZI, J. **Primeiro registro de *Corbicula largillierti* (Philippi 1844) na bacia do Rio Paraíba e implicações potenciais com a transposição das águas do Rio São Francisco.** Biota Neotropica. 14(4): e20140036. http://dx.doi.org/10.1590/1676-0603003614

Resumo: *Corbicula largillierti* é um molusco nativo da China. No Brasil esta espécie foi registrada primeiramente no Pantanal do Mato Grosso. Esta nota registra a primeira ocorrência de *C. largillierti* na bacia do Rio Paraíba (semiárido brasileiro). Considera também os riscos potenciais de introdução de outros moluscos invasores nesta bacia devido à transposição das águas do Rio São Francisco. As densidades do molusco variaram de 33 a 65 ind.m^{-2} (atingindo valor máximo de 484 ind.m^{-2}) em sedimentos grossos (cascalho, 2-4 mm). A transposição das águas do Rio São Francisco pode ocasionar a introdução de novas espécies exóticas potencializando problemas ecológicos na bacia do Rio Paraíba.

Palavras-chave: *Espécies invasoras, Semiárido, Moluscos, Corbiculidae.*

Introduction

The introduction of exotic species is the second most important cause for biodiversity loss in global scale (Darrigran et al. 2011). Exotic species can become pests (Fernandes et al. 2012) and cause a range of problems with environmental and human health consequences, as well as, economical and even political implications (Shine 2007). Therefore, the study of the dynamics and distribution of invasive species can explain the process of invasion and predict the dispersion patterns of these species (Darrigran et al. 2009).

Corbicula largillierti is a freshwater bivalve belonging to the Corbiculidae family (Bivalvia, Heterodonta, Veneroida) from Asian origin and endemic of lakes from the Yangtze Kiang river systems, in China. In has been found in several areas in South America (Mansur et al. 2004) but for the first time in the Rio de la Plata River, near Buenos Aires (Ituarte 1981). It has latter been recorded in Uruguay (Ituarte 1984) and again in Argentina (Ituarte 1994). In Brazil, *Corbicula largillierti* was first recorded in the Pantanal, Mato Grosso (Callil & Mansur 2002) and latter in the Sinos River basin, Rio Grande do Sul (Mansur & Pereira 2006). Recently, the species was recorded in Minas Gerais, Espírito Santo, Santa Catarina and Ceará states (Silva & Barros 2011). In a recent review, Pereira et al. (2012) reported *C. largillierti* for the Brazilian northeastern coastal basins, the São Francisco River, eastern, southern and southeastern basins, as well as the Paraná/Paraguay and Uruguay basins.

The waters from the São Francisco river will be diverted to the Paraiba river basin (Brasil 2007). This divertion is likely to cause ecological damage to the receiving basins with the introduction of exotic species, water pollution and decrease in discharges of the São Francisco river (Li et al. 2013) as well as proliferation of green algae (Zhu & Ketola 2012).

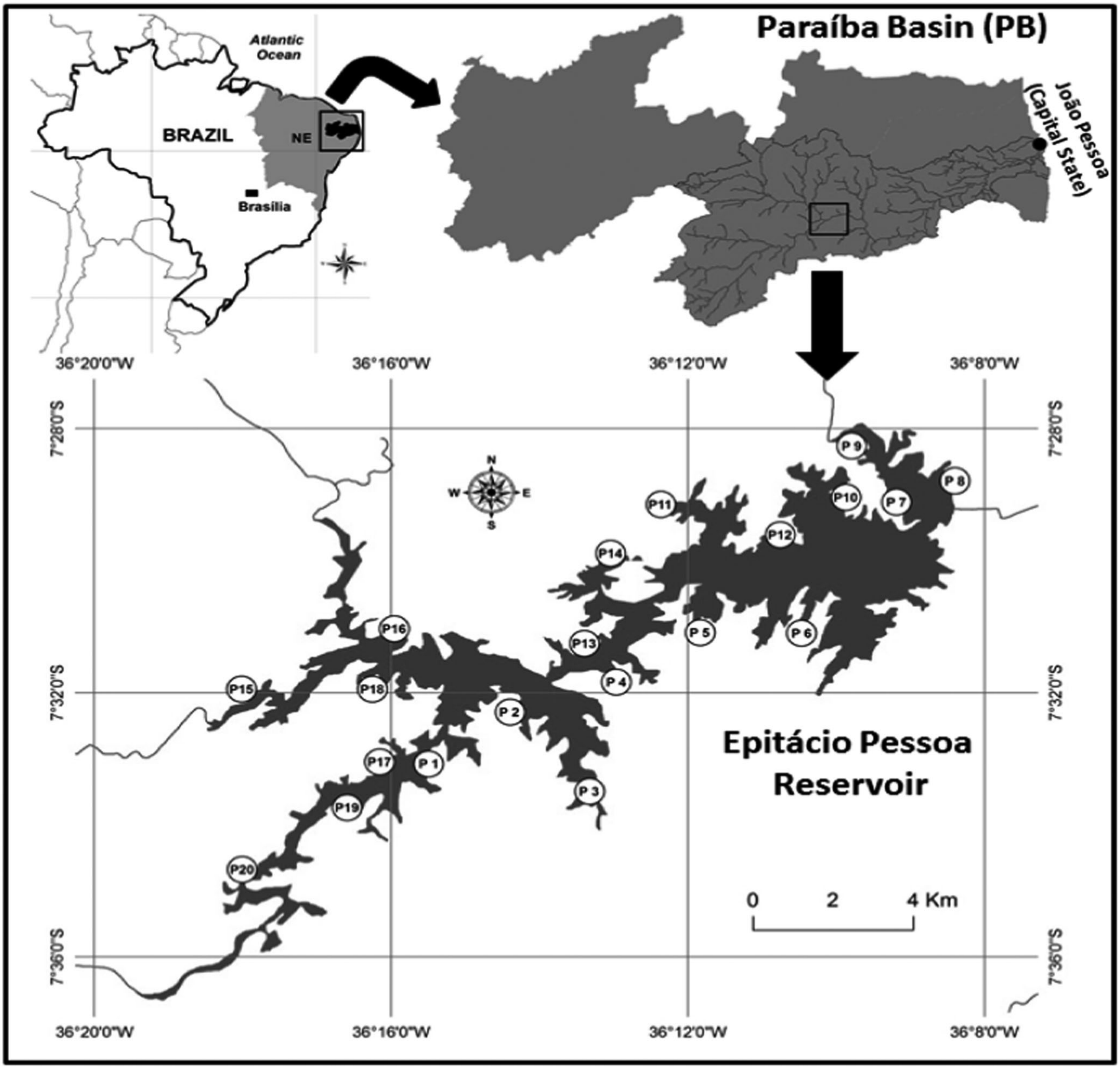

Figure 1. Sampling sites reservoir Epitácio Pessoa, Paraíba River basin, Brazilian semiarid.

This short communication reports the occurrence of *C. largillierti* for the first time in the Paraíba basin river (Brazilian semi-arid) and also considers the risk of the introduction of other mollusc invaders in this basin due to the diversion of waters from the São Francisco River.

Materials and Methods

Study Area

The Paraíba river basin (Figure 1) encompasses an area of 20,071.83 km^2 (6°51'31" - 8°26'21" S; 34°48'35" - 37°2'15" W). This basin is the second largest of the Paraíba State, covering 38% of the State and harboring 1,828,178 inhabitants (52% of the State population). This basin is, therefore, among the most important freshwater systems in the Brazilian semi-arid (Paraíba, 2012) being also a receiver of waters to be diverted from the São Francisco river.

Sampling

The specimens of *C. lagillierti* from the present study were collected in sediment samples from 20 sites taken from the margins of the Epitácio Pessoa reservoir (7° 28'4'' - 7° 33' 32'' S, 36° 8'23'' - 36° 16'51'' W) located in the Paraíba river, Brazilian semiarid region. Samples were taken using a Van-Veen (477 cm^2) dredge in June 2010 and December 2011.

Results and Discussion

Corbicula largillierti is easily mistaken for the *C. fluminea*, the former having a fragile shell, lower height and lower umbos (Mansur & Pereira 2006, Pereira et al. 2012). The

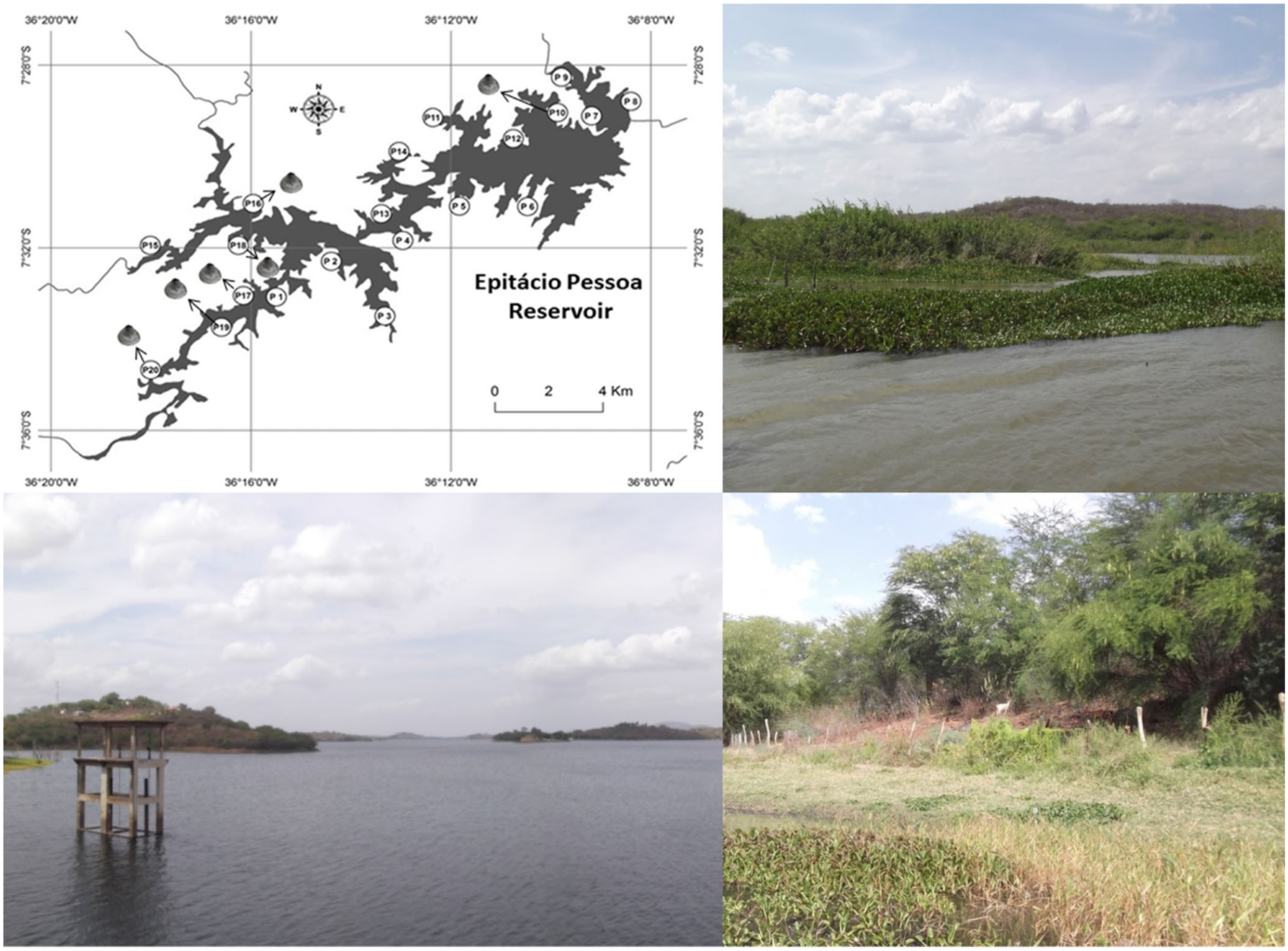

Figure 2. Reservoir Epitácio Pessoa and places of occurrence *Corbicula largillierti*, Paraíba River basin, Brazil.

introduction of Corbiculidae in freshwater ecosystems may alter fish diets and impair industrial activities, leading to economical loss (Darrigran 2002, Santos et al. 2012). It can also cause damage to human health given that some Corbiculidae are bioaccumulators of heavy metals (Darrigran 2002, Santos et al. 2012).

Densities of individuals ranged from 33 to 65 ind.m^{-2} (maximum values of 484 ind.m^{-2}) in coarse sediments (gravel, 2-4 mm), in six sampling sites (Figure 2). Identification of specimens was performed through shell characterization according to Mansur et al. (2004) and Pereira et al. (2012). The specimens were deposited in the Reference Collection of the Malacology and Molecular Systematics Laboratory of Universidade Federal de Minas Gerais, lots LMSM 3582 and 3583 (Figure 3).

The introduction of the mollusk in the study reservoir may have happened due to a variety of reasons. Given the higher densities near entry points of tributary streams into the reservoir, we believe that the mollusk was carried into the reservoir from these affluent tributaries. An alternative is that *Corbicula largillierti* may have been brought along with exotic molluscivorous fish that have been introduced into the reservoir (Gurgel & Fernando 1994). It is known that some species of

Figure 3. Record of *Corbicula largillierti*, reservoir Epitácio Pessoa, Paraíba River basin, Brazil.

mollusks can stay alive even after passing through the digestive tract of fish. Another possible way for the introduction of *Corbicula largillierti* is through the many small boats which are commonly used in the reservoir for fishing, recreation and inspection (Fernandes et al. 2012).

The presence of *C. largillierti* and other introduced species, such as *Melanoides tuberculatus* (Müller 1774) (Caenogastropoda, Thiaridae) (Paz et al. 1995), in the Paraíba river basin are examples of the threat of dispersion of exotic species throughout aquatic systems, which is commonly magnified by river flow and aquatic birds (Figuerola & Green 2002). Furthermore, in a study on niche models, Oliveira et al. (2010) highlighted the potential threat of the introduction of *Limnoperna fortunei* (Dunker 1857) (Bivalvia, Mytilidae) in the São Francisco river basin. With the water diversion from this basin, this species may spread to the Paraiba river basin, affecting native species of fish and mollusks. Another invasive mussel, which has caused serious environmental damage, *Corbicula flumminea* (Muller 1774), has also invaded semiarid ecosystems. There is the risk that shellfish reach the Paraíba River basin as a result of the diversion of waters from the São Francisco River, considering that this has already been recorded in the Hydroelectric of Xingó, in the São Francisco River Basin (state of Sergipe) (Santana et al. 2013).

Water diversions have been reported to alter water flow. In the Paraiba river, which is an intermittent system, it is expected that the water flow become perennial, which will lead to modifications of the habitat characteristics and will favor invasive species (Kingsford 2000). Changes in flow regime have been associated with the invasion success of introduced species. Hence, the water diversion of the São Francisco river invasive species may become established given that (i) the natural water flow is a major player in habitat structure; (ii) aquatic species have specific strategies to respond to flow regime; and (iii) the maintenance of natural patterns of longitudinal and lateral connection are essential to the viability of riverine species (Bunn & Arthington, 2002).

The semi-arid region of Brazil has been receiving alien species for many years. Government policies executed by the Departamento Nacional de Obras Contra a Seca (DNOCS) led to the introduction of 42 species of fish and crustaceans in over 100 reservoirs in the semi-arid region (Gurgel & Fernando 1994). This is a threat to native diversity and highlights the need for more studies on the introduction of species in the semi-arid region, especially as a consequence of the São Francisco river waters diversion.

We propose that future studies on the subject should use a niche modeling approach (e.g.: Peterson and Vieglais 2001) and evaluate limiting abiotic factors in order to predict systems at risk of species invasion (Darrigran et al. 2011).

Acknowledgments

We thank Coordenação Aperfeiçoamento de Pessoal de Nível Superior (Capes) for the provision of a masters scholarship that enabled the development of this work, the Universidade Estadual da Paraíba (UEPB), all of Laboratório de Ecologia de Bentos and Laboratório de Ecologia Aquática (UEPB), Universidade Federal de Minas Gerais. MC was awarded a research productivity grant by the CNPq - Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq No. 302960/2011-2) and a Minas Gerais researcher grant by FAPEMIG - Fundação do Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG PPM-00077/13).

References

CALLIL, C.T. & MANSUR, M.C.D. 2002. Corbiculidae in the Pantanal: history of invasion in souther and South America and biometrical data. Amazoniana 17(1):153-167.

BUNN, S.E. & ARTHINGTON, A.H. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental management 30(4):492-507, http://dx.doi.org/10.1007/s00267-002-2737-0

DARRIGRAN, G. 2002. Potential impact of filter-feeding invaders on temperate inland freshwater environments. Biological Invasions 4(1):145-156, http://dx.doi.org/10.1023/A:1020521811416

DARRIGRAN, G., BOEGER W., BAMBORENEA, C. & MAROÑAS, M. 2009. Evaluation of sampling and analysis techniques for early detection of Limnoperna fortunei (Mytilidae) in limit areas of its distribution. Braz. J. Biol. 69(3):979-980, http://dx.doi.org/10.1590/S1519-69842009000400029

FERNANDES, F.C., MANSUR, M.C.D., PEREIRA, D., FERNANDES, L.U.G., CAMPOS, S.C. & DANELOS, O.M. 2012. Abordagem conceitual dos moluscos invasores nos ecossistemas límnicos brasileiros. In: MANSUR, M.C.D, SANTOS, C.P., PEREIRA, D., PAZ, I.C.P., ZURITA, M.L.L., RODRIGUEZ, M.T.R., NEHRKE, M.V. & BERGONCI, P.E.A. Moluscos límnicos invasores no Brasil: biologia, prevenção e controle. Porto Alegre: Redesp. 19-23.

FIGUEROLA, J. & GREEN, A.J. 2002. Dispersal of aquatic organisms by waterbirds: a review of past research and priorities for future studies. Freshwater Biology 47(1):482-494.

GURGEL, J.J.S. & FERNANDO, C.H. 1994. Fishes in semi-arid northeast Brazil with special reference to the role of tilapias. Internationale Revue der gesamten Hydrobiologie und Hydrographie 79(1):77-94.

ITUARTE, C.F. 1984. Aspectos biológicos de las poblaciones de *Corbicula largillierti* (Philippi, 1844) (Mollusca, Pelecypoda) en el Rio de La Plata. Revista del Museu de La Plata 13(143):231-247.

Received 27/02/2014
Revised 05/09/2014
Accepted 13/10/2014

Biota Neotropica 14(4): e20140038, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

The ethnoecological knowledge of fishermen from three coastal lagoons in the northern of the State of Rio de Janeiro, Brazil

Alexandre Ferreira Lopes[1,3] *& Reinaldo Luiz Bozelli*[2]

[1]*Departamento de Ciências do Meio Ambiente, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.*
[2]*Departamento de Ecologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.*
[3]*Corresponding author: e-mail: alexandrelopes@ufrrj.br*

LOPES, A.F., BOZELLI, R.L. **The ethnoecological knowledge of fishermen from three coastal lagoons in the northern of the State of Rio de Janeiro, Brazil.** Biota Neotropica. 14(4): e20140038. http://dx.doi.org/10.1590/1676-06032014003814

Abstract: *The current study investigated the ethnoecological knowledge developed by fishermen through their fish*ing activities and searched for ways to match such knowledge to empirical data available in the scientific literature. The research involved fishermen from three coastal lagoons in the northern region of the State of Rio de Janeiro, Brazil, who were consulted through semi-structured interviews after the establishment of a trustful relationship over a period of three years with the interviewer. Their knowledge, in addition to its cultural and historical importance to these populations' survival, in many ways matches scientific studies based on an ethnoecological approach. Their knowledge considers reproductive aspects, feeding habits, and migratory fishing as well as the consequences and the importance of sandbar openings to estuarine-dependent species and the understanding of the consequences of sandbar openings to lagoon trophic state and other organisms' control (such as macrophytes). This set of data can contribute to the construction of plans for managing these ecosystems, in which fishermen may have a more important role than at present.
Keywords: *Fishing, co-management, ethnoecology.*

LOPES, A.F., BOZELLI, R.L. **O conhecimento etnoecológico dos pescadores de três lagoas costeiras do norte do Estado do Rio de Janeiro, Brasil.** Biota Neotropica. 14(4): e20140038. http://dx.doi.org/10.1590/1676-06032014003814

Resumo: O presente estudo investigou o conhecimento etnoecológico desenvolvido pelos pescadores no exercício da atividade da pesca, além disso, investigou maneiras de agregar esse conhecimento aos dados disponíveis na literatura científica. A pesquisa envolveu pescadores de três lagoas costeiras na região norte do Estado do Rio de Janeiro, Brasil, os quais foram consultados por meio de entrevistas semiestruturadas após o estabelecimento de uma relação de confiança construida ao longo de três anos. Foi observado que o conhecimento dos pescadores, além de sua importância histórica e cultural para a sobrevivência dessas populações, em muitos aspectos, é compatível com os estudos científicos baseados em uma abordagem etnoecológica. Esse conhecimento se refere aos aspectos reprodutivos, hábitos alimentares, pesca migratória, bem como as conseqüências de aberturas de barra das lagoas para as espécies de estuarino dependentes e seus efeitos no estado trófico e no controle das macrófitas aquáticas. Este conjunto de dados pode contribuir para a construção de uma proposta de manejo para esses ecossistemas, no qual os pescadores possam ter um papel mais relevante do que se apresenta atualmente.
Palavras-chave: *Pesca, manejo compartilhado e etnoecologia.*

Introduction

Coastal lagoons are inland water bodies widely spread along the entire continental coast, and approximately 10% of these systems are located in South America (Barnes 1980). In Brazil, coastal lagoons are viewed as a very important set of freshwater ecosystems. They are distributed along the Brazilian coast mainly in the states of Rio Grande do Sul and Rio de Janeiro (Esteves 1998). Both ecologically and economically important ecosystems due to their high productivity, coastal lagoons support communities that are unique in structure and diversity, making them ecosystems that contain important features in terms of conservation (Gordon 2000). The conservation of those systems is linked to uses established by society.

In addition to the local residents, the government and researchers recognize the role played by fishermen who historically developed a relationship of direct use of fishery resources from these systems. Therefore, we use the ethnosciences in order to understand the relationship between human populations and these ecosystems. Ethnoecology studies concepts and knowledge regarding nature, enabling traditional societies to set and reproduce material and spiritual conditions related to their social existence by means of the appropriate management of their natural resources and ecosystems (Toledo 1990).

The present study aimed to investigate the ecological knowledge developed by fishermen through their fishing activity and to search for ways to match such knowledge to the empirical data available in the scientific literature. It is expected that the final outcomes may provide the basis for a proposal regarding the conservation of these ecosystems, one that comprises different sectors of society and respects all forms of knowledge construction.

Materials and methods

Study area

The research involved fishermen from three lagoons in the northern region of the State of Rio de Janeiro, Brazil. The three lagoons are Saquarema, Imboassica and Carapebus, the last of which is located within the boundaries of the Restinga de Jurubatiba National Park (Figure 1). Carapebus is a coastal lagoon located in Carapebus city; it is isolated from the sea by a sandbar and is part of the sandy coastal plain phytogeographical region. It has an area of 6.5 km^2, with a drainage basin of 126 km^2, and a mean depth of 2.4 m. Imboassica is an impacted urban lagoon located between Rio das Ostras and Macaé cities. It has an area of 3.26 km^2 with a mean depth of 1.09 m and a drainage basin of 50 km^2 (Panosso et al. 1998).

Saquarema lagoon is located at Saquarema city and has an area of 21.2 km^2 with a mean depth of 1.15 m and a drainage basin of 215 km^2 (Wasserman 2000). This lagoon has four different compartments (Mombaça, Jardim, Boqueirão and Lagoa de Fora) and is permanently linked to the sea by a sandbar that has been opened to minimize impacts from sewage disposal.

1. Saquarema: 22°55′06′′S 42°32′08′′O
2. Imboassica: 22°24′41′′S 41°49′47′′O
3. Carapebus: 20°13′42′′S 40°12′43′′ O

Figure 1. Location of Saquarema lagoon (1), Imboassica lagoon (2) and Carapebus lagoon (3) (Illustration: Américo Pastor).

Data sampling

Data sampling was based on qualitative research, including field notes, interviews, chats, photographs and recordings (Quintas 2005), established over a three-year relationship with interviewees. Initially, free interviews were performed to establish mutual trust between researcher and informant. This initial approach has supported the construction of a question script and the definition of interviewees for the semi-structured interviews (Mello 1995, Elliot 2012).

Scripts for the semi-structured interviews had questions related to ecological knowledge, fishing techniques, observation, response of ecosystem to sandbar opening, and management proposals and possibilities.

To take part in the experiment, interviewees from each lagoon were chosen by *snowball sampling* in which some of the interviewees are previously identified and, after being interviewed, are asked to indicate new possible interviewees for the research (Biernacki & Waldorf 1981). Initially, legitimate representatives from all lagoons were contacted. Thus, Carapebus' lagoon Residents Association former president - who is the son of one of the fishermen - was interviewed. After him, two old fishermen were also interviewed. The representative from a fishermen colony at Imboassica - who also works at the Carapebus lagoon - was interviewed in public locations. He is recognized by fishermen from both colonies and other sectors of society as a local leader. At Saquarema lagoon, the interviews were initiated with the fishermen's leader. From his recommendations, two other fishermen were contacted and they indicated five more fishermen, totaling eight fishermen interviewed at this lagoon. Thus, in total, 11 fishermen were interviewed in addition to the chairman of the Association of Residents of Carapebus beach who provided important historical information. The sample was considered sufficient based on the effect of a progressive inclusion that allowed applying the criterion for completeness (Andrade et al. 2006a b). The number of interviewees was adequate for the purpose of this research, given the semi-structured interview questions, which were seeking answers of a technical nature. This research did not target issues related to personal opinions, which would have required a quantitative analysis. Moreover, as already mentioned, the fishermen have long experience in the profession and are recognized among other fishermen as leaders and experts in fisheries in coastal lagoons. The number of interviewees was similar to those used by Costa-Neto et al. (2002) and Costa-Neto (2000) in ethnoichthyological studies. It is worth noting that finding active fishermen at Imboassica lagoon is very rare, due to urbanization, as mentioned by Frota & Caramaschi (1998). Each interview took from 30 to 70 minutes, depending on the interviewees' mood to speak with researchers. All interviews were recorded, for a total of 10 hours of recordings, which are stored at the Limnology Lab of the Federal University of Rio de Janeiro.

Analysis

The recordings were analyzed considering qualitative factors, interpreting the interviewees' speech and searching for as much contrast as possible between the ethnoecological and the scientific knowledge, according to Martins et al. (2011) and Mourão & Nordi (2003). Therefore, based on an ethnoecological approach (Diegues 2002), we presented a data set and discussed the similarities and differences to available scientific knowledge.

Results and discussion

Ecological aspects of ichthyofauna

The fishermen's responses demonstrated a good range of information about the lagoons' ecology. Such knowledge was acquired through their fishing activities. Thus, it differs from scientific knowledge according to origin and validation criteria (Table 1).

Regarding fish origins, the classification system used by the fishermen is extremely similar to that suggested by the scientific community. There are several ways to classify fish from estuarine regions. Fischer et al. (2004) stated that fish are divided into estuarine residents, estuarine dependents and estuarine opportunistic, in addition to freshwater fish. The classification system proposed by the fishermen perfectly meets their needs because the most relevant issue for them is the commercial value given to the fish they catch, as observed by Ramires et al. (2012). Once marine fish hold a higher commercial value than freshwater fish, such a point of view is reasonable enough. Marine and freshwater fish are classified by the fishermen as "white fish" and "black fish", respectively. However, in spite of appearances, the fishermen's classification system shows an interesting level of complexity. Along with the issue of a fish's origin, another factor that demonstrates the logic behind the classification system proposed by the fishermen is related to the reproductive cycle of marine fish. All interviewees state that there is practically no marine fish reproduction in the lagoons, and this observation supports their arguments in favor of open sandbars in coastal lagoons. While fishermen did not list all resident species, they are aware of their existence. The species mentioned are especially those of commercial interest, which reinforces the fact that fishermen do have the knowledge that is essential for their activity. This discussion is extremely relevant because there are commercially important species in the studied lagoons, e.g., *Genidens genidens* (Cuvier, 1829) and *Atherinella brasiliensis* (Quoy & Gaimard, 1825) at the Imboassica lagoon (Frota & Caramaschi 1998), and *Platanichthys platana* (Regan, 1917), *Genidens genidens*, *Atherinella brasiliensis* and *Jenynsia multidentata* (Jenyns, 1842) at the Carapebus lagoon (Sánchez-Botero et al. 2009). Although the fish mentioned by the fishermen, such as *Centropomus parallellus* Poey, 1860 and *Centropomus undecimalis* (Bloch, 1792), are classified by the aforementioned authors as marine dependents, the complex fish classification system among the professionals is highlighted. Similar results were reported by other authors who aimed to inform about species' ethnology (Costa-Neto & Marques 2000); taxonomy (Costa-Neto et al. 2002); habitat preferences (Moura & Marques 2007) and seasonality (Lopes & Begossi 2008). The studies have emphasized the criteria refinement used by the fishermen to create ethnoecological categories.

According to Sánchez-Botero et al. (2008), *Mugil curema* Valenciennes, 1836 and *Mugil liza* Valenciennes, 1836 or mullets, whose occurrence was documented in the region, are marine dependent species. Fischer et al. (2004) asserted that

Table 1. Summary information provided by fishermen

Topic	% mentioned	Statement	Example
Sandbar opening for entrance of different species	100	Favors species that need the lagoon at some life stage	*"Because in the lagoon there are two categories of fish. Black fish and white fish. The black fish is the one that is born and reproduces in the lagoon and has low commercial value, but also important, it is a fish that do not grow too much. The white fish is the one that enters the sea, with high commercial value and reaches 10Kg, 12 Kg."*
How was the learning of fishing	100	With father or older relatives	*"My father... I was raised here in the lagoon"*
Salinity at the lagoons	100	Increases with sandbar opening but decreases after a while	*"The tendency here is to turn into freshwater. The whole lagoon. But in 6 or 8 months it becomes brackish water. In two, three years it is freshwater."*
Sandbar openings and improving of sanitary conditions of the lagoons	81	Entrance of sea-water with higher salinity and output of excess nutrients improves the sanitary conditions of the lagoons	*"Because when the sewage comes, it goes to the bottom. It (sandbar opening) stirred all this mud in the bottom, those things that were quite is now emerged (…) but is leaving, it is leaving, and the sea later will renovate it."* *"I guess, because I'm not a technician nor a scientist, but I guess that salt kills thousands of harmful bacteria, the exceeding vegetation, this black mud, so the salt comes in and clean it"*
Importance of aquatic macrophytes for some fish species	55	Macrophytes act as shelters for larvae of some fish species	*"Disappearing of cattails at Mombaça there are no more fish breeding sites."*
Variations of macrophytes stands	72	Macrophytes increase with eutrophication and decrease with salinity	*"We associate that the amount of sewage proliferates an amount of vegetation, disordered, in excess. Like cattails, water hyacinth..."* *"When it (the lagoon) fills, it brings renewed water from sea to fill enough, to reach the edge of the cattails, the cattails in excess, their roots absorb the salty water and dies, the excess, you see it does not die, the cattails are here."*

mullets inhabit shallow coastal waters, form shoals in order to spawn in the sea, and enter the lagoons for the estuarine phase necessary for juvenile stages (Bizerril & Costa 2001). Such scientific information corroborates the observation by a fisherman at Imboassica lagoon that these fish leave the lagoon to spawn at sea, which usually happens in June. Costa-Neto (2000) also observed that fishermen from the State of Bahia note June as the spawning time for this species. The information from the fisherman about the mullets' reproductive cycle was obtained when he was questioned about the species' closed season and the impossibility of opening sandbars. As he said: "What is the purpose of forbidding fishing during the breeding season if they cannot breed in the lagoon and cannot leave it once the sandbars cannot be opened?"

The argument in favor of sandbar openings is based on fish reproductive cycles and is supported by the assumption that marine species ("white fish") are part of the ichthyofauna in the lagoon. The motivation for opening sandbars concerns not only fish entering lagoons but also the need for estuarine dependent species to exit the lagoons. Thus, considering that fishermen have a grasp of factors such as population fluctuation, fish biology, fishing losses and temporal factors, it was clear that their proposals regarding the lagoons' management are worth consideration.

In addition to the reproductive issue, fishermen demonstrated a good understanding about the diet of some fish species. They realized that, just as other animals, fish have a varied diet, with some feeding on plants and others on other animals – such as small crustaceans -and even on other fish. They also talked about the habit of some fish that re-suspend sediments in their search for food. This knowledge indicated that fishermen are aware of the complexity of trophic interactions in the lagoons. According to Paiva et al. (2008), *Diapterus rhombeus* (Cuvier, 1829) shows preference for feeding on small benthic invertebrates. Moreover, Costa-Neto & Marques (2000) have identified- among fishermen and among the corresponding scientific literature - the awareness of foraging habits of certain species from benthic regions. Mullets, on the other hand, feed on small algae and detritus (Fischer et al. 2004) and present the strategy -mentioned by an interviewee- of re-suspending sediments in order to access items that are part of their diet. Such feeding behavior is also described by Costa-Neto & Marques (2000) and Ramires et al. (2007).

Some species had been identified by the fishermen as predators. According to one of them, *C. parallellus, Hoplias malabaricus* (Bloch, 1794) and *Caranx latus* Agassiz, 1831, are examples of predatory fish. According to the scientific literature, these three species feed on fish and invertebrates (Silvano 2001, Sánchez-Botero et al. 2008). The first two are piscivorous, both in number of food items and consumed biomass (Loureiro & Hahn, 1996, Toniniet al. 2007), whereas *C. latus* eats both fish and invertebrates, but the consumed biomass of fish is higher than the invertebrates'(Silvano 2001). *Clarias gariepinus* (Burchell, 1822), described by a fisherman as a "terrifying predator", presents few restrictions on feeding habits and its diet can consist of terrestrial invertebrates, aquatic insects, fish, crustaceans, mollusks, fish eggs, aquatic macrophytes and detritus (Groenewald 1964, Mwebaza-Ndawula 1984, Spataru et al.1987, Dadebo 2000).

In addition to being aware of this species' potential, fishermen are also concerned about the impacts caused by exogenous species. They demonstrated this concern by mentioning the occurrence of *Tilapia rendalli* (Boulenger, 1897) and *Clarias gariepinus* at the Imboassica lagoon. According to Caramaschi et al. (2004), the occurrence of *T. rendalli* on 10 mm mesh hauls went from 34% - between 1991 and 1993 – up to 66% - between 2000 and 2003 - at the Imboassica lagoon. According to the authors, such dominance is favored by salinity decrease during the closed periods of sandbars and by the species' colonizing ability. Fishermen have also demonstrated knowledge that the existence of exotic species can cause changes in the community. This understanding is clear to them because such changes modify species appearing in fishing nets and can bring economic losses due to a possible reduction of the availability of marine species. Despite the fact that *T. rendalli* has a good acceptance in the market, and as a result is often caught by fishermen, the species of marine origin are the most valuable for these professionals.

Fishermen's knowledge about fish feeding habits is widely discussed in ethnoecology studies. The results indicate detailed knowledge on specific criteria such as reproductive features. Fishermen recognize fish as generalists and specialists (Costa-Neto & Marques 2000), omnivorous, opportunists, carnivorous, planktivorous, iliophagous and piscivorous (Mourão & Nordi 2003). Furthermore, Mourão & Nordi (2003) state that the fishermen at the estuary of the Mamanguape River recognize a large variety of fish behaviors such as reproduction, sound emission, odor release, feeding, migration and protection from predators. Their behavior had also been observed by fishermen interviewed during our research. In a broader sense, Diegues (2002) states that fishermen are aware of fish behavior, location, availability and that they know about the species distribution as well as about taxonomic and habit classifications.

Lagoons physical and chemical features

Marine fish are the fishermen's primary target, but the fishermen also seem to understand other factors related to the ecosystem as a whole, such as salinity. A fisherman at Carapebus lagoon described a sequence of events that goes from salt water, right after the bar was opened, going to brackish water 6 months later and up to freshwater after a few years. Such a sequence is common in all the lagoons that have regular contact with the sea, where rain and river waters are the main sources for freshwater. Therefore, the time required for salinity reduction varies, because depending on the rainfall season, it could happen for a few months, as described by Santangelo (2009) at Imboassica lagoon, or for a year, as mentioned by the fisherman and Sánchez-Botero (2005).

A fisherman at Saquarema lagoon mentions the different salinity in distinct lagoon regions: "this first lake salinity is 35, almost equal to sea. At Boqueirão it is 30, and at Mombaça it is 25 according to our recent observations". Another fisherman at the same lagoon knows about the long-term changes in the salinity at Saquarema lagoon: "nowadays, it is more salty". The salinity data are corroborated by Wasserman (2000) and Azevedo (2005). The former author showed that inner lagoons' regions (Boqueirão e Mombaça) at Saquarema lagoon have lower salinity values than the region known as "Lagoa de Fora", and the latter states that after the permanent opening of the sandbar, the same region has salinity nearly equal to that of the sea.

Still concerning salinity, the fishermen believe that sea water intrusion leads to a decrease in pathogenic bacteria proliferation; these are present in the lagoon, due to non-treated sewage outflow. The fisherman at Imboassica lagoon reported that when salinity increases, the amount of "harmful" bacteria decreases, as does the amount of vegetation (macrophytes). Mallin et al. (2000) found that the abundance of pathogenic bacteria presents a negative correlation to an increase in salinity, a fact that was confirmed by Lutterbach et al. (2001), Meirelles-Pereira (2002) and Ajayi & Akonai (2003). Low salinity lagoons, such as Carapebus, usually have large macrophyte stands dominated by *Typha domingensis* Pers (Farjalla et al. 1999). On the other hand, the opposite condition was confirmed by Glenn et al. (1995) and Macek & Rejmánková (2007). According to Palma-Silva (1998), *T. domingensis* is the species of the genus *Typha* more tolerant to brackish water and is also tolerant to seawater intrusion in Imboassica lagoon. However, considering other authors' results, such a tolerance does not prevent its decrease in periods of sandbar openings.

Lagoons trophic features

Sandbar openings, in general, are related to trophic features in lagoons. The lagoons were historically surrounded by houses (Imboassica and Saquarema), crops and industries (Carapebus) that drain their sewage into such freshwater systems. Regarding this particular subject, the fisherman at Imboassica lagoon understands important concepts about the lagoon's trophic state. This understanding could first be seen when he mentioned the sewage deposition in the sediment and also when he talked about the relationship between sandbar openings and the nutrient's excessive outputs. Fishermen at Saquarema lagoon report differences between the closed sandbar period and the current period of permanent opened sandbar. According to them, after this change in the lagoon dynamics, there was no fish mortality, which was common in earlier times. As they said: "The constant opened sandbar was good because at first there was a great deal of fish mortality; many fish died when the water heated during warm weather. That is the only advantage of this permanently opened sandbar: there is no more fish mortality". "There used to be great fish mortality. This channel was good for the lagoon. Because the sandbar is opened. The channel is opened. Since it is this way, what was the fish mortality? None."

The aforementioned mortality is related to two common phenomena in lagoons that have periodical sandbar openings: fish death caused by the sanitary conditions of the lagoon, leading to high organic matter decomposition and oxygen consumption, when the lagoon receives effluents and remains closed for a long period (Esteves 2011), and after openings that promote seawater input, leading to the death of freshwater fish (Frota & Caramaschi 1998).

This specific case has been discussed by the scientific community; systematic openings may contribute to the export of nitrogen forms, which does not happen with phosphorus. Because phosphorus is deposited on the bottom, it is re-suspended, enriching the water column, and is accumulated in the lagoons over the years (Meirelles 2003, Bozelli et al. 2009). This highlights the gaps in fishermen's knowledge. Based on this case, Johannes et al. (2000) argue that even though there are flaws in the fishermen's knowledge about the system, such gaps also exist in the scientific knowledge. Such a conclusion supports part of the present research's proposal, which does not intend to diminish the importance of a certain form of knowledge in favor of another. It is meant to reinforce the dialogue between the various existing forms of knowledge.

Aquatic macrophytes

The fishermen argued that excessive amounts of macrophytes are a problem for their activities. They reported some activities performed by the plants as well as the response to the changes caused by the sandbar openings. According to the fisherman at Imboassica lagoon, many aquatic macrophyte species are found in the lagoon. Due to sewage disposal, there is an increase in the density of some of them, which can be an obstacle for sailing.

The species mentioned by him (*Nymphaea ampla* (Salisb.) DC., *Typha domingensis* Pers and *Eichhornia crassipes* (Mart.) Solms are aquatic macrophytes found at Imboassica lagoon (Lopes-Ferreira 1998, Santos & Esteves 2004). *Cyperus rotundus* L. and *Brachiaria* sp. are terrestrial and invasive worldwide species that can colonize transitional areas of aquatic systems and that can become mixed with aquatic macrophytes, depending on the water level (Ricci et al. 2000). The macrophytes mentioned by the fishermen include free-floating and attached macrophytes as well as submerged and emergent macrophytes, including charophytes.

In addition to the information given on the species found in the lagoon, the fisherman discussed the macrophytes' expansion and the consequent reduction of the water surface, and he associated the plants spreading with the increase of sewage discharge in the lagoon. Such information is quite similar to results found by Palma-Silva (1998). The author assumes that *T. domingensis* Pers. development is favored by eutrophication, because - near the sewage channel - the species presents higher growth rates compared to other species that are not influenced by nutrient loading. It is corroborated by Macek & Rejmánková (2007), who state that *T. domingensis* Pers. responds mainly to nitrogen and phosphorus additions.

Despite the fact that macrophytes in excess are considered as obstacles by fishermen, its total absence is harmful for the reproductive cycles of some species as mentioned by fishermen at Saquarema lagoon. These fishermen state that "with the disappearance of cattails (*T. domingensis* Pers.) at Mombaça, there is no more fish breeding". The use of macrophytes by different fish species in coastal lagoons is highlighted by Sánchez-Botero et al. (2008). According to them, some species are highly dependent on such environments, for both feeding in juvenile or adult stages and for using macrophytes for parental fish eggs and larval care. Similar results were found by Sánchez-Botero & Araujo-Lima (2001) in floodplain lakes in the central Amazon. The authors claim that macrophyte roots create an important nursery for many species in these ecosystems, including the commercially important ones.

The relevance of ethnoecological knowledge

The type of information presented by the current study, according to its historical value, displays what we call innate relevance or, as stated by Berkes et al. (1995): "by itself and the socio-cultural value." Moreover, one should take into consideration that such knowledge "through generations ensure the sustenance of human populations by using natural resources" and that an essential factor to the present discussion is the fact that many areas are currently protected, were preserved and kept a high biodiversity while being inhabited and managed by traditional populations (Diegues & Viana 2004).

When analyzed by means of an ethnoscientific point of view, the information given by the fishermen indicates a high correlation to scientific knowledge, just as it was observed in several regions of Brazil by Costa-Neto (2000), Costa-Neto & Marques (2000), Silvano et al. (2006), Costa-Neto et al. (2002), Mourão & Nordi (2003), Thé (2003), Silvano & Begossi (2005), Rosa et al. (2005), Mourão & Nordi (2006), Grando (2006), Moura & Marques (2007), Ramires et al. (2007) and others. Thus, according to the aforementioned authors, such knowledge gives to the fishermen the status of essential partners when studying and managing ecosystems of which they are a part, exactly as stated by Berkes et al. (1998). Therefore, these people's knowledge should be taken into account by decision makers when elaborate projects of local conservation are proposed for both the maintenance of wildlife and access to this natural resource (Pereira & Schiavetti 2010).

In general, fishermen can provide information about temporal factors (annual, seasonal, daily, lunar, tide-related), pointing to different behaviors, habitats and species abundance and stating how these influence fishing strategies. In cases in which long-term data are unavailable, older fishermen may also be the only source of information regarding historical changes in fish stocks and on environmental conditions. Fishermen's ecological knowledge can thus help improve management of fish stocks and rebuilding of marine ecosystems (Johannes et al. 2000). Nevertheless, there are cases in which observations reported by fishermen –essential to decisions regarding fishing strategies -are not supported by the ichthyological literature. They are viewed as folklore or popular belief, even with the existing gaps in scientific knowledge. Accordingly, the relevance of partnerships between scientific and local knowledge becomes evident for research development (Mourão & Nordi 2003).

Based on the scenario presented by the current study, we refer to Gadgil & Berkes (1991), who have proposed rethinking and rebuilding the sciences involved in ecosystems management, making these better suited to fulfill the needs of ecological sustainability and of the people who use such resources. To do so, it is imperative to maintain both biological and cultural diversity, because together, they offer a variety of practices and traditional management resource systems. In sum, collective-choice rules affect who is involved in deciding about future rules and how preferences will be aggregated (Ostrom et al. 1999).

Acknowledgements

Thanks to PPGE/UFRJ, Capes, to ICMBio, Petrobras, CNPq, Projeto Pólen, to the members of the UFRJ Limnology Lab, to Adriana de Melo Rocha and Américo Pastor, to everyone who contributed to the present research and, especially, to the fishermen who made the work possible.

References

ANDRADE, C.T.S., MARQUES, J.G.W. & ZAPPI, D. 2006. Utilização de cactáceas por sertanejos baianos. Tipos conexivos para definir categorias utilitárias. Sitientibus Série Ciências Biológicas 6 (Etnobiologia). 3(12):3-12.

ANDRADE, C.T.S., MARQUES, J.G.W. & ZAPPI, D. 2006. Utilização medicinal de cactáceas por sertanejos baianos. Rev. Bras. Pl. Med., Botucatu. 36(8):36-42.

AJAYI, A.O. & AKONAI, K.A. 2003. Antibiotic sensitivity profile of microorganisms encountered in the Lagos lagoon, Nigeria. Afr. J. Biomed. Res. 6(2):79-84.

AZEVEDO, F.B.B. 2005. Modelagem da capacidade de suporte da laguna de Saquarema – RJ após a abertura de uma conexão permanente com o mar. Dissertação de mestrado, Universidade Federal Fluminense, Niterói.

BARNES,R.S.K. 1980. Coastal lagoons. Cambridge University Press.

BEGOSSI, A. 2006. Temporal stability in fishing spots: conservation and co-management in Brazilian artisanal coastal fisheries. Ecol soc. 11(1):5. http://www.ecologyandsociety.org/vol11/iss1/art5/.

BERKES, F., KISLALIOGLU, M., FOLKE, C. & GADGIL, M. 1998. Exploring the Basic Ecological Unit: Ecosystem-like Concepts in Traditional Societies. Ecosystems. 1(5):409-415, http://dx.doi.org/10.1007/s100219900034

BERKES, F., FOLKE, C. & GADGIL, M. 1995. Traditional ecological knowledge, biodiversity, resilience and sustainability. In Biodiversity conservation: problems and policies. (C.S. Perrings, K.G. Müler, C. FOLKE, C.S. HOLLING, & B.O. JANSSON, eds.). Dordrecht, Kluwer Academic.

BIERNACKI, P. & WALDORF, D. 1981. Snowball sampling problems and techniques of chain referral sampling. Sociol. Methods Res. 10(2):141-163.

BIZERRIL, C.R.S.F. & COSTA, P.A. 2001. Peixes Marinhos do Estado do Rio de Janeiro. Rio de Janeiro: Fundação de Estudos do Mar (FEMAR) Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável do Estado do Rio de Janeiro.

BOZELLI, R.L., CALIMAN, A., GUARIENTO, R.D., SANTANGELO, J.M., LEAL, J.J.F., ROCHA, A.M., QUESADO, L.B., MARINHO, P.L., FARJALLA, V.F & ESTEVES, F.A. 2009. Interactive Effects of Environmental Variability and Human Impacts on the Long-Term Dynamics of Neotropical Aquatic Ecosystems. Limnologica. 39:306-313, http://dx.doi.org/10.1016/j.limno.2009.06.004

CARAMASCHI, E.P., SÁNCHEZ-BOTERO, J.I., BRANDÃO, C.A.S., SOARES, C.L., NOVAES, J.L.C., ARAÚJO, B.R. 2004. Peixes das lagoas costeiras de Macaé: Estudos de caso. In Ecologia, História Natural e Conservação da restinga do Parque Nacional de Jurubatiba. (C.F.D. Rocha, F.A. Esteves & F.R. Scarano, eds). Rio de Janeiro.

COSTA-NETO, E.M. 2000. Sustainable development and traditional knowledge: a case study in a brazilian artisanal fishermen's community. Sustain Dev. 8:89-95, http://dx.doi.org/10.1002/(SICI)1099-1719(200005)8:2<89::AID-SD130>3.0.CO;2-S

COSTA-NETO, E.M., DIAS, C.V. & MELO, M.N. 2002. O conhecimento ictiológico tradicional dos pescadores da cidade de Barra, região do médio São Francisco, Estado da Bahia, Brasil. Acta sci. 34(11):561-573.

COSTA-NETO, E.M. & MARQUES, J.G.W. 2000. Etnoictiologia dos pescadores artesanais de Siribinha, município de Conde (Bahia): aspectos relacionados com a etologia dos peixes. Acta Sci. 22(2):553-560.

DADEBO, E. 2000. Reproductive biology and feeding habits of the catfish *Clarias gariepinus* (Burchell) (Pisces: Clariidae) in lake Awassa, Ethiopia. Ethiop J Health Sci. 23(2):231-246.

DIEGUES, A.C. 2002. Traditional Fisheries Knowledge and Social Appropriation of Marine Resources in Brazil. Mare Conference: People And The Sea, Amsterdam.

DIEGUES, A.C., & VIANA, V.M. 2004. Comunidade tradicionais e manejo dos recursos naturais na mata atlântica. 2^a Ed. Hucitec: NUPAUB. São Paulo.

ELLIOT, L.G. 2012. Instrumentos de avaliação e pesquisa: caminhos para construção e validação. Wak Editora. Rio de Janeiro.

ESTEVES, F.A. 1998. Lagoa Imboassica: impactos antrópicos, propostas mitigadoras e sua importância para a pesquisa ecológica. In Ecologia de lagoas costeiras do Parque Nacional da Restinga de

Jurubatiba e do Município de Macaé (RJ). (F.A. Esteves, ed) Macaé..

ESTEVES, F.A. 2011. Fundamentos de Limnologia. 3. ed. Rio de Janeiro: Interciência, 2011. v. 1.

FARJALLA, V.F., MARINHO, C.C., ESTEVES, F.A. 1999. Aspects of the uptake of dissolved oxygen in the initial stages of decomposition of aquatic macrophytes and detritus from terrestrial vegetation in a tropical coastal lagoon. Acta Limnol. Bras. 11:185-193.

FISHBASE. http://www.fishbase.org/home.htm (last access at 09/09/2014)

FISCHER, LG., PEREIRA, L.E.D. &VIEIRA, J.P. 2004. Peixes estuarinos e costeiros. Ecoscientia. Rio Grande.

FROTA, L.O.R. & CARAMASCHI, E.P. 1998. Aberturas artificiais de barra da Lagoa Imboassica e seus efeitos sobre a fauna de peixes. In Ecologia de lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do Município de Macaé (RJ). (F.A. Esteves, ed). Macaé.

GADGIL, M. & BERKES, F. 1991. Traditional resource management systems. Resour Manage Opt. 8(3-4):127-141.

GLENN, E., THOMPSON, T.L., FRYE, R., RILEY, J. & BAUMGARTNER, D. 1995. Effects of salinity on growth and evapotranspiration of *Typha domingensis* Pers. Aquatic Botany. 52(1–2):75-91, http://dx.doi.org/10.1016/0304-3770(95)00492-I

GORDON, C. 2000. Hypersaline lagoons as conservation habitats: macro-invertebrates at Muni Lagoon, Ghana. Biodivers Conserv. 9(4):465-478, http://dx.doi.org/10.1023/A:1008906503227

GRANDO, R.O. 2006. Conhecimento Etnoecológico de Pescadores da Praia do Forte, Litoral Norte - BA: Um Saber Ameaçado. Enciclopédia Biosfera, N.02.

GROENEWALD, A.A.V.J. 1964. Observations on the food habits of *Clarias gariepinus* Burchell, the South African freshwater barbel (Pisces: Clariidae) in Transvaal. Hydrobiologia. 23(1–2):287-291, http://dx.doi.org/10.1007/BF00043737

JOHANNES, R.E., FREEMAN, M.M.R. & HAMILTON, R.J. 2000. Ignore fishers' knowledge and miss the boat. Fish Fish. 1(3):257-271, http://dx.doi.org/10.1046/j.1467-2979.2000.00019.x

LOPES, P.F, M., & BEGOSSI, A. 2008. Temporal changes in caiçara artisanal fishing and alternatives for management: a case study on the southeastern Brazilian coast. 8(2):53-62 http://www.biotaneotropica.org.br/v8n2/en/abstract?article+bn00708022008 (last access at 05/03/2014).

LOPES-FERREIRA, C. 1998. Redução das concentrações de nitrogênio e fósforo dos efluentes lançados na lagoa Imboassica, através de uma região colonizada por macrófitas aquáticas. In Ecologia de lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do Município de Macaé (RJ). (F.A Esteves, ed). Macaé.

LOUREIRO, V.E. & HAHN, N.S. 1996. Dieta e atividade alimentar, *Hoplias malabaricus* (Bloch, 1794) (Osteichthyes, Erythirinidae), nos primeiros anos de formação do reservatório de Segredo, PR. Acta Limnol. Bras. 8:195-205.

LUTTERBACH, M.T.S., VAZQUEZ, J.C., PINET, J.A., ANDREATA, J.V. & SILVA, A.C. 2001. Monitoring and spatial distribution of heterotrophic bacteria and fecal coliforms in the Rodrigo de Freitas Lagoon, Rio de Janeiro, Brazil. Braz. Arch. Biol. Technol. 44(1):7-13, http://dx.doi.org/10.1590/S1516-89132001000100002

MACEK, P. & REJMÁNKOVA, E. 2007. Response of emergent macrophytes to experimental nutrient and salinity additions. Funct. Ecol. 21:478-488, http://dx.doi.org/10.1111/j.1365-2435.2007.01266.x

MALLIN, M.A., WILLIAMS, K.E., ESHAM, C.R., & LOWE, R.R. 2000. Effect of human development on bacteriological water quality in coastal watersheds. Ecol. appl. 10(4):1047-1056, http://dx.doi.org/10.1890/1051-0761(2000)010[1047:EOHDOB]2.0.CO;2

MARTINS, V.S., SCHIAVETTI, A. & SOUTO, F.J.B. 2011. Ethnoecological knowledge of the artisan fishermen of octopi (*Octopus* spp.) in the community of Coroa Vermelha (Santa Cruz Cabrália, Bahia). An. Acad. Bras. Cienc. 83(2):513-522, http://dx.doi.org/10.1590/S0001-37652011000200011

MEIRELLES, F.S.P. 2003. Variação da profundidade da coluna d'água e sua influência sobre a ecologia da lagoa Imboassica (Macaé, RJ) e do lago Batata (Oriximiná, PA). Dissertação de mestrado, Universidade Federal do Rio de Janeiro. Rio de Janeiro.

MEIRELLES-PEREIRA, F. 2002. Ecological aspects of the antimicrobial resistance in bacteria of importance to human infections. Braz. J. Microbiol. 33(4):287-293.

MELLO, L.G. 1995. Antropologia Cultural: iniciação, teoria e temas. Vozes. Petrópolis.

MOURA, F.B.P. & MARQUES, J.G.W. 2007. Conhecimento de pescadores tradicionais sobre a dinâmica espaço-temporal de recursos naturais na Chapada Diamantina, Bahia. 7(3):119-126 http://www.biotaneotropica.org.br/v7n3/pt/abstract?article+bn0180703200. (last access at 05/03/2014).

MOURÃO, J.S. & NORDI, N. 2003. Etnoictiologia de pescadores artesanais do estuário do rio Mamanguape, Paraíba, Brasil. B. Inst. Pesca, São Paulo. 29(1):9-17.

MOURÃO, J.S. & NORDI, N. 2006. Pescadores, peixes, espaço e tempo: uma abordagem etnoecológica. Interciencia (Caracas). 31:358-363.

MWEBAZA-NDAWULA, L. 1984. Food and feeding habits of *Clarias mossambicus* from four areas in the Lake Victoria basin, East Africa. Environ. Biol. Fisches. 10:69-76, http://dx.doi.org/10.1007/BF00001663

OSTROM, E., BURGUER, J., FIELD, C.B., NORGAARD, R.B. & POLICANSKY, D. 1999. Revisiting the commons: local lessons, global challenges. Science. 284:278-282, http://dx.doi.org/10.1126/science.284.5412.278

PAIVA, A.C.G., CHAVES, P.T.C. & ARAÚJO, M.E. 2008. Estrutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. Rev. Bras. Zool. 25(4):647-661, http://dx.doi.org/10.1590/S0101-81752008000400010

PALMA-SILVA, C. 1998. Crescimento e Produção de *Typha domingensis* Pers na lagoa Imboassica. In Ecologia de lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do Município de Macaé (RJ). (F.A. Esteves, ed). Macaé.

PANOSSO, R.F., ATTAYDE, J.L. & MUEHE, D. 1998. Morfometria das lagoas Cabiúnas, Comprida e Carapebus: implicações para seu funcionamento e manejo. In Ecologia de lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do Município de Macaé (F.A Esteves, ed). Macaé.

PEREIRA, J.P.R & SCHIAVETTI, A. 2010. Conhecimentos e usos da fauna cinegética pelos caçadores indígenas "Tupinambá de Olivença" (Bahia). 10(1):175-183 http://www.biotaneotropica.org.br/v10n1/ pt/abstract?article+bn03210012010. (last access at 05/03/2014).

QUINTAS, J.S. 2005. Introdução à gestão ambiental pública. Ibama. Brasília.

RAMIRES, M., MOLINA, S.M.G., HANAZAKI, N. 2007. Etnoecologia caiçara: o conhecimento dos pescadores artesanais sobre aspectos ecológicos da pesca Biotemas. 20(1):101-113.

RAMIRES, M., CLAUZET, M. & BEGOSSI, A. 2012. Folk Taxonomy of Artisanal Fishermen of Ilhabela (São Paulo/Brazil). 12(4): 000-000. http://www.biotaneotropica.org.br/v12n4/pt/fullpaper?bn00412042012+en. (last access at 09/04/2014).

RICCI, M.S.F., ALMEIDA, D.J., FERNANDES, M.C.A., RIBEIRO, R.L.D. & CANTANHEIDE, M.C.S. 2000. Efeitos da solarização do solo na densidade populacional da tiririca e na produtividade e hortaliças sob manejo orgânico. Pesq. Agropec. Bras. Brasília. 35(11):2175-2179, http://dx.doi.org/10.1590/S0100-204X2000001100008

ROSA, I.M.L., ALVES, R.R.N., BONIFÁCIO, K.M., MOURÃO, J.S., OSÓRIO, F.M., OLIVEIRA, T.P.R. & NOTTINGHAM, M.C. 2005. Fishers' knowledge and seahorse conservation in Brazil. J Ethnobiol Ethnomed. 1:1-12, http://dx.doi.org/10.1186/1746-4269-1-1

SÁNCHEZ-BOTERO, J.I. 2005. Efeitos de distúrbios naturais e antrópicos sobre a fauna ictíica em lagoas costeiras na região de Macaé / RJ. Tese de doutorado, Universidade Federal do Rio de Janeiro. Rio de Janeiro.

SÁNCHEZ-BOTERO, J.I., GARCEZ, D.S., CARAMASCHI, E.P. & SAAD, A. 2009. Indicators of Influence of salinity in the resistance and resilience of fish assemblage in a tropical coastal lagoon (Southeastern Brazil). Bol Investig Mar Costeras. 38:52-68.

SÁNCHEZ-BOTERO, J.I., CARAMASCHI, E.P., & GARCEZ, D.S. 2008. Spatiotemporal variation in fish assemblage in a coastal lagoon without direct contact with the sea (southeastern Brazil). J Coastal Res. 24(4C):225-238, http://dx.doi.org/10.2112/06-0752.1

SÁNCHEZ-BOTERO, J.I. & ARAUJO-LIMA, C.A.R.M. 2001. As macrófitas aquáticas como berçário para a ictiofauna da várzea do Rio Amazonas. Acta Amazon. V. 31(3):437-447.

SANTANGELO, J.M. 2009. Estrutura do Banco de Ovos de Resistência do Zooplâncton em Sistemas Aquáticos Continentais e Influência da Salinidade e da Predação na Diapausa. Tese de doutorado, Universidade Federal do Rio de Janeiro. Rio de Janeiro.

SANTOS, A.M. & ESTEVES, F.A. 2004. Influence of Water Level Fluctuation on the Mortality and Aboveground Biomass of the Aquatic Macrophyte Eleocharis interstincta (VAHL) Roemer et Schults. Braz Arch Biol Techn. 47(2):281-290, http://dx.doi.org/10.1590/S1516-89132004000200016

SILVANO, R.A.M. 2001. Feeding habits and interspecific feeding associations of *Caranx latus* (Carangidae) in a subtropical reef. Environ Biol Fish. 60:465-470, http://dx.doi.org/10.1023/A:1011064923544

SILVANO, R.A.M., MACCORD, P.F.L., LIMA, R.V. & BEGOSSI, A. 2006. When does this fish spawn? Fishermen's local knowledge of migration and reproduction of Brazilian coastal fishes. Environ Biol Fish. 76:371-386.

SILVANO, R.A.M. & BEGOSSI, A. 2005. Local knowledge on a cosmopolitan fish Ethnoecology of *Pomatomus saltatrix* (Pomatomidae) in Brazil and Australia. Fish Res. 71:43-59, http://dx.doi.org/10.1016/j.fishres.2004.07.007

SPATARU, P., VIVEEN, W.J.A.R. & GOPHEN, M. 1987. Food composition of *Clarias gariepinus* (C. lazera) (Cypriniformes, Clariidae) in Lake Kinneret (Israel). Hydrobiologia. 144:77-82, http://dx.doi.org/10.1007/BF00008053

THÉ, A.P.G. 2003. Conhecimento Ecológico, Regras de uso e Manejo local dos Recursos Naturais na Pesca do Alto-Médio São Francisco, MG. Tese de doutorado, Universidade Federal de São Carlos. São Carlos.

TOLEDO, V.M. 1990. La Perspectiva Etnoecológica: Cinco Reflexiones Acerca de las ''Ciencias Campesinas'' Sobre la Naturaleza con especial Referencia a México. Ciências. 4:22-29.

TONINI, W.C.T., BRAGA, L.G.T., VILA NOVA, D.L.D. 2007. Nova dieta de juvenis do robalo *Centropomus parallellus* Poey, 1860 no sul da Bahia, Brasil. B. Inst. Pesca. São Paulo. 33(1):85-91.

WASSERMAN, J.C. 2000. Estudo do Impacto Ambiental da Barra Franca na Lagoa de Saquarema/Relatório de Impacto Ambiental da Barra Franca na Lagoa de Saquarema – RJ.

Received 12/03/2014
Revised 29/09/2014
Accepted 06/10/2014

Biota Neotropica 14(4): e20130073, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Intra annual seed production and availability of two morphotypes of *Brosimum rubescens* taubert in forests of the Colombian Amazon

Luis Eduardo Rivera[1], María Cristina Peñuela[2] & Flavio Moreno[3,4]

[1]Universidad Nacional de Colombia, Sede Amazonia, Leticia, Amazonas, Colombia.
[1,2]Universidad Regional Amazónica IKIAM, Ciudad de Tena, Provincia de Napo, Ecuador.
[3]Department of Forest Science, Universidad Nacional de Colombia Sede Medellín, Medellín, Colombia
[4]Corresponding author: Flavio Moreno, e-mail: fhmoreno@unal.edu.co

RIVERA, L.E., PEÑUELA, M.C., MORENO, F. **Intra annual seed production and availability of two morphotypes of *Brosimum rubescens* taubert in forests of the Colombian Amazon.** Biota Neotropica. 14(4): e20130073. http://dx.doi.org/10.1590/1676-06032014007313

Abstract: We assessed the reproductive phenology, production, and availability of seeds for two morphotypes of *Brosimum rubescens* Taub. (Moraceae), locally known as black palosangre (**BP**) and white palosangre (**WP**) during an annual cycle in a 20-ha mega plot located in a primary forest at the El Zafire Biological Station, in the Colombian Amazon. We found that 87% and 41% of potentially reproductive individuals of **BP** and **WP** respectively, was fertile and the production of reproductive structures was variable within and between morphotypes. The phenological pattern was seasonal in both morphotypes, characterized by flowering at the end of the dry season and fruiting at the start of the rainy season. **BP** produced and aborted large amounts of infructescences (approximately 21743), possibly as a response to satiate predators. Relative predation in terms of pre-dispersion of seeds was similar in both morphotypes, with a greater damage generated by a Scolytidae Curculionidae (Coleoptera) and to a lesser degree by frugivorous vertebrates. The number of mature fruits, total seeds, and removed seeds was similar for both morphotypes. Differences in the amount of reproductive structures and in the timing of phenophases between morphotypes decreased the competition and contributed to their coexistence. It seems that in undisturbed forests seed limitation could be more conditioning for **WP,** while other limitations after fruit and seed production could occur in **BP.**

Keywords: *Fecundity, predation, reproductive phenology, seed limitation, seed removal.*

RIVERA, L.E., PEÑUELA, M.C., MORENO, F. **Producción y disponibilidad intra anual de semillas de dos morfotipos de *Brosimum rubescens* Taubert en bosques de la amazonía colombiana.** Biota Neotropica. 14(4): e20130073. http://dx.doi.org/10.1590/1676-06032014007313

Resumen: Se evaluó la fenología reproductiva, producción y disponibilidad de semillas de dos morfotipos de *Brosimum rubescens* Taub. (Moraceae), conocidos localmente como palosangre negro (PN) y palosangre blanco (PB), durante un ciclo anual en una megaparcela de 20 ha localizada en bosques primarios de la Estación Biológica El Zafire, Amazonía colombiana. Se encontró que estuvieron fértiles el 87% y 41% de los individuos potencialmente reproductivos de PN y PB, respectivamente. La producción de estructuras reproductivas fue variable dentro y entre morfotipos. El patrón fenológico fue estacional en ambos: florecieron al final de la época seca y fructificaron al inició de la lluviosa. Aunque en PB aparentemente ocurre limitación en la polinización, la maduración de los óvulos fecundados es más eficiente que en PN. Este último produjo y abortó abundante cantidad de infrutescencias, posiblemente para saciar depredadores. En ambos morfotipos la depredación relativa pre-dispersión de las semillas fue similar, siendo mayor el daño generado por un Curculionidae Scolytidae (Coleóptera) y menor por frugívoros vertebrados. El número de frutos maduros, semillas totales y semillas removidas también fue similar entre morfotipos. Diferencias en la cantidad de estructuras reproductivas y en el tiempo de manifestación de las fenofases entre morfotipos, disminuyen la competencia y contribuyen a su coexistencia. Aparentemente, en bosques no disturbados la limitación de semillas podría ser más condicionante para PB, pero otras limitaciones posteriores a la producción de frutos y semillas podrían presentarse en PN.

Palabras clave: *Depredación, fecundidad, fenología reproductive, limitación de semillas, remoción de semillas.*

Introduction

The production of seeds and their dispersion are critical processes for the population dynamics of tree communities in neotropical forests (Levin *et al.* 2003, Muller-Landau *et al.* 2008, Stoner & Henry 2010). Low and uncertain seed production is a limitation for the transition in sufficient quantities to subsequent stages of the biological cycle of populations and for the reproductive success (Schupp & Fuentes 1995, Tufto *et al.* 1997, Clark *et al.*1998, de Steven & Wright 2002, Muller-Landau *et al.* 2008). It has been shown that a high variability in seed production diminishes the interspecific competition, thus allowing for the coexistence of many species as well as for the promotion of a high diversity at multiple scales (Tilman 1994, Hurtt & Pacala 1995, Hubbell *et al.* 1999, Schupp *et al.* 2002).

In rain forests, despite the production of abundant pistillate flowers with potential of fecundation, it is common that a limited number of seeds mature and spread (Larson & Barrett 2000, Clark *et al.* 2004). This may happen for different reasons: 1) limited pollen availability (Larson & Barrett 2000, Stoner & Henry 2010), 2) deficiency in resource availability (Wright *et al.* 1999), and 3) losses pre dispersion by predators (Maron & Gardner 2000, Hulme 2001). Many species overcome these limitations through different strategies in their reproductive characteristics (Herrera 1998, van ulft 2004, van Rheenen 2005, Wright *et al.* 2005a, Muller-Landau *et al.* 2008), which are associated with evolutionary processes such as abiotic and biotic interactions, endogenous factors and or phylogenetic relations (Wright & Calderón 1995, Williams-Linera & Meave 2002, Marques *et al.* 2004, Brearly *et al.* 2007).

The identification of reproductive phenological patterns from species groups, guilds, or conspecific individuals is key to understand the assemblages of vegetation communities, especially of those groups with very similar phylogenetic characteristics that coexist in similar habitats. High similarity in the availability of fruits for dispersion might increase intra and interspecific competition, with yet unknown consequences for future regeneration processes (Levin *et al.* 2003, Clark *et al.* 2004).

Such is the case of two morphotypes of the woody tree *Brosimum rubescens* Taub. (Moraceae). These morphotypes coexist in Terra firme forests of the Colombian Amazon. The species is a long-lived, shade tolerant, generalist species,which inhabits different landscapes over well-drained soils of the Amazonia (Marimon & Felfili 2001, Duque *et al.* 2003, Palacios 2005, Rivera *et al.* 2006). These two morphotypes, locally named Palosangre negro (Black palosangre-**BP**) and Palosangre blanco (White palosangre-**WP**) differ mainly in their foliar structures but are similar in terms of size, weight, shape and color of fruits and seeds (Palacios 2005). The study of temporality and productivity of cyclical biological events of each morphotype will be fundamental to better understanding their regenerative niche and their coexistence in the same habitat. In this study we assessed whether possible differences in the reproductive phenology and final availability of seeds, contribute both to the coexistence and abundance of these two morphotypes in terra firme forests. Specifically, our research questions were: Are there differences in the reproductive phenology between the two morphotypes? And how does seed availability vary in each morphotype?

Materials and methods

1. *The studied especies*

Brosimum rubescens Taubert is a species from the Moraceae family (Berg 1972, Berg & Simonis 2000) distributed in the tropical rain forests from America, being the Amazonia its center of dispersion, where it has been reported in terra firme forests (Duivenvoorden & Lips 1993, Urrego 1997, Sánchez 1997, López & Cárdenas 2002, Duque et al. 2003, Rudas & Prieto 2005, Palacios 2005, Parrado-Roselli 2005, Rivera et al. 2006, Peñuela & Pijache 2007). Adult trees reach the main canopy, with maximum heights of 30 - 35 m and up to 90 cm of diameter. It is considered as a shade-tolerant and long-lived species, typical of primary forests (Marimon & Felfili 2001, Palacios 2005, Rivera et al. 2006). According to results from 14 to 18 years of growth data in permanent plots, the life cycle of this species could be between 450 - 700 years (Laurance et al. 2004), though recent studies based on radio carbon would support the higher limit (Vieira et al. 2011). Our data at the El Zafire Biological Station average 1 mm per year of diametric growth (Peñuela & Jiménez, unpublished data).

Brosimum rubescens is a monoiceous tree, whose male and female reproductive structures occur in the same inflorescence. Though Berg & Hijman (1999) suggest that inflorescences of *Brosimum* are adapted for insect pollination, in a phylogenetic study of Moraceae Datwyler & Weiblen (2004) say that pollination syndrome of *Brosimum* is anemophilous; however, the pollination biology of many Moraceae is not known and observations of floral visitors are lacking, particularly in *Sorocea* and the tribe Dorstenieae (to which *Brosimum* belongs). Fruit is round and fleshy, light green when ripening, its diameter is about 2 cm and has one seed. Diameter of brown seeds is on average 1.5 cm and is covered with sweet and almost transparent mucilage. The germination is hypogeous and occurs in few days (usually within 15-20 days) because seeds are recalcitrant. Seedlings are abundant in the understory of terra firme forests, especially under the crown of maternal trees (Palacios 2005, Rivera et al. 2006).

A wide variety of frugivorous animals are potential dispersers of *B. rubescens*, including primates (Rodríguez et al. 1995, Palacios et al.1997, Defler 2003). In 2003, when occurred a massive fructification of this species in the study area, we observed flocks of parrots (*Brotogeris* sp.) consuming the fruits. Groups of Psittacidae, Ramphastidae, Cotingidae, Callithrichidae, and Cebidae have been reported removing sees of *Brosimum utile* (Parrado-Roselli 2005),and Quiróptera in *Brosimum alicastrum* (Acosta & Aguanta 2006). We also have seen secondary dispersion of this species by small rodents (*Proechimys* sp.), which used fruits for the construction of burrows in terra firme forests.

2. *Study area*

The study was carried out in a 20-ha permanent plot of a terra firme forest located at the El Zafire Biological Station in the southern Colombian Amazon in a National Forest Reserve, bordering Brazil (4° 00’ 00” S and 69° 53’ 57” W) (Figure 1). The studied forest is well conserved; it has about 650 trees greater than 10 cm of diameter at breast height (DBH) in 160 species per hectare. The most abundant species belong to the genera *Eschweilera* from the Lecythidaceae family (*E. bracteosa, E. coriacea,* and *E. punctata*), as well as the Woody tree Andiroba (*Carapa guianensis*). According to Caldas-Lang’s

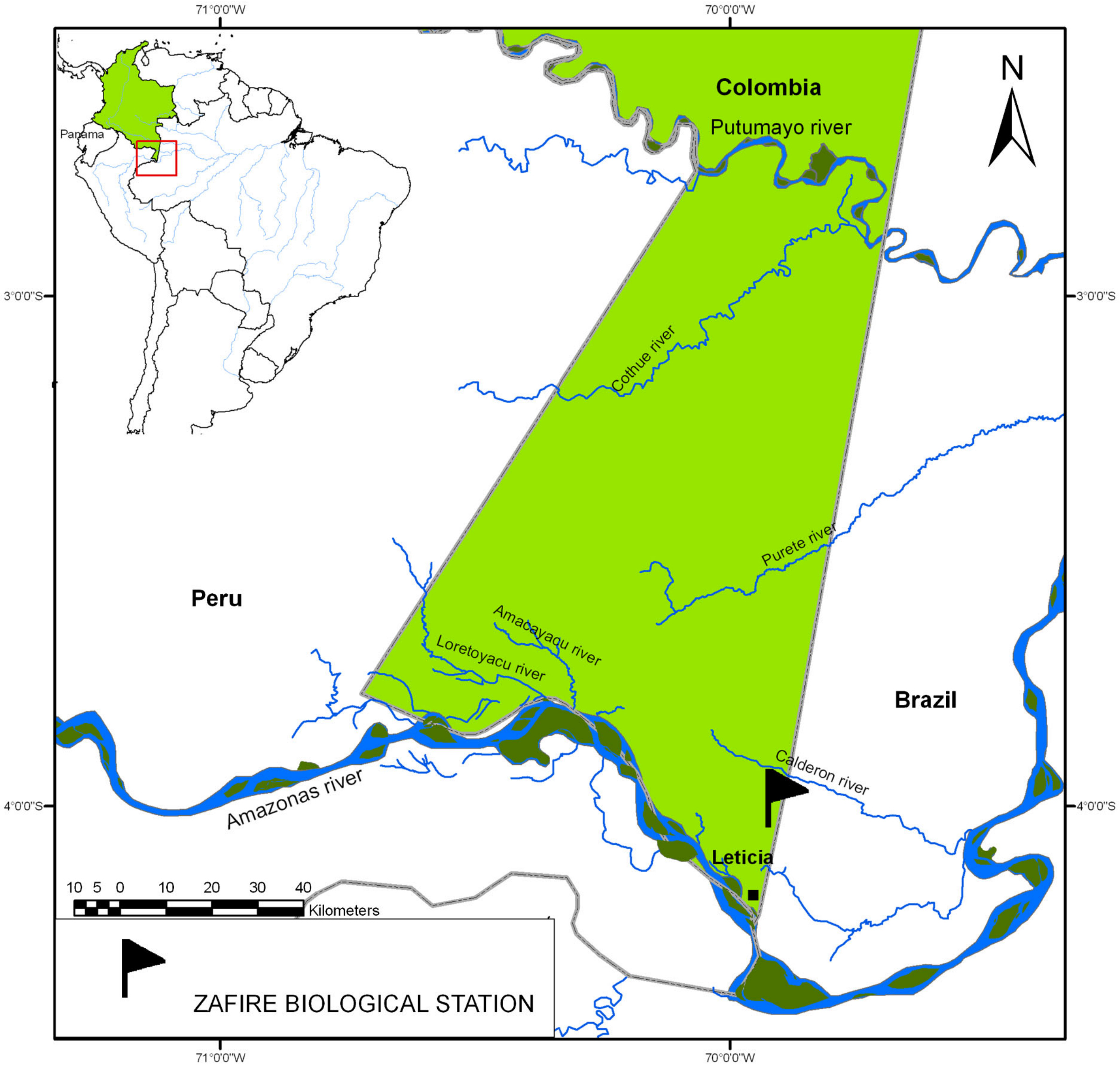

Figure 1. The El Zafire Biological Station study area (S 4°00′00′′, W 69°53′57′′) and National forests reserve in the Colombian Amazon (modified from Peñuela-Mora 2014).

climate classification (Rangel & Luengas 1997), the study area is wet and warm with and average temperature of 27° C and an average annual rainfall varying between 2600 and 3400 mm. The regime of precipitation is dominated by a rainy season from October to May and a dry season from June to August.

Geologically, the area belongs to the upper tertiary Mariñame formation, which forms the predominant subsoil of the Amazon basin (Arbeláez 2003) and is characterized by large sand deposits (Palacios 2005). Important variations in soils and topography are reported with altitude, which varies between 80 and 120 m, and characterizes the terra firme forests with undulated, moderate to flat slopes. Soils are generally classified as Ultisols with medium to coarse sands and high quartz contents. These conditions result in a mostly sandy and sandy-loam texture dominating the region with clay loam soils in some areas. Soils are extremely acidic (pH<4.5), with very low CEC and total base saturation. Mineral elements such as calcium, magnesium, potassium, and sodium occur in minimal quantities, less than 0.2 meq/100 g (Arbeláez 2003).

3. *Tree selection for phenological monitoring*

All adult trees of *B. rubescens* were sampled in a 20-hectare plot previously established in primary forests. Botanical samples of both *Brosimum* morphotypes were collected and separated according to biological traits described by Palacios (2005). We selected trees with DBH > 33.5 cm, which were considered sexually mature and potentially fertile trees (PFT). To estimate the crown area (square meters) of each tree we measured 8 radii from the main stem of the tree (separated by an angle of 45^{o}) to the projection of the crowns edge to the ground. Crown area was calculated as the sum of the areas of each of the triangles formed by two consecutive radii. Each month from February 2007 to January 2008 the phenological state of each tree was recorded. Phenophases were described as follows: *flowering,* when there were flowers in the crown or on the ground. *Early fruiting,* when fruits were harder and fertilized ovules showed no distinguishable seeds, and *advanced fruiting,* when pericardium fragments showing the cavity that holds the seeds or fruits with clearly differential seeds were found (Figure 2f).

4. *Trap sampling under parent trees*

Ten **BP** and six **WP** individuals displaying fertile activity were monitored; under each tree four traps were installed along cardinal points in the midpoint between the tree stem and the crown drip line. A total of 40 traps were located under **BP** and 24 under **WP** trees. Each trap of 1m^2 area was placed 0.50 m above the ground (Rozo-Mora & Parrado-Roselli 2004, Parrado-Roselli *et al.* 2006). Trap content was collected every two weeks from September 2007 to January 2008 (8 samplings), during the main reproductive activity of both morphotypes. Samples were processed and analyzed at the Natural Products Lab of the National University of Colombia in Leticia.

5. *Laboratory processing*

Collected samples were oven dried at 103° C to constant weight. Reproductive structures were separated, counted and grouped into: *inflorescences, unripe fruits, ripe fruits*, *damaged fruits* (with holes or mechanical damage), *empty fruits* (those with diameter ⩾ 1cm and an empty cavity showing that there was at least one well developed seed (Figure 2f), and *free, ripe seeds* (when well-developed free seeds were found). Each sample was weighted in analytical scale to the nearest 0.001g.

6. *Variables evaluated*

The absolute and relative density of actively fertile trees with relation to PFT was assessed for each morphotype. Because all reproductive structures of both morphotypes are green (even after ripening), it was extremely difficult to distinguish through observations with binoculars the change from inflorescence to fruit; for this reason, the level of synchrony of fertile activity was assessed from the percentage of individuals that started fertile activity (flowering only) and we did not determine this variable for fruting. Following Bencke & Morellato (2002), a phenophase was considered synchronous when more than 60% of trees exhibited that

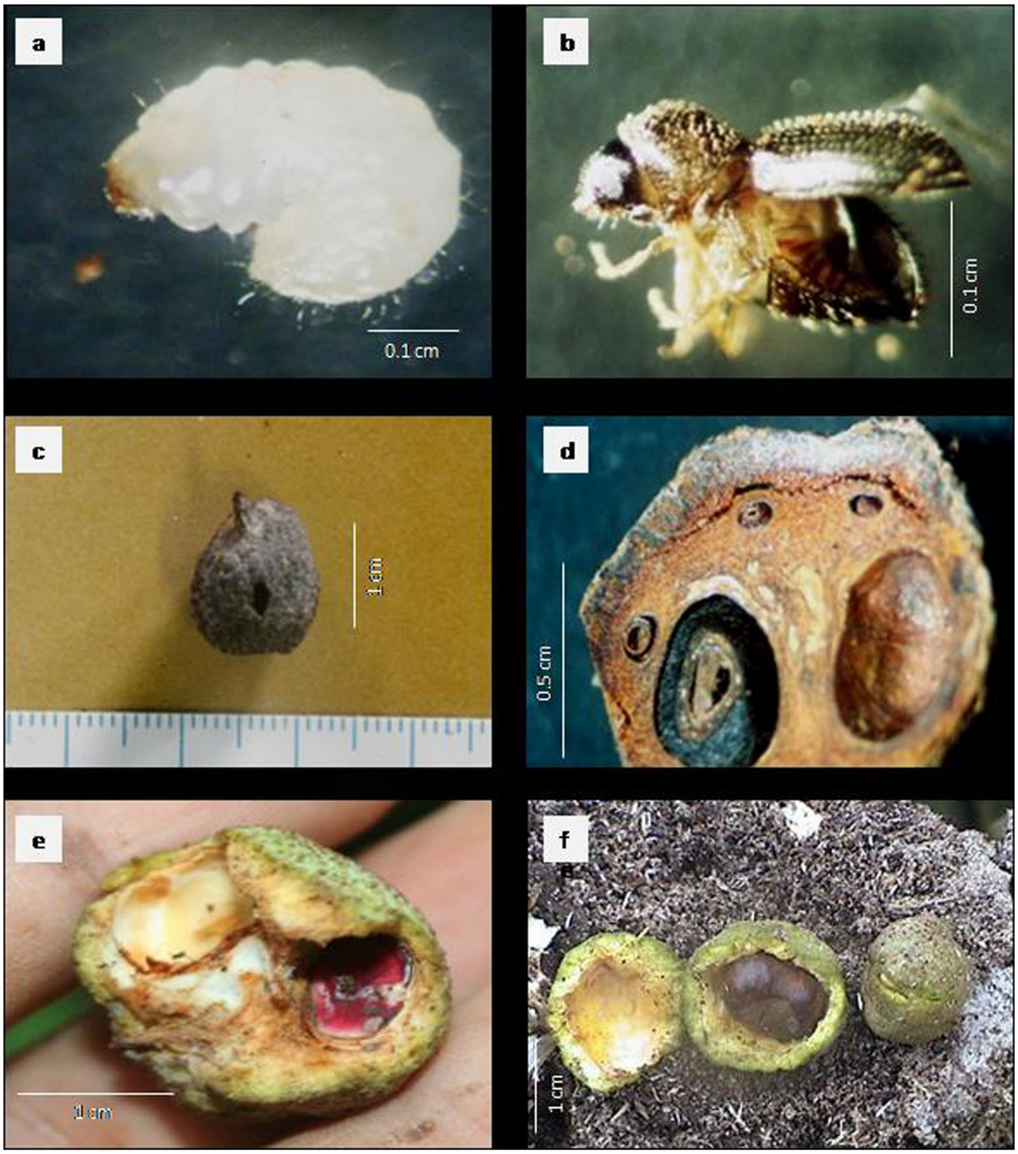

Figure 2. Fruits damaged in ***B. rubescens***. **a** and **b** Larvae and adult stages of Scolytidae. **c** and **d**. Holes in seeds and fruits made by Scotylidae. **e**. Damage in fruits caused by vertebrate frugivores. **f**. Holes in fruits (pericarpium) suggesting that a well-developed seed developed inside the fruit.

phenophase, with low synchrony if the phenophase occurred between 20% and <60% of trees, and asynchronous if less than 20% of individuals showed the phenophase. Distances (m) to the nearest potential reproductive neighbour was also determined, as well as distances to the nearest fertile neighbour.

Data from traps were used to quantitatively evaluate variables associated with flowering, fruiting, pre-dispersion fruit damage, seed production, seed removal, and biomass of reproductive structures per tree. In doing so, the average value of each variable per trap (1 m^2) of each sampled tree was multiplied by the crown area of the tree. ***Unfertilized inflorescences*** were those fallen on the ground before pollination and captured in the traps and ***total number of inflorescences*** was the sum of infertile inflorescenes and total number of fruits produced.

For fruiting we defined the following variables: ***number of ripe fruits,*** those well-developed fruits with at least one seed or evidence of a well-developed ripe seed (Figures 2e and 2f); ***number of abortions,*** those structures with ovaries that fell down to the ground before ripping; ***total number of fruits,*** the sum of ripe fruits and abortions. Seeds were accounted as: ***removed seeds,*** fragments (>50%) of empty fruits (pericarpium); ***free seeds***, those well developed and morphologically viable; and ***total number of seeds,*** the sum of free seeds, ripe fruits, and removed seeds.

Predation was assessed in two classes: ***damaged fruits by insects,*** those with holes, and ***fruits damaged by frugivores,*** those with beaks and teeth marks, both in ripe and unripe fruits. To estimate the ***biomass*** of reproductive structures produced per tree in each monitoring period, we averaged the biomass collected in the four traps below each tree, which was then multiplied by the crown area of the respective tree.

7. *Data analysis*

For data analysis we used the software Statgraphics Centurion XVI.II. All data were tested for normality using the Shapiro-Wilk test. Non-normal data were log and square root- transformed. According to our research questions, we are interested in assessing differences in the reproductive phenology and seed availability between the two morphotypes of *B. rubescens*. Therefore, for all variables evaluated in this study (for example, DBH, crown area, and distance to the nearest PFT, as well as the variables associated to reproductive phenology, such as flowering, incipient fruiting, and advanced fruiting, etc.) were compared with a Student's t-test, which allows to evaluate the null hypothesis of no differences between morphotypes. Variables associated to reproductive phenology were also compared using a Kolmogorov-Smirnov test, which allows to compare the differences between cumulative relative frequencies of two independent samples, especially when data numbers are reduced (Guisande *et al.* 2006). Finally, Pearson correlation analyses were carried out to test the correlation between observations of variables associated with reproductive phenology per tree along time.

Results

1. *Population of reproductive trees in the 20 ha plot*

There were 16 PFT of **BP** whose DBHs varied between 35.2 and 75.3 cm, and 17 PFT of **WP** with DBHs between 34.4 and 75.4 cm. Along the year of monitoring, twice of PFT of **BP** flowered in comparison to **WP** (Table 1). This phenophase was slightly synchronic in **BP**, with up to 43.8% of total PFT flowering in the same month. In **WP** flowering began 30 days later than in **BP** and was completely asynchronous, with values of up to 17.6%. Distances between nearest PFT were not significantly different between morphotypes (P=0.345), with averages (± SD) of 56.2 ± 30.8 m in **BP** and 60.5 ± 33.5 m in **WP**. However, distances between fertile trees were significantly different between morphotypes (P<0.000). In **BP** these distances were similar to those between PFT (63.1 m), while in **WP** they were greater (92.3 m).

2. *Flowering*

Flowering began in September 2007 in **BP** trees and 30 days later in **WP** trees. In both morphotypes maximum flowering occurred at the end of October and decreased gradually at the end of December for BP and at the end of November for WP (Figures 4a and 4b). In **BP** flowering was more conspicuous given the amount and size of inflorescences (mean ± SD= 5 ± 0.4 mm) than in **WP** (mean= 3 ± 0.3 mm). Temporal variation, evaluated through the cumulative relative frequencies of the total *inflorescence production*, was not statistically different between morphotypes (Kolmogorov Smirnov KS= 1.2, P= 0.09), as well as the variation of the *number of unfertilized inflorescences* (KS= 0.8, P= 0.63) (Table 2). However, there was a positive correlation between u*nfertilized inflorescens* and *abortions* (r= 0.878, P= 0.041) and with fruit damage (r= 0.800, P= 0.017) in **BP**, but no relationships were found in **WP.** No significant differences were found on infertile inflorescences between morphotypes, although average in **BP** was twice that of **WP** (21565 vs. 10240 inflorescences) (Table 4); however, in terms of percentage of total inflorescences, the trend was opposite: infertile inflorescences were significantly higher in **WP** than in **BP** (79% vs. 0.29%), i.e. the morphotype with the smaller production of inflorescences had the higher percentage of infertile ones.

3. *Fruiting*

Temporal distribution of abortions was significantly different between morphotypes (KS= 2, P= 0.00; Table 2). At the end

Table 1. Total number of fertile trees per month of two morphotypes of *Brosimum rubescens* Taub. that came to fertile activity along one year of monitoring. The value in parenthesis is the relative monthly percentage of potentially fertile trees (PFT) that were active. The number in bold is the maximum percentage per morphotype.

Morrphotype	Total PFT	Aug	Sep	Oct	Nov	Dec	Jan	Fertile activity	Total percentage
Black palosangre (BP)	16	0 (0%)	4 (25%)	7 (**43.8**)	3 (18.8)	0 (0%)	0 (0%)	14	87.5%
White palosangre (WP)	17	0 (0%)	0 (0%)	3 (**17.6**)	3 (**17.6**)	1 (5.9%)	0 (0%)	7	41.2%

Table 2. Results of the Kolmogorov-Smirnov statistical test comparing the cumulative distribution of relative frequencies for each reproductive phenological variable through time (*n= 8 observations along a six-month period*) between morphotypes of *Brosimum rubescens* Taub.

Variables	Black palosangre (BP)				White palosangre (WP)				Kolmogorov-Smirnov			
	SD	VC%	MIN	MAX	SD	VC%	MIN	MAX	MD	K-S	P	S
Total number of inflorescences	5726	114	193	15553	2080	167	23	5246	0.6	1.2	0.09	ns
Unfertilized inflorescences	3036	127	0	8257	2080	167	23	5245	0.4	0.8	0.63	ns
Number of abortions	2715	107	121	7254	46	130	0	113	1.0	2.0	0.00	*
Number of ripe fruits	65	70	12	192	62	97	0	183	0.3	0.5	0.96	ns
Number of damaged fruits	815	92	121	2101	34.1	98	0	85	1.0	2.0	0.00	*
Number of free seeds	27	91	0	71	17	118	0	44	0.4	0.8	0.63	ns
Number of removed seeds	41	77	0	110	56	183	0	164	0.5	1.0	0.27	ns
Total number of seeds	64	78	0	181	62	138	0	183	0.5	1.0	0.27	ns
Biomass reproductive structures (g)	378	104	0	938	10	98	0.3	27.5	0.9	1.8	0.00	*

SD= Standard deviation, VC%= variation coefficient; MD= maximum distance between cumulate distributions of both samples; K-S= Kolmogorov-Smirnov statistic; P= P value; S= statistical significance (statistical significant level = 0.05). ns= non-significant. *= significant

of October there was a peak in abortions, coincident with flowering in **BP,** whereas the peak occurred 30 days after the peak of flowering in **WP**. (Figure 4d). Ripe fruit production reached its maximum at the end of November, 30 days after maximum flowering. In **WP** it occurred in the middle of December, 45 days after peak flowering (Figures 4c and 4d). Relative distribution values of ripe fruits through time did not show significant differences between morphotypes (KS= 0.5, P= 0.96) (Table 2).

Some correlations were found between variables associated with reproductive phenology. In **BP** number of abortions was positively correlated with: *infertile inflorescences* (r = 0.878 and P = 0.004), *damaged fruits* (r= 0.984, P= 0.000), *free seeds* (r = 0.713, P = 0.047) and *biomass of reproductive structures* (r = 0.975, P = 0.000). In **WP** the *number of abortions* was correlated with *damaged fruits* (r= 0.748, P= 0.033) and total seeds (r= 0.780 and P= 0.023) (Table 3).

The total number of fruits was significantly different between morphotypes (P= 0.010), and much higher in **BP** (22448) than in **WP** (858) (Table 4). This difference is counteracted with 97% abortions (21743) in **BP** vs. 35% abortions (329) of fertilized ovules in **WS** (P= 0.00). No statistical differences were found in total number of ripe fruits between morphotypes (P=0.506) as **BP** showed 705 ripe fruits and **WP** 528; however, in terms of percentage of ripe fruits WP showed higher values than BP (65% vs. 3%) (Table 4).

4. *Fruit predation*

Two types of damage were found for both morphotypes: **a)** damaged caused by insects in the larvae and adult stages of the Scolitydae family (Coleoptera), expressed by tissue necrosis and one or two small holes (1-2mm) in unripe fruits, ripe fruits and inflorescences (Figures 2c, 2d) and **b)** damaged caused by vertebrates frugivores as evidenced by beak and teeth scars.

Damaged fruit fall for BP occurred at the beginning of October, concomitant, with the inflorescence fall, abortions, and fertilized inflorescences that increase towards the end of the month. The trend continued for about 30 days and then progressively diminished, whereas the production of ripe fruits and seeds increased (Figures 4c ,4e). Damage in fruits was found in October for **WP,** when abortions were also observed, and reached their maximum in the middle of November (Figures 4d, 4f). Temporal variation of damaged fruits was statistically different between morphotypes (KS =2, P=0.00) (Table 2).

Mean number of damaged fruits was significantly different between **BP** (7061) and **WP** (308.2) (P= 0.006) (Table 4). However, relative damaged in relation to the total number of fruits was not different between morphotypes (44.5% vs. 37.5%) (P= 0.313) (Table 4). Damage caused by vertebrate frugivores in **BP** was 33% vs. 29% in **WP** and mainly affected the ripe fruits, whereas the damaged caused by Scolytidae was 62% and 71% respectively, mainly in unripe fruits (Figure 2c). In **BP** the damage of fruits showed a strong correlation with the fall of infertile inflorescences (r= 0.802, P= 0.017), abortions (r= 0.984, P= 0.000) and biomass of reproductive structures (r = 0.997, P= 0.000), whereas **WP** damage of fruits was correlated with abortions (r= 0.812, P= 0.014) and ripe fruits (r= 0.748, P= 0.033) (Table 3).

5. *Production and removal of seeds*

Temporal variation of seed production showed a similar trend to the ripe fruit production in both morphotypes, with maximum numbers occurring towards the end of November in **BP** and towards the middle of December in **WP** (Figure 4e and 4f). The temporal distribution of the number of free seeds was not significantly different between morphotypes (KS=0.8, P= 0.63) as well as the total number of seeds produced (KS=1, P=0.27) (Table 2). The total number of seeds per tree showed non-significant differences between morphotypes (P = 0.396), with an average (±SD) of 1382 ± 705 and 933 ± 471 seeds for **BP** and **WP,** respectively (Table 4). Of this total, 259 free seeds (18.7%) in **BP** and 124 (13.4%) in **WP** fell down beneath the parent tree, which added to the total number of ripe fruits produced (705 and 528, respectively), represented about 70% of all seeds produced (i.e. about 30% of seeds produced were

Table 3. Significant (P<0.05) correlation coefficients of Pearson for the temporal variation of each phenological variable in two morphotypes of *Brosimum rubescens* Taub (correlation: upper number, P value: lower number (*n*= *8*)).

		Unfertilized inflorescences	**Abortions**	**Ripe fruits**	**Damaged fruits**	**Free seeds**	**Removed seeds**	**Total number of seeds**	**Biomass (g)**
Black palosangre (BP)	Unfertilized inflorescences								
	Abortions	0.878 0.004							
	Ripe fruits								
	Damaged fruits	0.802 0.017	0.984 0.000						
	Free seeds		0.713 0.047	0.746 0.034					
	Removed seeds			0.991 0.000		0.752 0.031			
	Total number of seeds			0.978 0.000		0.859 0.006	0.980 0.000		
		0.787 0.021	0.975 0.000		0.997 0.000				
White palosangre (WP)	Unfertilized inflorescences								
	Abortions								
	Ripe fruits								
	Damaged fruits		0.812 0.014	0.748 0.033					
	Free seeds								
	Removed seeds								
	Total number of seeds			0.780 0.023			0.922 0.001		
	Biomass (g)								

removed) (Table 4). These seeds are exposed to dense-dependent predation under the parental tree or to dispersion by secondary agents.

Of total seeds produced, 418 and 281 were removed in **BP** and **WP,** respectively; these data show that crown frugivory was about 30% in both morphotypes. According to the type of damage of reproductive structures that fell on the ground (a cavity inside the fresh and ripe pericarpium where a well-developed and morphologically viable seed was located), seed removal and the behaviour of vertebrate frugivores in the crowns were similar in both morphotypes (Figure 2e, 2f). Seed removal peaked at the end of November in **BP** and in the middle of December in **WP** (Figure 4e, 4f). However, temporal distribution was not significantly different between morphotypes (KS= 1, P= 0.27. Table 2). In **BP** seed removal was correlated with the production of ripe fruits (r = 0.991, P= 0.000), free seeds (r= 0.752, P= 0.031) and total of seeds (r= 0.970, P= 0.000). In **WP** seed removal was only correlated with the total number of seeds (r= 0.932, P= 0.001) (Table 3). The number of seeds removed did not show significant differences between morphotypes (P=0.72).

Discussion

1. *Availability of seed sources, fecundity and phenological variation*

Temporal variation of reproductive phenophases of *B. rubescens* was not different from the typical patterns of most tree species of humid tropical forests, characterized by flowering in the dry season and fruiting in the rainy season (ter Steege & Persaud 1991, Rivera & Borchert 2001, Chapman *et al.* 2005, Stevenson *et al.* 2008). Likewise, a similar pattern has been reported for other phylogenetically similar species, such as *B. alicastrum*, *B. guianense, B. lactescens* in forests of the Colombian Amazon (Stevenson *et al.* 2008). However, our results should be taken cautiously as much they are based on one year of observations, which is short because phenological behaviour might vary from year to year (ter Steege & Persaud 1991, Williams-Linera & Meave 2002, Marques *et al.* 2004).

Though the timing of flowering showed a slight discrepancy between morphotypes at the beginning of the phase, it showed synchrony at its maximum expression. However, timing of peaks of maximum production of ripe fruits and seeds were different (Figures 4e and 4f). This phenological pattern would reduce competition between them and would enhance fruiting and seed dispersion at the beginning of the rainy season, when germination of ***B. rubescens*** would be favored, given the recalcitrant condition of their seeds, as well as growth and survival of seedlings (Rivera et al. 2006).

The sample size (17 and 16 PFT of BP and **WP**, respectively) seems low for making conclusions on phenology and reproductive biology of the entire population of a species. However, this is the number of PFT of each morphotype found in a mega plot of 20 ha, which is a big sampling area in comparison with most of studies in tropical forests. The main reason for this limitation is the low density of trees of most

Table 4. Statistical results per tree for reproductive variables of two morphotypes of *Brosimum rubescens* Taub. Significant differences ($P<0.05$) with the t test in bold. Highlighted are variables expressed as percentage of totals. SD: standard deviation.

Variables	Black palosangre (BP)				White palosangre (WP)				t test
	Mean	SD	Min	Max	Mean	SD	Min	Max	P
Total number of inflorescences	44013	35988	2538	149688	11097	11416	1232	29422	0.074
Number of infertile inflorescences	21565	42235	288	128484	10240	10826	616	27321	0.438
Total number of fruits	22448	21120	1819	63206	858	742	142	2102	**0.010**
% fructification	0.71	0.27	0.14	0.94	0.21	0.23	0.01	0.50	**0.002**
Number of abortions	21743	20539	1729	61506	329	364	35	947	**0.009**
% abortion	0.97	0.02	0.91	1.00	0.35	0.16	0.19	0.57	**0.000**
Number of ripe fruits	705	636	0	1700	528	399	105	1154	0.506
% ripe fruits	0.03	0.02	0.00	0.09	0.65	0.16	0.43	0.81	**0.000**
Number damaged fruits	7061	6012	1472	22287	308.2	243.4	47.3	710.4	**0.006**
Relative fruit damage (%)	44.5	23.2	18.8	80.9	37.5	4.3	33.3	42.9	0.313
Total number of seeds	1382	705	0	1683	933	471	95	1036	0.396
Number of free seeds	258.6	241	0	629	123.9	88.8	0	236.8	0.136
% free seeds	0.20	0.10	0.11	0.44	0.13	0.08	0.00	0.20	0.162
Number of removed seeds	418	415	0	1097	281	304	59	799	0.463
% removed seeds	0.26	0.10	0.00	0.33	0.30	0.14	0.13	0.50	0.574
Fruit biomass (g)	3188	3987	89	10394	83	63	14	189.4	**0.036**
DBH (cm)	55.7	12.3	36.9	75.3	56.4	13.5	38	75.4	0.496
Crown area (m^2)	60.3	19.9	20.1	82.4	75.6	23.4	47.3	118.4	0.214

species in tropical forests, which makes difficult and extremely expensive the monitoring of large samples due to the extensions that would need to be covered.

Quantitative analyses of flowering showed that annual production of inflorescences was not statistically different between morphotypes. Nevertheless, the proportion of unfertilized inflorescences in relation to the total was different, since in **BP** it was about half of that in **WP** (49% and 92.3%, respectively) (Table 4). This result suggests certain inability for effective pollination in **WP**, which could suggest a limitation of pollination as a consequence of a greater effective distance between active PFT in the last one (92.3 m as compared to 63.1 m in **BP)** despite distances between PFT were similar (**BP**= 56.2 m and **WP**= 60.5 m). Greater distances between fertile trees have the potential to negatively affect pollination and therefore the number of fruits and seeds at the end of the cycle (Murcia 2002). Greater density of trees with fertile activity in **BP** (>87% of PFT) probably increased the rate of pollination by insects and wind due to the shorter distance between reproductive trees and subsequently the greater probability of fecundation as compared to **WP.**

On the other hand, abortions were significantly higher in **BP** (97% of total number of fruits) as compared to **WP** (35%). The abortion of young fruits is common due to self-incompatibility when self-pollination occurs (Bawa & Webb 1984). This could be the case in monoiceous species such as *B. rubesecens* when flower production is high; under such conditions pollinators are easily satiated in a single tree, which increases the chances of self-pollination. Although this hypothesis was not tested in this study, it is a plausible explanation for the high level of abortion in **BP**, whose number of inflorescences was four times that in **WP.** However, abortions could also result as a consequence of a Scotylidae attack in inflorescences and unripe fruits (Figure 2). As a result of these processes, annual production of fruits and seeds was similar for the two morphotypes (Table 4), although the energetic cost was much lower for **WP.** The lack of a significant relationship between the production of inflorescences with that of fruits and seeds (Table 3) suggests that the strategies for fruiting seemed to be different between morphotypes, with rates of transition between phases in **BP** mainly controlled by predation and abortion. Therefore, the higher number of flowers does not necessarily mean a higher number of fruits and seeds (Roberson & Mac Nair 1995).

2. *Predation effects on the availability of fruits and seeds*

Predation of ripe fruits and seeds before dispersion highly affected the availability of fruits for primary dispersion (Table 4), as reported for other neotropical tree species (Janzen & Vasquez-Yanes 1991, Forget *et al.* 1999, Hulme 2001). The pattern of damage was similar between morphotypes and was probably associated with fruit similarity (Figure 3c and 3d) and the coexistence in the same habitat (Wright et al. 1999). Damage caused by vertebrate frugivores mainly occurs on ripe fruits, probably by primates and birds, which have been reported consuming *Brosimum* fruits (Defler 2003, Stevenson *et al.* 2000, Parrado-Roselli 2005), as well as by bats. Insect damage associated with immature reproductive parts could be related to the time required for larvae to complete their life cycle and emerge before being consumed by vertebrates along with the fruits (Restrepo 2002, Wright *et al.* 2005b).

Early attack of Scolytidae (Coleoptera) could be responsible for the massive abortion, mainly in BP (Table 4), because probably it is unfavorable to develop and mature a high number of unripe fruits infested by larvae. This type of relationship with predators supports the satiation hypothesis (Auspurguer 1981, Shupp 1992), which states that a high production of fruits increases the predator satiation and consequently a large number of seeds could reach maturity evading an attack.

3. *Seed removal by frugivores*

Close to 30% of seeds produced were removed from tree crowns of the two morphotypes. Beak and teeth scars in the reproductive structures, mainly in ripe fruits (Figure 2), and a

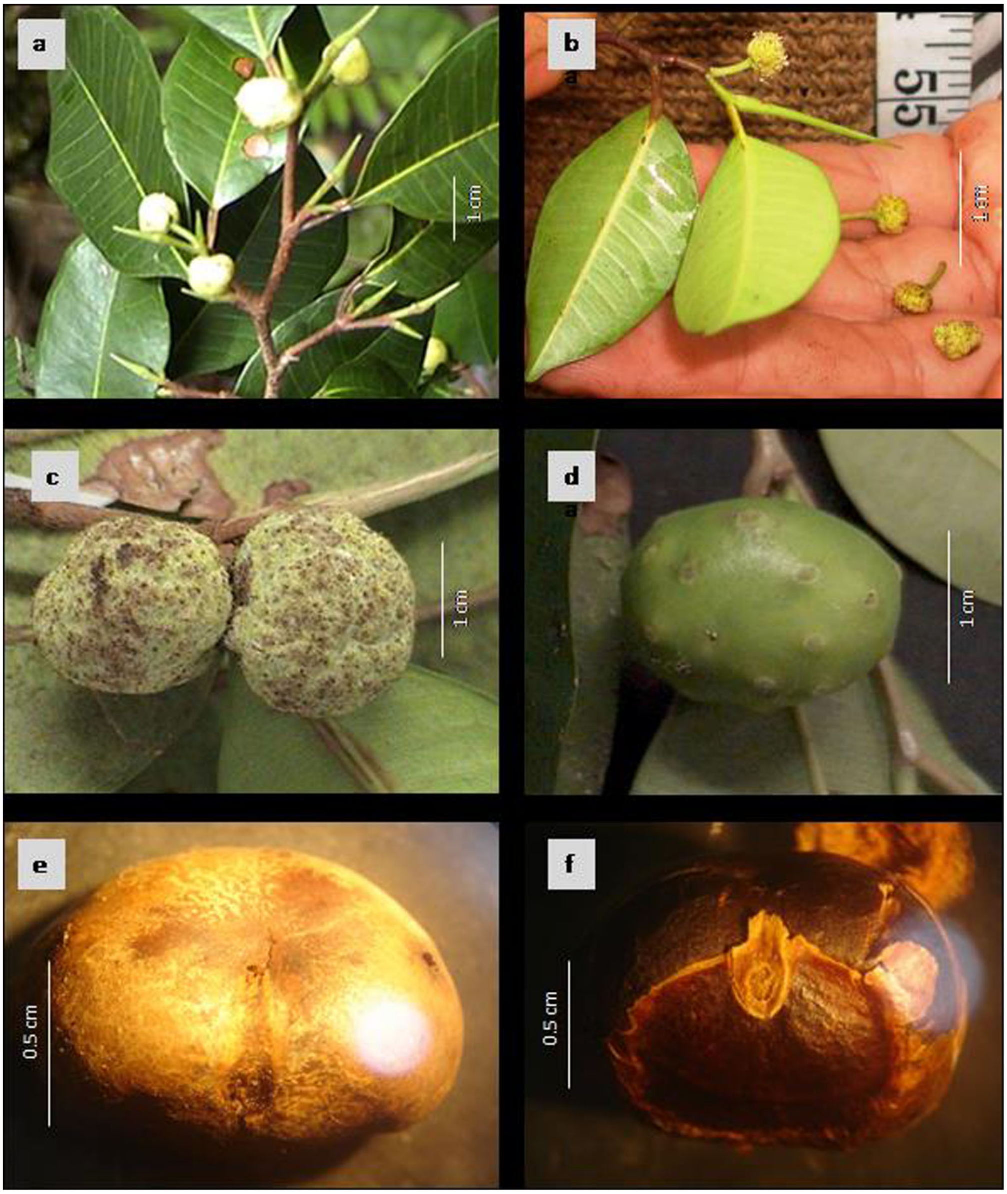

Figure 3. Reproductive structures of two morphotypes of ***B. rubescens***. **BP** at the left and **WP** at right. **a** and **b**. Leaves and pistillate inflorescences. **c** and **d**. Well-developed fruit structures almost ripe. **e** and **f**. Ripe fruits.

similar number of removed seeds in both morphotypes (Table 4) suggest a similar behaviour of frugivores. These results are probably due to the high similarity in size, weight, and colour of fruits and seeds (Figure 3) (Restrepo 2002), even though the morphology of the two morphotypes is strictly different (Palacios 2005).

Various species of monkeys and parrots from the genus *Brotogeris* have been reported as *B. rubescens* consumers and potential dispersers (Stevenson 2002, Defler 2003, Rivera, pers. obs.). Groups of Psittacidae, Ramphastidae, Cotingidae, Callithrichidae and Cebidae have also been reported as removing seeds from *B. utile* (Parrado-Roselli 2005), and Quiroptera in *B. alicastrum* (Acosta & Aguanta 2006). According to the theory of no frugivore-specialization (Hubbell et al. 1999, Terborgh et al. 2002), the availability of a wide group of frugivores would give *B. rubescens* an adaptive advantage for dispersion.

In neotropical forests, there is a strong seasonality in the annual supply of available fruits for the frugivores associated with rains. Therefore, a shortage season occurs in the dry season and an abundant one in the rainy season (Borchert 1998, Wright & Van Schaik 1994, Stevenson et al. 2000, Parrado-Roselli 2005, Stevenson et al. 2008). Availability of ripe fruits and seeds, coincident in the two morphotypes *of B. rubescens*, with the abundant season (Table 4), would allow them to share several fruit consumers. Conversely during the dry season, there is less overlap between diets of animals (Terborgh 1986). However, competition between morphotypes of *B. rubescens* by frugivores could be reduced by the slight temporal variation of seed production peaks between them (Figure 4c and 4d) and by the wide offer of potential frugivores during this season. The high number of removed seeds (Table 4) highlights the important role that frugivores play in the fitness of these two morphotypes.

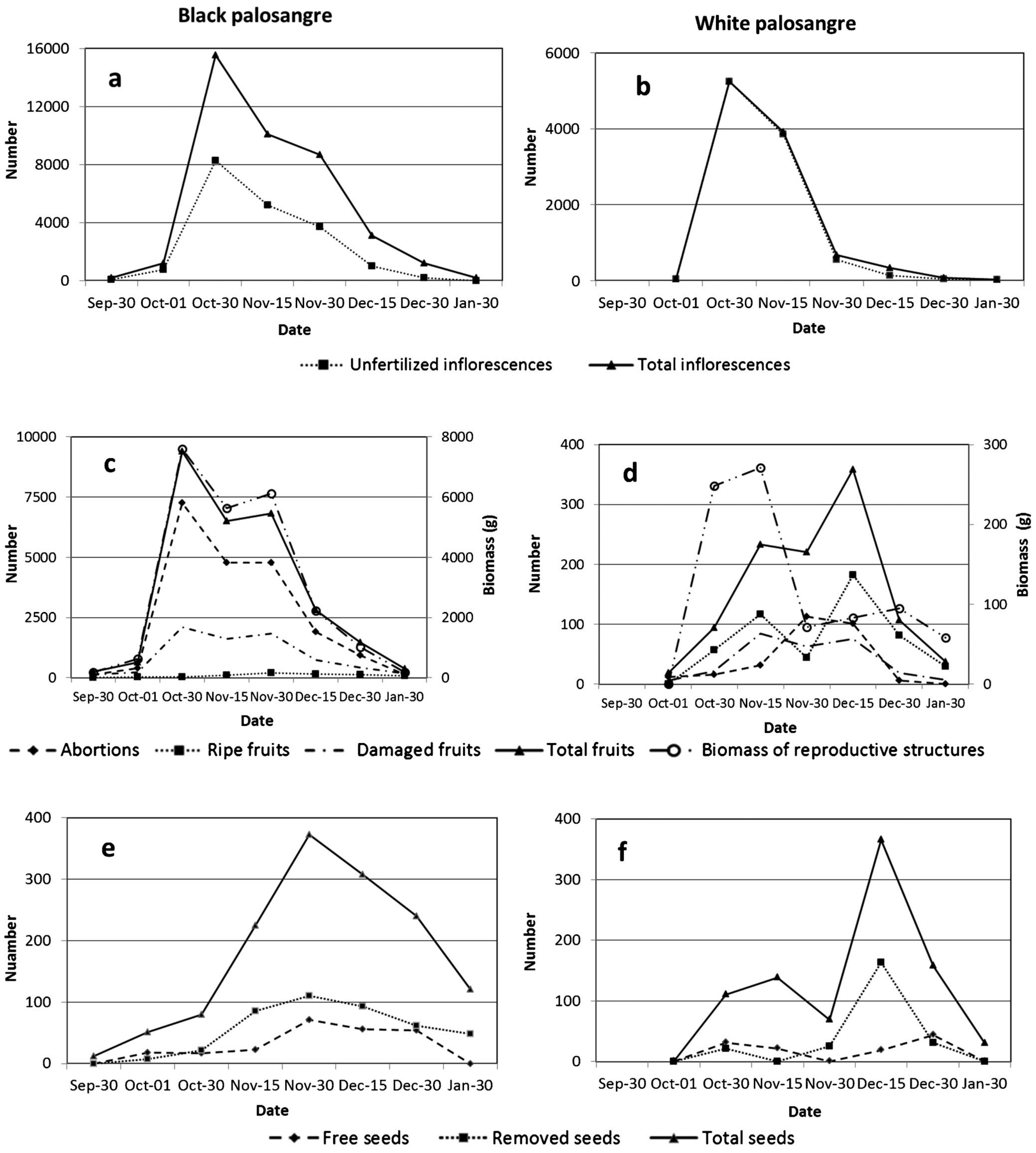

Figure 4. Temporal course of variables describing reproductive phenology of two ***B. rubescens*** morphotypes. Each value shows the average by tree. **a** and **b**. Total number of inflorescences vs. infertile inflorescences. **c** and **d**. Total number of fruits, ripe fruits, abortions, damaged fruits, and biomass of reproductive structures **e.** and **f.** Total number of seeds, removed seeds, and free seeds.

Conclusions

The availability of potential seed sources was similar between morphotypes, as well as the seed production per fertile tree. However, a low number of PFT of **WP** went into fertile activity over the annual cycle. Therefore, it is more probable that **WP** shows seed limitations than does **BP**. Given that population structure is similar for both morphotypes, other processes after fruit and seed production should be occurring in **BP** to make similar the number of individuals between them.

Both morphotypes showed similar production of ripe fruits and viable seeds available for primary dispersion thanks to niche separation by adopting slightly different reproductive strategies, which probably diminishes competition between morphotypes and allow the coexistence over the same habitats.

In **BP** the strategy is to produce massive inflorescences and abortions during the fruiting phase, and by doing so, it satiates predators and produces enough viable seeds. On the other hand, **WP** fertilizes a significantly lower number of inflorescences and shows a reduced rate of abortions, with the result of a similar number of viable seeds to **BP**. This behavior corresponds to the pollination limitation hypothesis.

These findings imply that unplanned wood extraction via the harvest of reproductive trees would diminish the density of these individuals per unit area as well as the distance between reproductive neighbors. This probably will affect processes such as pollination, flowering, fruiting, fruit removal, dispersion and seedling establishment. To evaluate such effects on the local populations is important in the immediate future, particularly in **WP**, since effects of extraction probably will be more drastic in its populations by increasing pollination limitation and subsequently seed production.

References

ACOSTA, L.S. & AGUANTA, F. 2006. Un nuevo aporte en el conocimiento de la dieta de los murciélagos frugívoros *Artibeus lituratus* y *Artibeus jamaicensis*. Kempffiana 2(1):127–133.

ARBELÁEZ, F. 2003. Spatial variation of fish communities among terra firme forest streams of the Colombian Amazonia. M.Sc Thesis, Universiteit van Amsterdam, Amsterdam.

AUSPURGUER, C.K. 1981. Reproductive synchrony of a tropical shrub: experimental studies on effects of pollinators and seed predators on Hybanthus prunifolius (Violaceae). Ecology 62:755–788.

BAWA, K.S. & WEBB, CJ. 1984. Flower, fruit, and seed abortion in tropical forest trees: implications for the evolution of paternal and maternal reproductive patterns. Am. J. Bot. 71:736–751, http://dx.doi.org/10.2307/2443371

BENCKE, C. & MORELLATO, P. 2002. Comparação de dois métodos de avaliação da fenologia de plantas, sua interpretação representação. Rev Bras Bot 25(3):269–275, http://dx.doi.org/10.1590/S0100-84042002000300003

BERG, C.C. 1972. Flora Neotropica. Olmedieae, Brosimeae. Monograph No. 7. Hafner Publishing Company, Inc., New York.

BERG, C.C., & HIJMAN, E E. 1999. The genus Dorstenia (Moraceae). Ilicifolia 2:1–211.

BERG, C C. & SIMONIS, J E. 2000. Flora de Venezuela, Moraceae-Cecropiaceae. Instituto Botánico de Venezuela. Editorial Reflit C. A, Caracas.

BORCHERT, R. 1998. Responses of tropical tree to rainfall seasonality and its long-term changes. Climatic Change 39:381–393, http://dx.doi.org/10.1023/A:1005383020063

BREARLEY, F.Q., PROCTOR, J., SURIANTATA, NAGY, L, DALRYMPLE, G. & VOYSEY B.C. 2007. Reproductive phenology over a 10-year period in a lowland evergreen rain forest of central Borneo. J. Ecol. 95:828–839, http://dx.doi.org/10.1111/j.1365-2745.2007.01258.x

CHAPMAN, C.A., CHAPMAN, L.J., ATRUHSAKER, T.T., ZANNE, A.E., CLARK, C.J. & POULSEN, J.R. 2005. A long-term evaluation of fruiting phenology: importance of climate change. J. Trop. Ecol. 21:1–14, http://dx.doi.org/10.1017/S0266467404001993

CLARK, J.S., MACKLIN, E. & WOOD, L. 1998. Stages and spatial scales of recruitment limitation in southern Appalachian forests. Ecol. Monogr. 68:213–235, http://dx.doi.org/10.1890/0012-9615(1998)068[0213:SASSOR]2.0.CO;2

CLARK, J.S., LADEAU, S. & IBANEZ, I. 2004. Fecundity of trees and the colonization-competition hypothesis. Ecol. Monogr. 74:415–422, http://dx.doi.org/10.1890/02-4093

DATWYLER, S. & WEIBLEN, G. 2004. On the origin of the fig: phylogenetic relationships of Moraceae from ndhf sequences. Am. Jour. Bot. 91(5):767–777, http://dx.doi.org/10.3732/ajb.91.5.767

DE STEVEN D, & WRIGHT, J.S. 2002. Consequences of variable reproduction for seedling recruitment in three neotropical tree species. Ecology 83(8):2315–2327.

DEFLER, T.R. 2003. Primates de Colombia. Serie de Guías de campo. Conservación Internacional, Bogotá.

DUIVENVOORDEN, J.F. & LIPS, J M. 1993. Ecología del paisaje del Medio Caquetá. Memoria explicativa de los mapas. Estudios en la Amazonia Colombiana. Tropenbos – Colombia, Bogotá.

DUQUE, A., CAVALIER, J. & POSADA, A. 2003. Strategies of tree occupation at a local scale in terra firme forests in the Colombian Amazon. Biotropica 35(1):20–27.

FORGET, P.M., KITAJIMA, K. & FOSTER, R.B. 1999. Pre and post-dispersal seed predation in *Tachigali versicolor* (Caesalpinaceae): effects of timing of fruiting and variation among trees. J. Trop. Ecol. 15:61–81, http://dx.doi.org/10.1017/S026646749900067X

GUISANDE, G.C., BARREIRO, F.A., MANEIRO, E.I., RIVEIRO, A.I., VERGRA, C.A.R. & VAAMONDE, L.A. 2006. Tratamiento de datos. Universidad de Vigo, Vigo.

HERRERA, C.M. 1998. Population-level estimates of inter-annual variability in seed production: what do they actually tell us? Oikos 82:612–616, http://dx.doi.org/10.2307/3546384

HUBBELL, S.P., FOSTER, R.B., O'BRIEN, S.T., HARMS, K.E., CONDIT, R., WECHSLER, B., WRIGHT, S.J & LOO DE LAO S. 1999. Light-gap disturbances, recruitment limitation, and tree diversity in a neotropical forest. Science 283:554–557, http://dx.doi.org/10.1126/science.283.5401.554

HULME, P.E. 2001. Seed-eaters: Seed dispersal, destruction and demography. In Seed dispersal and frugivory: ecology, evolution and conservation (Levey, D.J, Silva, W.R. & Galetti, M. eds.). CABI Publishing, Wallingford, p. 257–273.

HURTT G.C. & PACALA, S W. 1995. The consequences of recruitment limitation: reconciling chance, history and competitive differences between plants. J. Theor. Biol. 176:1–12, http://dx.doi.org/10.1006/jtbi.1995.0170

JANZEN, D.H. & VAZQUEZ-YANES, C. 1991. Aspects of tropical seed ecology of relevance to management of tropical forested wildlands. In Rain forest regeneration and management (Gómez-Pompa, A., Whitmore, T.C. & Hadley, M. eds.). UNESCO/Parthenon, Paris, p. 137–157.

LARSON, B.M.H. & BARRETT, S.C.H. 2000. A comparative analysis of pollen limitation in flowering plants. Biol. J. Linn. Soc. 69:503–520, http://dx.doi.org/10.1111/j.1095-8312.2000.tb01221.x

LAURANCE, W., NASCIMENTO, H.E.M., LAURANCE, S.G., CONDIT, R., D' ANGELO, LAURANCE, SAMMYA & ANDRADE, A. 2004. Inferred longevity of Amazonian rainforest trees based on a long-term demographic study. For. Ecol. Man. 190(2-3):131–143, http://dx.doi.org/10.1016/j.foreco.2003.09.011

LEVIN, S.A., MULLER-LANDAU, H.C., NATHAN, R. & CHAVE, J. 2003. The ecology and evolution of seed dispersal: a theoretical perspective. Annu. Rev. Ecol. Evol. S. 34:575–604, http://dx.doi.org/10.1146/annurev.ecolsys.34.011802.132428

LÓPEZ, R. & CÁRDENAS, D. 2002. Manual de identificación de especies maderables objeto de comercio en la Amazonia colombiana. Instituto Amazónico de Investigaciones Científicas, SINCHI, Bogotá.

MARIMON, B.S. & FELFILI, J.M. 2001. Studies in monodominant forests in eastern Mato Grosso, Brazil: ii. A forest in the areões Xavante indian reserve. Edinburgh Journal of Botany 58:483–497.

MARON, J.L. & GARDNER, S.N. 2000. Consumer pressure, seed versus safe site limitation, and plant population dynamics. Oecologia 124:260–269.

MARQUES, M.C.M., ROPER, J.J. & SALVALAGGIO, A.P.B. 2004. Phenological patterns among plant life-forms in a subtropical forest in southern Brazil. Plant Ecol. 173:203–213, http://dx.doi.org/10.1023/B:VEGE.0000029325.85031.90

MULLER-LANDAU, H.C., WRIGHT, S.J., CALDERON, O., CONDIT, R. & HUBBELL, S.P. 2008. Interspecific variation in primary seed dispersal in a tropical forest. J. Ecol. 96:653–667, http://dx.doi.org/10.1111/j.1365-2745.2008.01399.x

MURCIA, C. 2002. Ecología de la polinización. In Ecología y Conservación de bosques neotropicales (Guariguata, M. & Kattan, G. eds.). LUR, San José, p. 493–530.

PALACIOS, P.A. 2005. Patrones estructurales y distribución espacial de poblaciones de *Brosimum rubescens* Taub. en relación con la variabilidad fisiográfica en la rivera colombiana del rio Amazonas. Tesis de Maestría, Universidad Nacional de Colombia, Sede Amazonia. Leticia.

PALACIOS, A.E., RODRÍGUEZ, A. & DEFLER, T.R. 1997. Diet of group of Callicebus torquatuslugens during the annual resource bottleneck. Internat. Jour. Primat. 18(4):503–522, http://dx.doi.org/10.1023/A:1026307121583

PARRADO-ROSELLI, A. 2005. Fruit availability and seed dispersal in terra firme rain forests of Colombian Amazonia. Ph,D. Thesis, University of Amsterdam, Amsterdam.

PARRADO-ROSELLI, A., MACHADO, S.P. & PRIETO-LOPEZ, T. 2006. Comparison between two methods for measuring fruit production in a tropical forest. Biotropica 38(2):267–271, http://dx.doi.org/10.1111/j.1744-7429.2006.00125.x

PEÑUELA, M.C. & PIJACHE, A. 2007. Densidad y estructura de 17 especies maderables en una megaparcela de 20 hectáreas en bosque de tierra firme. En: Actualidades Biológicas. Suplemento 1. Vol. 29. Resúmenes IV Congreso Colombiano de Botánica.

PEÑUELA-MORA, M.C. 2014. Understanding Colombian Amazonian White-Sand Forests. Ph.D. Thesis, Utrecht University, Utrecht.

RANGEL, O. & LUENGAS, B. 1997. Clima y Aguas. In Zonificación ambiental para el plan modelo colombo-brasilero (eje Apaporis-Tabatinga: PAT) (IGAC, ed.). Linotipia Bolívar, Bogotá, Maryland, p. 49–68.

RESTREPO, C. 2002. Frugivoría. InEcología y Conservación de bosques neotropicales (Guariguata, M. & Kattan, G. eds.). LUR, San José, p. 531–557.

RIVERA, G. & BORCHERT, R. 2001. Induction of flowering in tropical trees by a 30 min reduction in photoperiod: evidence from field observations and herbarium collections. Tree Physiol. 21(4):201–212, http://dx.doi.org/10.1093/treephys/21.4.201

RIVERA, L.E., LÓPEZ, J.E. & TRIANA, M.A. 2006. Efecto del sombreado en el crecimiento y mortalidad de plántulas de regeneración natural de Palosangre (*Brosimum rubescens* Taubert) en el sur del Trapecio Amazónico. Colombia Forestal 9:60–69, http://dx.doi.org/10.14483/udistrital.jour.colomb.for.2005.1.a05

ROBERSON, A.W. & MAC NAIR, M.R. 1995. The effects of floral display size on pollinator service to individual flowers of Myosotis and Mimulus. Oikos 72:106-114, http://dx.doi.org/10.2307/3546044

RODRÍGUEZ, M., J V., HERNÁNDEZ, J., DEFLER, T., ALBERICO, M., MAST, R, MITTERMEIER, R. & CADENA, A. 1995. Mamíferos colombianos: sus nombres comunes e indígenas. Ocasional Paper no. 3. Conservation International, Washington, D. C.

ROZO-MORA, M.C., & PARRADO-ROSELLI, A. 2004. Diurnal primary seed dispersal of Dacryodes chimantensis and Protium paniculatum (Burseraceae) in a tierra firme rain forest of Colombian Amazonia. Caldasia 6:11–124.

RUDAS, A. & PRIETO, A. 2005. Flórula del Parque Nacional Natural Amacayacu, Amazonas, Colombia. Missouri Botanical Garden. Press., St. Louis.

SÁNCHEZ, M. 1997. Catalogo preliminar y comentado de la flora del Medio Caquetá. Estudios en la Amazonia colombiana XIII. Tropenbos – Colombia, Bogotá.

SCHUPP E.W. 1992. The Janzen-Connell model for tropical tree diversity: population implications and the important of spatial scale. Am. Nat. 140:526–530, http://dx.doi.org/10.1086/285426

SCHUPP, E.W. & FUENTES, M. 1995. Spatial patterns of seed dispersal and the unification of plant population ecology. Ecoscience 2:267–75.

SCHUPP, E.W., MILLERON, T. & RUSSO, S.E. 2002. Dissemination limitation and the origin and maintenance of species-rich tropical forests. In Seed dispersal and frugivory: ecology, evolution and conservation (Levey, D.J., Silva, W.R. & Galetti, M. eds.). CAB International, Wallingford, p. 19–33.

STEVENSON, P.R. 2002. Frugivory and seed dispersal by woolly monkeys (Lagothrix lagothricha) in Tinigua National Park, Colombia. Ph.D Dissertation, State University of New York at Stony Brook, New York.

STEVENSON, P.R., CASTELLANOS, M.C., CORT, A.I. & LINK, A. 2008. Flowering Patterns in a Seasonal Tropical Lowland Forest in Western Amazonia. Biotropica 40(5):559–567, http://dx.doi.org/10.1111/j.1744-7429.2008.00417.x

STEVENSON, P.R., QUIÑONES, M.J. & AHUMADA, J.A. 2000. Influence of fruit availability on ecological overlap among four neotropical primates at Tinigua National Park, Colombia. Biotropica 32(3):533–544.

STONER K.E. & M HENRY. 2010. Seed Dispersal and Frugivory in Tropical Ecosystems. In Encyclopedia of Life Support Systems: Tropical Biology and Natural Resources. UNESCO. http://www.eolss.net/outlinecomponents/International-Commission-Tropical-Biology-Natural-Resources.aspx

TER STEEGE, H, & PERSAUD, C.A. 1991. The phenology of Guyanese timber species: a comparison of a century of observations. Biotropica 10:194–210.

TERBORGH, J.T. 1986. Community aspects of frugivory in tropical forests. In Frugivores and Seed Dispersal (Estrada, A. & Fleming, T.H. eds.). Junk, Dordrecht, p. 371–384.

TERBORGH, J.T., PITMAN, N., SILMAN, M., SCHICHTER, H. & NÚÑEZ, P. 2002. Maintenance of tree diversity in tropical forest. In Seed dispersal and frugivory: ecology, evolution and conservation (Levey, D.J., Silva, W:R. & Galetti, M. eds.). CAB International, Wallingford, pp. 1–17.

TILMAN, D. 1994. Competition and biodiversity in spatially structured habitats. Ecology 75:2–16, http://dx.doi.org/10.2307/1939377

TUFTO, J., ENGEN, S & HINDAR, K. 1997. Stochastic dispersal processes in plant populations. Theor. Popul. Biol. 52:16–26, http://dx.doi.org/10.1006/tpbi.1997.1306

URREGO, L.E. 1997. Los bosques inundables del medio Caquetá. Caracterización y sucesión. Estudios Amazonia colombiana XIV. Tropenbos - Colombia. Impreandes Presencia, Bogotá.

VAN RHEENEN, J. 2005. The role of seed trees and seedling regeneration for species maintenance in logged-over forest – a study in the Bolivian Amazon rainforest. Ph.D Dissertation, Universiteit Utrecht, Utrecht.

VAN ULFT, L.H. 2004. Regeneration in natural and logged tropical rain forest. Modelling seed dispersal and regeneration of tropical trees in Guyana. Tropenbos-Guyana Series 12,Tropenbos-Guyana Programme, Georgetown.

VIEIRA, S., TRUMBORE, S, CAMARGO, PB, SELHORST, D, CHAMBERS, J.Q, HIGUCHI N., & MARTINELLI, L.A. 2011. LBA-ECO CD-08 Radiocarbon Dating of Tree Ages in Amazonas, Acre, and Para in Brazil. Data set from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. http://daac.ornl.gov

WILLIAMS-LINERA, G. & MEAVE, J. 2002. Patrones fenológicos. En Ecología y conservación de bosques neotropicales (Guariguata, M & Kattan, G eds.). LUR. San José, p. 407–431.

WRIGHT, S.J., & VAN SCHAIK C.P. 1994. Light and phenology of tropical trees. Am. Nat. 143:192–199, http://dx.doi.org/10.1086/285600

WRIGHT, S.J., & CALDERÓN, O. 1995. Phylogenetic patterns among tropical flowering phenologies. J. Ecol. 83:937-948, http://dx.doi.org/10.2307/2261176

WRIGHT, S.J., CARRASCO, C., CALDERÓN, O. & PATON, S. 1999. The El Niño Southern Oscillation, variable fruit production and famine in a tropical forest. Ecology 80:1632–1647.

WRIGHT, S.J., JARAMILLO, M.A., PAVON, J., CONDIT, R., HUBBELL, S.P. & FOSTER, R.B. 2005a. Reproductive size thresholds in tropical trees: variation among individuals, species and forests. J. Trop. Ecol. 21:307–315, http://dx.doi.org/10.1017/S0266467405002294

WRIGHT, J., MULLER-LANDAU, H., CALDERON, O. & HERNANDEZ, A. 2005b. Annual and spatial variation in seedfall and seedling recruitment in a neotropical forest. Ecology 86(4):848–860, http://dx.doi.org/10.1890/03-0750

Received 18/11/2013
Revised 16/10/2014
Accepted 21/10/2014

Biota Neotropica 14(4): e20140062, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
inventory

Checklist of climbing plants in an Araucaria forest of Rio Grande do Sul State, Brazil

Guilherme Dubal dos Santos Seger[1,2] & Sandra Maria Hartz[1]

[1] Programa de Pós-Graduação em Ecologia, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, Prédio 43422, Sala 102, CEP 91501-970, Porto Alegre, RS, Brazil.
[2] Corresponding author: Guilherme Dubal dos Santos Seger, e-mail: guiseger@yahoo.com.br

SEGER, G.D.S., HARTZ, S.M. **Checklist of climbing plants in an Araucaria forest of Rio Grande do Sul State, Brazil.** Biota Neotropica. 14(4): e20140062. http://dx.doi.org/10.1590/1676-06032014006214

Abstract: Climbing plants are remarkable components of forests, highly contributing for the diversity and dynamics of communities. Studies focusing on climbing plants are scarce and for many vegetation types little is known about climbing species composition and their traits relevant for dispersal and establishment. The focus of this study is to provide the first floristic inventory of climbing plants in an *Araucaria* forest of Brazil, describing the dispersal syndromes and climbing mechanisms of species and comparing these traits and species composition patterns with other study sites in Southern Brazil. We found 104 taxa belonging to 33 families, with Asteraceae (22 spp.) and Apocynaceae (14 spp.) being the richest families. Among climbing mechanisms, stem twiner (50 spp.) is the most common, followed by tendril (20 spp.) and scrambler (12 spp.), while in relation to the dispersal syndromes, anemochoric species (65 spp.) are the most relevant followed by endozoochoric (28 spp.). Three new species registries were found for Rio Grande do Sul State expanding their occurrence range towards South Brazil. The comparison of climbers' survey sites showed two sharp groups in relation to species composition and traits proportion, Seasonal and *Araucaria*/Atlantic forest sites, but with no difference of traits frequency between sites. There is a predominance of stem twiners species in all sites, but the relative difference for tendril species increases in *Araucaria* and Atlantic forest sites. The Asteraceae and Apocynaceae families were the most relevant, contrasting to Seasonal forests of Southeast Brazil. Interesting patterns can be achieved with a more detailed classification of climbing mechanisms and the results found in this study contributes to enhance the knowledge on climbers' traits and diversity in South Brazil.
Keywords: *Lianas, Vines, Climbing mechanisms, Dispersal syndromes, Floristic of climbers.*

SEGER, G.D.S., HARTZ, S.M. **Florística de trepadeiras em uma floresta de Araucária do Estado do Rio Grande do Sul, Brasil.** Biota Neotropica. 14(4): e20140062. http://dx.doi.org/10.1590/1676-06032014006214

Resumo: Trepadeiras são importantes componentes florestais, contribuindo na diversidade e dinâmica de comunidades vegetais. Estudos focados em trepadeiras são escassos e para muitos tipos vegetacionais pouco se sabe sobre a composição de espécies de trepadeiras e seus atributos relevantes para dispersão e estabelecimento. O foco deste estudo é fornecer o primeiro inventário florístico de plantas trepadeiras em uma floresta de Araucária no Brasil, descrevendo as síndromes de dispersão e mecanismos de escalada das espécies e comparando esses atributos e a composição de espécies com outros sítios no Sul do Brasil. Foram encontrados 104 taxa pertencentes a 33 famílias, sendo Asteraceae (22 spp.) e Apocynaceae (14 spp.) as famílias mais ricas. Dentre os mecanismos de escalada, o tipo volúvel (50 spp.) é o mais comum, seguido por gavinhas (20 spp.) e apoiantes (12 spp.), enquanto em relação às síndromes de dispersão as espécies anemocóricas (65 spp.) são as mais relevantes seguidas por endozoocóricas (28 spp.). Três novos registros de espécies foram encontrados para o Estado do Rio Grande do Sul, expandindo suas extensões de ocorrência para o Sul do Brasil. A comparação entre sítios evidenciou dois grupos nítidos em relação à composição de espécies e proporção de atributos, sítios em florestas sazonais e nas florestas com Araucária e Atlântica, porém não há diferença na frequência dos atributos entre os sítios. Há uma predominância de espécies volúveis em todos os sítios, entretanto a diferença relativa para espécies com gavinhas aumenta nos sítios de floresta com Araucária e Atlântica. As famílias Asteraceae e Apocynaceae foram as mais relevantes, contrastando com florestas sazonais no Sudeste do Brasil. Padrões interessantes podem ser encontrados com uma classificação mais detalhada dos mecanismos de escalada e os resultados encontrados neste estudo contribuem para aumentar o conhecimento sobre os atributos e a diversidade de trepadeiras no Sul do Brasil.
Palavras-chave: *Lianas, Mecanismos de Escalada, Síndromes de dispersão, Florística de Trepadeiras.*

Introduction

The *Araucaria* forest, part of Mata Atlântica Biome, is the main forest type of South Brazil (IBGE 2004). It occurs continuously in the highlands of the Southern Brazilian Plateau and in small isolated areas of Argentina, Paraguay, Southeast Brazil and "Serra do Sudeste" formation in Rio Grande do Sul State, Brazil (Hueck 1972, Carlucci *et al.* 2011a). Timber logging of *Araucaria angustifolia* (Bertol.) Kuntze and other species was an important economic feature in the last century (Reitz *et al.* 1983), which contributed for reducing the *Araucaria* forest to less than 12.6% of its original area (Ribeiro *et al.* 2009). In spite of its wide geographic range, studies in the *Araucaria* forest manly focused on trees' communities (e.g. Duarte *et al.* 2012), no study to date has focused on climbing plants.

Climbing plants are important components of forests dynamics, contributing with biomass and plant diversity (Schnitzer & Bongers 2011), affecting mortality and growth of trees (Ingwell *et al.* 2010), collaborating with treefall gaps formation and preventing trees regeneration on it (Schnitzer & Carson 2010). Climbing species show a diversity of climbing mechanisms/strategies (Hegarty & Caballé 1991) to reach the best productive position, with full access to sunlight where they reproduce and spread through other trees canopies (Campbell & Newbery 1993). Forest structure directly influences the abundance, diversity and distribution of climbers. For instance, forest edges and treefall gaps present high diversity and density of climbers (Laurance *et al.* 2001, Londré & Schnitzer 2006), strongly determined by light availability on these early successional stages (DeWalt *et al.* 2000).

The *Araucaria* forest is expanding over *Campos* grasslands since the Holocene (Behling & Pillar 2007), mainly through forest edge expansion (Carlucci *et al.* 2011b) and nucleation process (Duarte *et al.* 2006). These expansion processes create a great amount of habitats for climbing species like forest edges and patches with different sizes and light availability, which are similar to fragmented landscapes caused by anthropic action known to positively affect climber's abundance (Londré & Schnitzer 2006). Since climbers are considered pioneer species and play an important role in forest succession (DeWalt *et al.* 2000), it is important to know their diversity, as well as their traits that might give an important overview of their limitations and capacity of dispersal and establishment at different environments. In this context, the aim of this study is to provide the first survey focused on climbing plants in an *Araucaria* forest of Southern Brazil and compare species traits (dispersal syndromes and climbing mechanisms) and composition with other study sites belonging to different forest types in South Brazil. We hypothesize that study sites of the same forest type are similar in relation to species composition and traits proportion.

Material and Methods

The floristic survey was carried out at the National Forest of São Francisco de Paula - ICMBIO ("Floresta Nacional de São Francisco de Paula"; FLONA–SFP), a conservation unit of sustainable use, located in São Francisco de Paula municipality in Rio Grande do Sul State (29°25'24"S, 50°23'13"W; Figure 1). FLONA–SFP is composed by a mosaic landscape of *Araucaria* forest remnants together with ecologically-managed *Araucaria angustifolia* (Bertol.) Kuntze, *Eucalyptus* spp. and *Pinus* spp. plantations and a small area of unmanaged *Campos* grassland. It covers 1,606 ha, where 36.6 % is covered by *Araucaria* forest remnants, ranging in altitude from 600 to 923 m a.s.l. The regional climate is characterized as subtropical rainy, with precipitation uniformly distributed throughout the year. The annual mean rainfall reaches 2,252 mm and the annual mean temperature is 14.4 °C with the occurrence of negative temperatures from April to November and rare events of snow (National Institute of Meteorology – INMET).

Climbers were monitored monthly from July 2007 to August 2009 along 13 km of trails inside and at the edges of *Araucaria* forest remnants and planting areas of *A. angustifolia*. Additionally, another 15 field trips were done from March 2010 to October 2013 at areas not visited before. These extra field trips covered around 70 ha of *Araucaria* forest remnants and 240 treefall gaps. The total survey comprised around 200 days of field trips. Voucher specimens were deposited at ICN Herbarium (Departamento de Botânica, Instituto de Biociências, Universidade Federal do Rio Grande do Sul). All taxa were classified into families following the APG III system (APG 2009) and according to its dispersal syndrome and climbing mechanism, using specialized literature and personal observation. Dispersal syndromes were classified according to van der Pijl (1982) into anemochoric, endozoochoric, epizoochoric, autochoric and barochoric. Some species uncertain about their dispersal syndrome and not clearly classified in specialized literature, were classified as anemochoric only when specialized appendices like plumes or wings were present, otherwise were considered as barochoric. The climbing mechanisms were classified according to Hegarty (1991) into stem twiner, petiole twiner, secondary shoot twiner, tendril (that coil), clasp tendril, adhesive tendril (terminal adhesive pads), scrambler, hook/spine (also aculeus or trichomes that prevent slipping) and adherent roots. Many species combine different climbing mechanisms, making them difficult to be correctly classified (Hegarty 1991). In these cases, we considered the main climbing mechanism the first to appear during species development (personal observation), but we also cite the secondary climbing mechanism. Species abundance was estimated by counting individuals during July 2007 to August 2009 (with an exception for new species found within March 2010 to October 2013) and species were classified as singletons (one individual found), low abundance (two to five individuals) and high abundance (more than 100 individuals).

In the State of Rio Grande Sul (RS), 11 studies sampled climbing species (Table 1) in different forest types, but only three of them, besides this survey, strictly focused on climbing plants. For the comparison between sites we selected the studies with more than 40 climbing species (eight sites), considered as reliable surveys. In each study, we compiled the checklist, checked for species synonymies, excluded exotic species, and complemented the survey reviewing species deposited at ICN and PACA (Instituto Anchietano de Pesquisas/UNISINOS) herbariums, assessing herbarium records from *species*Link (CRIA 2014) and consulting taxonomic studies for RS State. Species were classified in relation to their dispersal syndromes and climbing mechanisms following the same classification explained before, combining personal knowledge and specialized literature. To analyze sites relationship according to species composition and traits proportion (dispersal syndromes and climbing mechanisms) we performed separate cluster

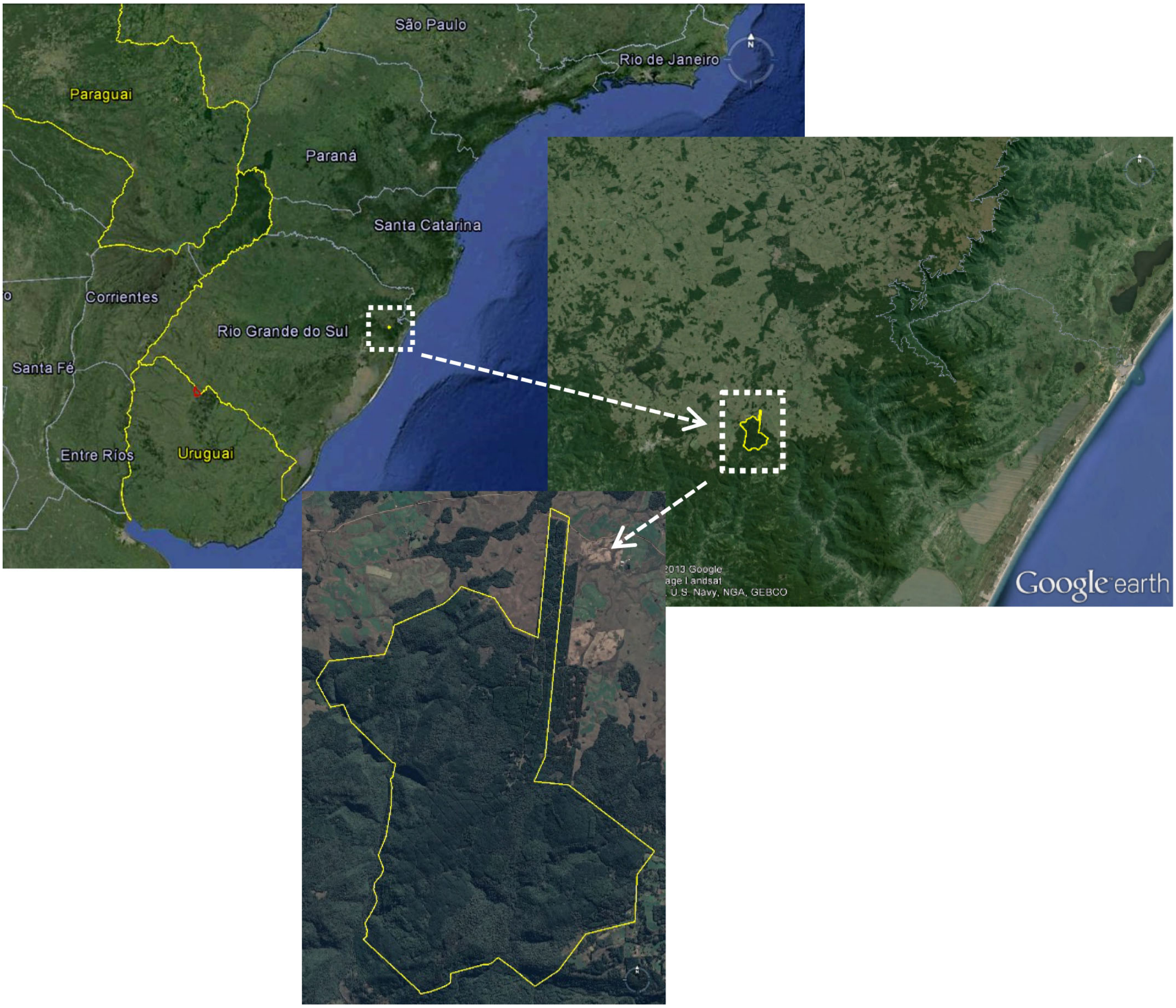

Figure 1. Location of the National Forest of São Francisco de Paula, RS, Brazil (29°25'24''S, 50°23'13''W) (Source: http://earth.google.com, 2013).

analyses, using Ward's clustering criterion and evaluating groups partition sharpness through 10,000 bootstrap resampling (Pillar 1999). As resemblance measurements between sites, we used the complement of Jaccard's similarity for species composition, and a modification of Gower's distance (Pavoine *et al*. 2009) for traits proportion. We also performed Fisher's exact tests with 10,000 Monte Carlo test replicates to evaluate whether there was a difference in the frequency of dispersal syndromes and climbing mechanisms between all sites. The modified Gower's distance was calculated in the package *ade4* v.1.6-2 (Dray & Dufour 2007) in the R Statistical Environment (R Core Team 2014). The complement of Jaccard's similarity and clustering analyses were performed using MULTIV 3.27b statistical software (by V.D. Pillar; available at http://ecoqua.ecologia.ufrgs.br/software).

Results

A total of 104 taxa were found at FLONA-SFP, belonging to 103 species, 62 genera and 33 families (Table 2). The richest families were Asteraceae (21 species), Apocynaceae (14), Fabaceae (10), Rubiaceae (7), Bignoniaceae and Malpighiaceae (5). Altogether these six families comprise 62 taxa (60% of total richness). Around a half of the families (16) contain two or more taxa, comprising 84% of total richness, while 20 genera containing two or more taxa comprise 62 taxa (60% of total richness). The richest genera were *Mikania* Willd. with 12 species, *Oxypetalum* R.Br. and *Manettia* Mutis ex L. with five. Around 29 species presented low abundance with a maximum of five individuals found and within them, six were singletons (Table 2). Considering the species in reproductive activity during July 2007 to August 2009 (G.D.S. Seger, unpublished data), eight species presented more than 100 individuals, while considering sterile individuals this number rises up to 27 species (Table 2).

The most common climbing mechanism is stem twinner (50 taxa) followed by tendril (20), scrambler (12), hook/spine (8), petiole twinner (6), adherent roots (3), clasp tendril (2), secondary shoot twinner (2) and adhesive tendril (1) (Table 2). A secondary climbing mechanism is present in six species.

Table 1. Floristic surveys of climbing plant species in Rio Grande do Sul State, Brazil. **Forest types**: AR - *Araucaria* forest; AT - Atlantic forest; D - Deciduous forest; R – Restinga forest; SD – Semideciduous forest; †Floristic survey of all plant life forms; Forest types classification is according to IBGE (2012).

Site (Coordinates)	Species richness	Forest type	Richest families (species number)	Reference
Derrubadas - P.E. Turvo † (27°13'15"S, 53°52'52"W)	130	D	Asteraceae (14), Bignoniaceae (13), Apocynaceae (12), Fabaceae (11) and Sapindaceae (9)	Brack *et al.* (1986) and herbarium review
Santa Maria (29°41'37"S, 53°48'51"W)	70	D	Sapindaceae (8), Apocynaceae, Bignoniaceae & Convolvulaceae (7)	Durigon *et al.* (2009)
São Jerônimo and Butiá † (29°57'23"S, 51°46'24"W)	37	SD	Bignoniaceae & Asteraceae (5) and Convolvulaceae & Sapindaceae (4)	Bueno *et al.* (1987)
Guaíba (30°10'47"S, 51°23'33"W)	92	SD	Asteraceae (14), Apocynaceae (11) and Fabaceae (9)	Durigon & Waechter (2011) and Matzenbacker *et al.* (2011)
Porto Alegre - Lami † (30°15'29"S, 51°6'11"W)	22	R	Asteraceae & Bignoniaceae (5) and Passifloraceae (3)	Fuhro *et al.* (2005)
Viamão - Morro do Coco † (30°16'3"S, 51°3'20"W)	60	SD	Bignoniaceae (8), Apocynaceae (6) and Convolvulaceae (5)	Knob (1978), Backes (1981), Aguiar *et al.* (1986) and herbarium review
Viamão - Morro da Grota † (30°21'57"S, 51°1'17"W)	33	SD	Bignoniaceae (5) and Asteraceae & Rubiaceae (3)	Aguiar *et al.* (1986)
Viamão - Morro Grande (30°5'8"S, 50°49'35"W)	44	SD	Asteraceae (7), Apocynaceae, Bignoniaceae & Passifloraceae (5)	Venturi (2000) and herbarium review
São Francisco de Paula (29°25'24"S, 50°23'13"W)	103	AR	Asteraceae (21), Apocynaceae (14), Fabaceae (10), Rubiaceae (7), Bignoniaceae & Malpighiaceae (5)	This study
Dom Pedro de Alcântara † (29°24'21"S, 49°50'53"W)	49	AT	Apocynaceae (7) and Asteraceae & Passifloraceae (5)	Silva Filho *et al.* (2013)
Torres - P.E. Itapeva † (29°21'28"S, 49°45'34"W)	100	AT	Asteraceae (20), Apocynaceae (13) and Cucurbitaceae (5)	SEMA (2006) and herbarium review

There is a predominance of anemochoric dispersal syndrome (65 taxa) followed by endozoochoric (28), barochoric (6), autochoric (4) and epizoochoric (1). Within anemochory, there are more pogonochoric species (plummed diaspores; 39 species) than pterochoric (winged diaspores; 26 species) (Table 2).

We found three new registries for the State of RS, *Matelea dusenii* Morillo (Apocynaceae family), *Manettia verticillata* Wernham (Rubiaceae) and *Piptadenia affinis* Burkart (Fabaceae) (Figure 2), extending their occurrence range towards South Brazil. *P. affinis* presented low abundance with only eight individuals found. *M. dusenii* is very rare with just one sapling and one individual at reproductive stage found, while *M. verticillata* presented only three individuals.

The floristic surveys with more than 40 species (eight sites) comprised 286 species, distributed in 131 genera and 49 families. The richest families were Apocynaceae and Asteraceae (36 spp.), Fabaceae (24), Bignoniaceae (18), Cucurbitaceae and Convolvulaceae (16), Malpighiaceae (15), Passifloraceae and Sapindaceae (13) and Rubiaceae (11). These families comprised 69% of total richness. The richest climbing mechanism was stem twiner (144 spp.), followed by tendrils (66), scramblers (31) and hook/spine (21). Anemochoric species (154 spp.) were the most common, followed by endozoochoric (81), barochoric (26) and autochoric (18). The cluster analysis of species composition revealed two major groups that were the only group's combination supported by group's partition sharpness analysis, one with the Atlantic and *Araucaria* forests sites and other with Seasonal forest sites (Figure 3). The cluster analysis of traits proportion showed support for up to four sharp groups (Figure 4), firstly separating the Atlantic and *Araucaria* forests sites from Seasonal forest sites, the Semideciduous from Deciduous forest sites and the Torres (Tr) site from the FLONA-SFP and Dom Pedro de Alcântara (DP) sites. There is a clear predominance of the anemochoric dispersal syndrome in all sites followed by endozoochoric syndrome (Figure 5). Comparing the most abundant climbing mechanisms (stem twiner, tendrils, scramblers and hook/spines), that together represent between 86 and 95% of total richness in each site, there is a predominance of stem twiners in all sites, followed by trendril climbers (Figure 6). Other interesting patterns are the inversion of scramblers proportion in relation to hook/spine species in the Atlantic forest sites (DP and Tr; Figure 6) and the presence of species that climb with the aid of adherent roots in eastern sites (FLONA-SFP, DP and Tr; Figure 6). Comparing the floristic surveys, the Fisher's exact test showed no difference for dispersal syndromes ($P = 0.94$) and climbing mechanisms ($P = 0.23$). Although there is a trend of observing a lower difference between anemochory and endozoochory in Semidecidual forest sites and a higher difference between stem twiners and tendril climbers in the Atlantic and *Araucaria* forest sites (Figures 5 and 6). When analyzing climbing mechanisms combining them in four major groups (joining stem twiner species with petiole twiner and secondary shoot twiner; tendril species with clasp tendril and adhesive tendril species; scrambler species with hook/spine species; and the adherent root species), as commonly seen in studies that classify the species' climbing mechanisms (e.g. Santos *et al.* 2009), the Fisher's exact test showed a significant result ($P = 0.02$).

Table 2. Species list, climbing mechanism, dispersal syndrome and the ICN voucher number of climbing species surveyed at the National Forest of São Francisco de Paula, RS, Brazil. **Climbing mechanism**: STw (Stem Twiner); PTw (Petiole Twiner); SSTw (Secondary Shoot Twiner); Td (Tendril); CTd (Clasp Tendril); ATd (Adhesive Tendril); Sc (Scrambler); HS (Hook/Spine); R (Adherent Roots). **Dispersal Syndrome**: A (Anemochoric); Z (Endozoochoric); Ep (Epizoochoric); T (Autochoric); B (Barochoric); Anemochoric subtypes (Pg - Pogonochoric; Pt - Pterochoric). **Abundance**: S (Singleton); L (Low; two to five individuals); H (High; more than 100 individuals). *Voucher deposited at the HUCS Herbarium (Universidade Federal de Caxias do Sul, Rio Grande do Sul State, Brazil).

Family/Species	Climbing mechanism	Dispersal Syndrome	Abundance	ICN Number
ALSTROEMERIACEAE				
Bomarea edulis (Tussac) Herb.	STw	Z	-	162137
APOCYNACEAE				
Araujia sericifera Brot.	STw	A (Pg)	L	175748
Forsteronia cf. *refracta* Müll.Arg.	STw	A (Pg)	L	175742
Mandevilla pentlandiana (A.DC.) Woodson	STw	A (Pg)	L	-
Marsdenia montana Malme	STw	A (Pg)	-	175100
Matelea dusenii Morillo	STw	A (Pg)	L	161668
Orthosia scoparia (Nutt.) Liede & Meve	STw	A (Pg)	H	183748
Orthosia urceolata E. Fourn.	STw	A (Pg)	H	183739
Orthosia virgata (Poir.) E. Fourn.	STw	A (Pg)	-	153827
Oxypetalum appendiculatum Mart.	STw	A (Pg)	L	175739
Oxypetalum pedicellatum Decne.	STw	A (Pg)	L	153826
Oxypetalum mosenii (Malme) Malme	STw	A (Pg)	-	162152
Oxypetalum pannosum Decne.	STw	A (Pg)	-	161716
Oxypetalum wightianum Hook. & Arn.	STw	A (Pg)	-	161718
Peltastes peltatus (Vell.) Woodson	STw	A (Pg)	L	175746
ASTERACEAE				
Baccharis anomala DC.	Sc	A (Pg)	H	172502
Baccharis oxyodonta DC.	Sc	A (Pg)	S	172508
Baccharis trinervis (Lam.) Pers.	Sc	A (Pg)	-	172526
Calea pinnatifida (R.Br.) Less.	Sc	A (Pg)	H	172510
Lepidaploa balansae (Chodat) H.Rob.	Sc	A (Pg)	-	172524
Mikania burchellii Baker	STw	A (Pg)	H	169834
Mikania campanulata Gardner	STw	A (Pg)	-	169822
Mikania cordifolia (L.f.) Willd.	STw	A (Pg)	S	-
Mikania hirsutissima DC.	STw	A (Pg)	-	169833
Mikania involucrata Hook. & Arn.	STw	A (Pg)	H	169836
Mikania laevigata Sch. Bip. ex Baker	STw	A (Pg)	-	161685
Mikania micrantha Kunth	STw	A (Pg)	-	169824
Mikania oreophila Ritter & Miotto	STw	A (Pg)	-	162153
Mikania orleansensis Hieron.	STw	A (Pg)	H	169840
Mikania paranensis Dusén	STw	A (Pg)	-	169842
Mikania parodii Cabrera	STw	A (Pg)	L	169844
Mikania ternata (Vell.) B.L.Rob.	STw	A (Pg)	-	161682
Mutisia campanulata Less.	Td	A (Pg)	L	162216
Mutisia speciosa Aiton ex Hook.	Td	A (Pg)	-	172498
Pentacalia desiderabilis (Vell.) Cuatrec.	R/Sc	A (Pg)	-	161683
Piptocarpha ramboi G.Lom.Sm.	Sc	A (Pg)	H	172519
BASELLACEAE				
Anredera tucumanensis (Lillo & Hauman) Sperling	STw	Z	L	175752
BEGONIACEAE				
Begonia fruticosa A. DC.	R	A (Pt)	-	175091
BIGNONIACEAE				
Amphilophium crucigerum (L.) L.G.Lohmann	Td	A (Pt)	H	175060
Bignonia sciuripabula (K.Schum.) L.G.Lohmann	Td	A (Pt)	-	175078
Dolichandra uncata (Andrews) L.G.Lohmann	CTd/R	A (Pt)	H	175081
Dolichandra unguis-cati (L.) L.G.Lohmann	CTd/R	A (Pt)	H	175065
Tanaecium selloi (Spreng.) L.G.Lohmann	Td	A (Pt)	L	-
BORAGINACEAE				
Tournefortia breviflora DC.	STw	Z	-	183179
Tournefortia paniculata Cham.	Sc	Z	-	172522

Continued on next page

Table 2. Continued.

Family/Species	Climbing mechanism	Dispersal Syndrome	Abundance	ICN Number
CANNABACEAE				
Celtis iguanaea (Jacq.) Sarg.	HS	Z	H	183511
CAPRIFOLIACEAE				
Valeriana scandens L.	STw	A (Pg)	-	175074
CELASTRACEAE				
Pristimera celastroides (Kunth) A.C.Sm.	STw	A (Pt)	L	175109
CONVOLVULACEAE				
Convolvulus crenatifolius Ruiz & Pav.	STw	B	L	183177
CUCURBITACEAE				
Apodanthera laciniosa (Schltdl.) Cogn.	Td	Z	-	161694
Cayaponia diversifolia Cogn.	Td	Z	L	161712
Cayaponia palmata Cogn.	Td	Z	-	161713
Cayaponia pilosa (Vell.) Cogn.	Td	Z	H	162151
DIOSCOREACEAE				
Dioscorea multiflora Mart. ex Griseb.	STw	A (Pt)	-	183514
Dioscorea subhastata Vell.	STw	A (Pt)	-	175088
EUPHORBIACEAE				
Tragia volubilis L.	STw	Ep	-	175063
FABACEAE				
Canavalia bonariensis Lindl.	STw	B	-	161672
Dalbergia frutescens (Vell.) Britton	SSTw	A (Pt)	H	172530
Lathyrus nervosus Lam.	Td	T	L	183549
Lathyrus paranensis Burkart	Td	T	S	175097
Mimosa niederleinii Burkart	Sc	T	-	183223
Phanera microstachya (Raddi) L.P.Queiroz	Td	A (Pt)	-	175111
Piptadenia affinis Burkart	HS	B	-	164538
Senegalia nitidifolia (Speg.) Seigler & Ebinger	HS	B	-	175747
Senegalia velutina (DC.) Seigler & Ebinger	HS	B	H	172517
Vigna peduncularis (Kunth) Fawc. & Rendle	STw	T	L	166514
GRISELINIACEAE				
Griselinia ruscifolia (Clos) Taub.	R	Z	-	183543
LOGANIACEAE				
Strychnos brasiliensis Mart.	HS	Z	H	175086
MALPIGHIACEAE				
Heteropterys aenea Gris.	STw	A (Pt)	-	172514
Heteropterys intermedia (A. Juss.) Griseb.	STw	A (Pt)	-	175902
Heteropterys syringifolia Griseb	STw	A (Pt)	-	175898
Janusia guaranitica (A. St.-Hil.) A. Juss.	STw	A (Pt)	L	172523
Tetrapterys phlomoides (Spreng.) Nied.	STw	A (Pt)	-	172529
MALVACEAE				
Abutilon vexillarium E. Morren	Sc	B	S	162390
MENISPERMACEAE				
Cissampelos pareira L.	STw	Z	-	175087
Disciphania contraversa Barneby	STw	Z	-	175106
ONAGRACEAE				
Fuchsia regia (Vell.) Munz	Sc	Z	L	161673
PASSIFLORACEAE				
Passiflora actinia Hook.	Td	Z	H	183527
Passiflora caerulea L.	Td	Z	H	161691
Passiflora foetida var. negelliflora L.	Td	Z	S	161693
PHYTOLACCACEAE				
Seguieria americana L.	HS	A (Pt)	H	175070
POACEAE				
Melica sarmentosa Nees	STw/HS	A (Pg)	L	175738
RANUNCULACEAE				
Clematis bonariensis Juss. ex DC.	PTw	A (Pg)	L	161678

Continued on next page

Table 2. Continued.

Family/Species	Climbing mechanism	Dispersal Syndrome	Abundance	ICN Number
Clematis dioica L.	PTw	A (Pg)	H	172528
ROSACEAE				
Rubus erythrocladus Mart.	HS	Z	H	175056
Rubus sellowii Cham. & Schltdl.	HS	Z	H	169892
RUBIACEAE				
Galium hypocarpium subsp. *gracillimum* (Ehrend.) Dempster	Sc	Z	-	175093
Galium hypocarpium subsp. *hypocarpium* (L.) Endl. ex Griseb.	Sc	Z	H	175090
Manettia gracilis Cham. & Schltdl	STw	A (Pt)	S	HUCS 10935*
Manettia paraguariensis Chodat	STw	A (Pt)	L	161695
Manettia pubescens Chamisso & Schlechtendal	STw	A (Pt)	-	183751
Manettia tweedieana K.Schum.	STw	A (Pt)	-	168751
Manettia verticillata Wernham	STw	A (Pt)	L	168754
SAPINDACEAE				
Serjania cf. *laruotteana* Cambess.	Td	A (Pt)	-	175704
Serjania meridionalis Cambess.	Td	A (Pt)	-	175705
Urvillea ulmacea Kunth	Td	A (Pt)	L	183744
SMILACACEAE				
Smilax cognata Kunth	Td/HS	Z	H	183555
SOLANACEAE				
Solanum flaccidum Vell.	PTw	Z	-	161700
Solanum inodorum Vell.	PTw	Z	-	167122
Solanum laxum Spreng.	PTw	Z	H	183212
TROPAEOLACEAE				
Tropaeolum pentaphyllum Lam.	PTw	Z	-	192397
VIOLACEAE				
Anchietea pyrifolia A. St.-Hil.	STw	A (Pt)	H	161708
VITACEAE				
Cissus striata Ruiz & Pav.	ATd	Z	H	175107
Cissus verticillata (L.) Nicolson & C.E.Jarvis	Td/R	Z	-	175062

Discussion

This is the first study focused only on climbing plant species realized in an *Araucaria* forest in Brazil. Studies focusing on climbing species are scarce in South Brazil (Citadini-Zanette 1997, Venturi 2000, Durigon *et al*. 2009, Durigon & Waechter 2011, Carneiro & Vieira 2012) and even when climbing habit is included on broad floristic surveys, the species richness is commonly underestimated. Nevertheless, in many cases broad floristic surveys give an important overview of climbers' richness, contributing for the knowledge of patterns like families' richness in some regions. Among them, the study of Brack *et al*. (1985) at the Seasonal forest of Turvo State Park presented the highest richness of RS State, with around 130 species and since it was not focused only on climber plants, the richness could be even greater. The cluster analysis results partially agreed with our hypothesis that species composition is similar within forest types, showing two sharp groups of Seasonal forests and *Araucaria*/Atlantic forests, with no clear pattern association of Deciduous and Semideciduous forests. The study of Durigon & Waechter (2011) found that the species composition of Guaíba site, one of the sites analyzed in this study, is similar to the biogeographic expansion line represented by the States from the north border of RS State. Our sites comparison is more detailed in relation to forest types, showing that the Semideciduous forests that are geographically close and present a mixture of floristic contingents of different origins (Waechter 2002) are more similar to Deciduous forests than *Araucaria*/Atlantic forests. It is noteworthy, as cited by Santos *et al*. (2009) that any species richness comparison between these surveys should be done with some caution, since they differ in sampled area and time effort and some studies may be underestimating the real richness of the study areas.

The richest families sampled at FLONA-SFP are according to other surveys in the Atlantic forest of Southeast Brazil (Lima *et al*. 1997, Barros *et al*. 2009, Villagra & Neto 2010), but there is a clear predominance of Apocynaceae and Asteraceae families not only at FLONA-SFP but also in most sites of RS State. In Seasonal forests of Southeast Brazil (Santos *et al*. 2009, Udulutsch *et al*. 2010), there is a predominance of species from Bignoniaceae, Fabaceae and Malpighiaceae families, in which the first two are also more representative in Seasonal forests of RS State. This demonstrates that the order of importance of families might not be only ruled by the vegetation type, but by the diversity center of some rich families/genera. In Seasonal forests of Southeast Brazil, Bignoniaceae presents its main diversity center (Lohmann *et al*. 2013), while in rainforests Asteraceae family increases in importance. The highest richness of Asteraceae family is reported to high altitudes and its great representativeness is

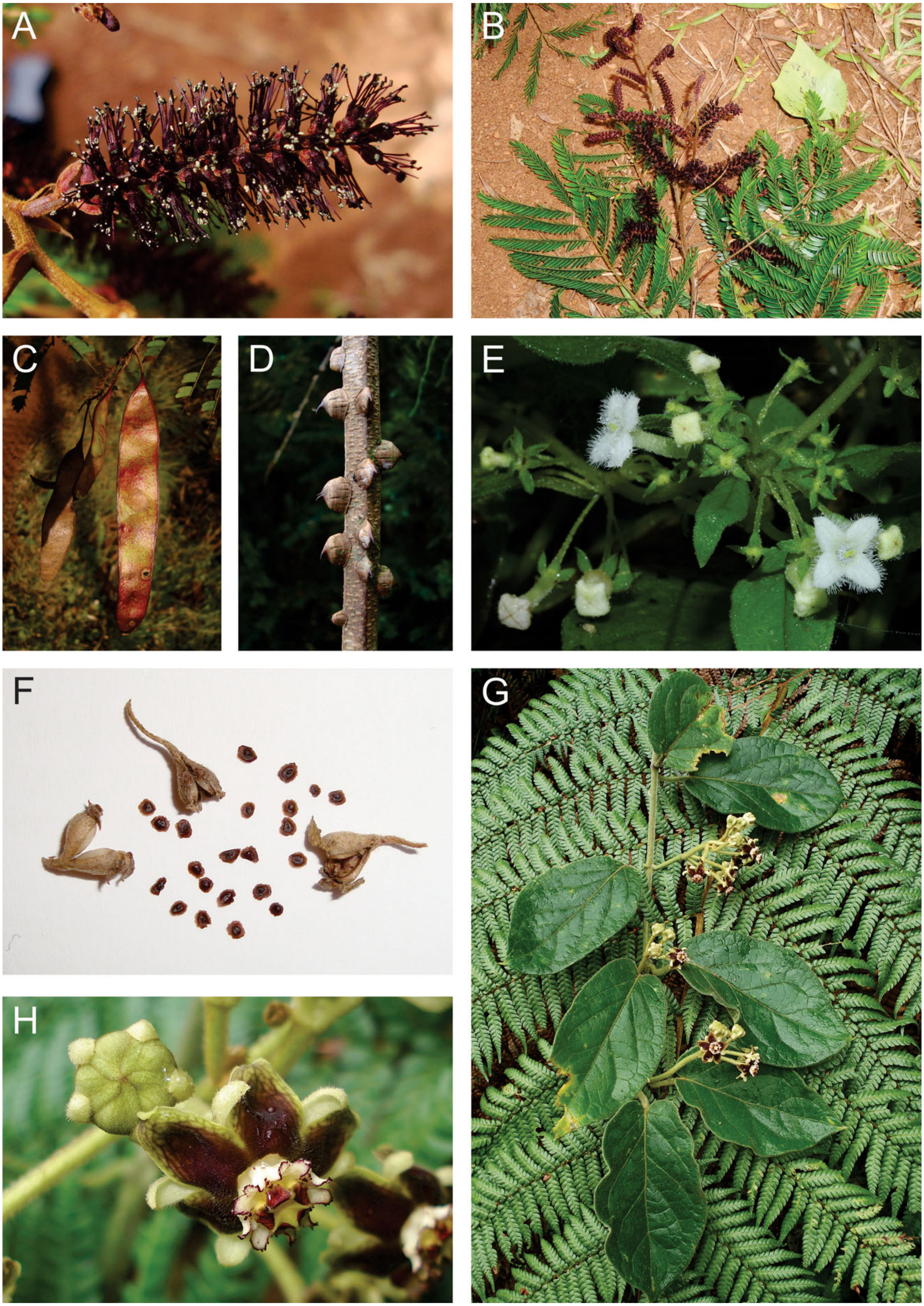

Figure 2. New species occurrences for Rio Grande do Sul State, Brazil. A-D: *Piptadenia affinis* Burkart; E and F: *Manettia verticillata* Wernham; G and H: *Matelea dusenii* Morillo.

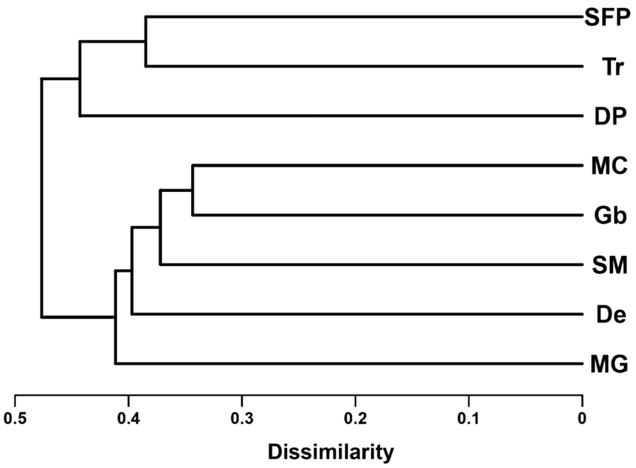

Figure 3. Dendrogram of climbers' survey sites according to species composition in Rio Grande do Sul State, Brazil. Cluster analysis performed using Ward's clustering criterion and the complement of Jaccard's similarity as resemblance measure. **Sites**: De – Derrubadas (Turvo State Park); SM – Santa Maria; MC – Viamão (Morro do Coco); MG – Viamão (Morro Grande); Gb – Guaíba; SFP – National Forest of São Francisco de Paula; DP – Dom Pedro de Alcântara; Tr – Torres (Itapeva State Park).

driven by *Mikania* Willd., the sixth world largest genus of climbers (Gentry 1991), that present its main diversity center in the Atlantic forest (Ritter & Waechter 2004). These phytogeographical patterns directly influences the climbing mechanisms and dispersal syndromes patterns over sites, since both families are anemochoric and Asteraceae is predominantly twiner while Bignoniaceae predominantly presents tendrils that coil. In Seasonal forests of Southeast Brazil, tendril species (encompassing trendrils that coil, clasp and adherent tendrils) overcome twiner species in many sites (Santos *et al.* 2009) whereas in Seasonal forests of RS State there is a prevalence of stem twiners. Adherent root climbers were more represented in the *Araucaria* and Atlantic forest sites, confirming their association with areas with high precipitation levels (Durigon *et al.* 2013).

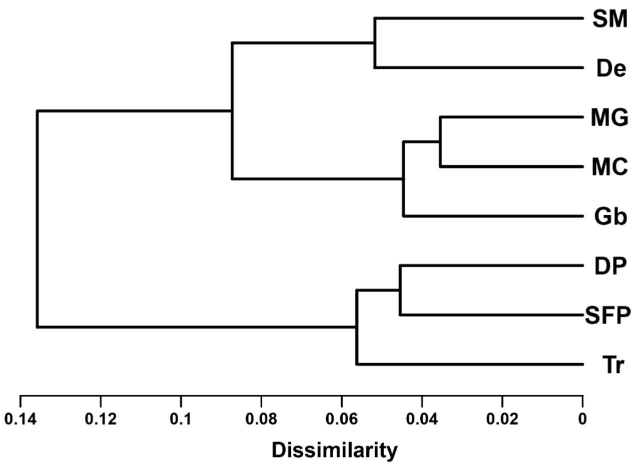

Figure 4. Dendrogram of climbers' survey sites according to climbing mechanisms and dispersal syndromes proportion in Rio Grande do Sul State, Brazil. Cluster analysis performed using Ward's clustering criterion and a modification of Gower's distance as resemblance measure. For sites abbreviations consult Figures 3 and 5.

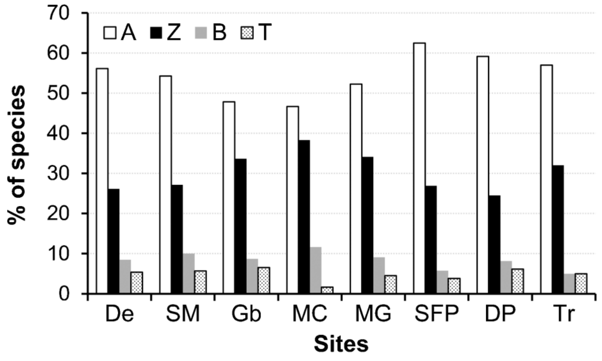

Figure 5. Species proportion at each study site (sites with more than 40 species) at Rio Grande do Sul State, according to its dispersal syndrome. Sites are disposed from west (left) to east (right). **Dispersal Syndrome:** A (Anemochoric); Z (Endozoochoric); B (Barochoric); T (Autochoric). **Sites:** De – Derrubadas (Turvo State Park); SM – Santa Maria; MC – Viamão (Morro do Coco); MG – Viamão (Morro Grande); Gb – Guaíba; SFP – National Forest of São Francisco de Paula; DP – Dom Pedro de Alcântara; Tr – Torres (Itapeva State Park).

The cluster analysis confirmed our hypothesis that species traits proportion were similar within forest types, showing that traits patterns are not modified by species turnover between sites and that it might be ruled by an association of vegetation type and geographic scale.

Not only light availability determines climbers' distribution, but also the presence of suitable supports, which influences each climbing mechanism. Trelisses density, that is higher on forest edges and treefall gaps, limits climbers' access to the canopy, since few species are capable to climb supports with more than 10-20 cm of diameter (Putz 1984, Putz & Holbrook 1991). In this way, each climbing mechanism has support limitations that direct its occurrence and abundance to different successional stages with particular vegetation structure and/or forest disturbance regimes (Schnitzer & Bongers, 2002). The trendril climbers' group formed by species with clasp tendrils, adhesive tendrils and tendrils that coil, present different support limitations which determine its success on climbing supports with high diameters and different types of bark. Tendrils are usually limited to supports with a maximum of 10 cm of diameter (Putz 1984), while clasp and adherent

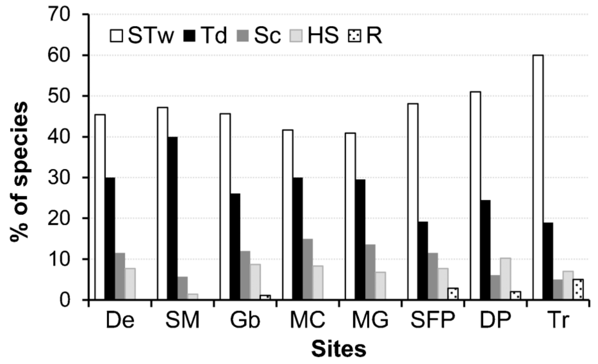

Figure 6. Species proportion at each study site (sites with more than 40 species) in Rio Grande do Sul State, according to its climbing mechanism. Sites are disposed from west (left) to east (right). **Climbing mechanism**: STw (Stem Twiner); Td (Tendril); Sc (Scrambler); HS (Hook/Spine); R (Roots). For sites abbreviations consult Figure 3 and 5.

tendril's species do not have any support limitation, climbing trees with large diameters. These limitations also occur with the twiner's group that climbs through shoot tips, secondary shoots and petioles. Our sites comparison revealed that the frequency of climbing mechanisms did not change over sites when using a detailed classification, while grouping species in major categories showed a significant result, indicating a difference between sites. So, it is interesting to classify the species as more specific as possible instead of grouping on major categories, to capture these strategies that directly influence species distribution in different environments. It is also important to pay attention on species that combine different climbing mechanisms, developing a secondary mechanism (e.g. adherent roots), which clearly gives them an advantage to firmly attach on their supports.

The three new occurrences for RS State found at FLONA-SFP had their occurrence range expanded towards South Brazil. The species *M. dusenii* was endemic to Paraná State (PR; Koch *et al*. 2013), *P. affinis* was endemic to Santa Catarina State (SC; Burkart 1979) and *M. verticillata* was registered for SC, PR, Minas Gerais and Rio de Janeiro States (Marinero *et al*. 2012). Based on this information we indicate these species to be included in future evaluations of the red list of threatened flora of RS State and Brazil.

As the definition of climber says it has to germinate and always keep contact with soil, some species can be confounded with hemiepiphytes, specifically the root-climber species. In this survey *Begonia fruticosa* A. DC., *Pentacalia desiderabilis* (Vell.) Cuatrec. and *Griselinia ruscifolia* (Clos) Taub. were considered climbers even though they can present a hemiepiphytes/epiphyte habit (Falkenberg & Voltolini 1995, Orihuela & Waechter 2010). The first species was always found as a climber, while the second was found a few times as a hemiepiphyte and the latter the majority of times as a hemiepiphyte (personal observation). Other example is *Mandevilla atroviolacea* (Stadelm.) Woodson, which was found just once with an epiphyte habit but was observed as a climber many times in adjacent areas near FLONA-SFP (*i.e.* Centro de Proteção e Conservação da Natureza Pró-Mata; personal observation). Another similar issue occurs with scrambler species that can be found at initial growth stages as shrubs or with a prostrate habit. The species *Fuchsia regia* (Vell.) Munz was found just three times as scrambler at FLONA-SPF, while in adjacent areas (*i.e.* CPCN Pró-Mata) this is the common habit. The species *Mimosa niederleinii* Burkart was commonly found as a prostrate herb, but in some cases it clearly climbs the vegetation, scrambling up to three meters of height.

An important issue at FLONA-SFP is the impact of the invasive climbing species *Hedera helix* L. and *Lonicera japonica* Thunb. that spreads over the edges and inside of tree plantations, preventing the recruitment and establishment of native species (personal observation). Their management and control is very difficult, being dispersed mainly by birds and may cause in a short time a great loss of habitat for many climbing species. In spite of this threat for climbing diversity, the great amount of forest edges, the unmanaged trees plantations where the understory is not periodically removed, and the *Araucaria* plantations that provide a high incidence of sunlight in the understory due to its canopy structure, allow a great establishment and development of climbers. These landscape features are only possible since FLONA-SFP is a conservation unit of sustainable use, and future management strategies of tree plantations in the area should consider the impact it may cause in climber species.

Acknowledgments

We are thankful to FAPERGS and CAPES for the scholarship to G.D.S Seger and CNPq for the researcher grant to S.M. Hartz (306816/2010-5); to Instituto de Biociências (UFRGS), Edenice B. S. Avila and the entire team of the São Francisco de Paula National Forest for all logistical support provided; Frediny B. Colla, Elisa V. Salengue and Evelise Bach for field work help; the graphic designer Victória D. Seger for species image treatment; Taís Guimarães for geoprocessing help; all the staff of ICN Herbarium; and the following taxonomists for the help on identifications: Mara R. Ritter, Renato A. Záchia, Martin Grings, Luis F. P. Lima, Silvia T. S. Miotto, Luis R. M. Baptista, João Iganci, Lilian Mentz, Édson L. Soares, Maria Ana Farinaccio, Angelo A. Schneider, Jaqueline Durigon, Priscila P. A. Ferreira, Jorge E. A. Mariath, Leila F. N. Macias, João A. Jarenkow, Cláudio A. Mondin, Rosangela S. Bianchini and Felipe Marinero.

References

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161:105–121, http://dx.doi.org/10.1111/j.1095-8339.2009.00996.x

AGUIAR, L.W., MARTAU, L., SOARES, Z.F., BUENO, O.L., MARIATH, J.E. & KLEIN, R.M. 1986. Estudo preliminar da flora e vegetação dos morros graníticos da grande Porto Alegre, Rio Grande do Sul, Brasil. Iheringia. Série Botânica 34:3–38.

BACKES, A. 1981. A flora do Morro do Coco, Viamão, RS. Iheringia. Série Botânca. 27:27–40.

BARROS, A.A.M., RIBAS, L.A. & ARAUJO, D.S.D. 2009. Trepadeiras do Parque Estadual da Serra da Tiririca (Rio de Janeiro, Brasil). Rodriguésia 60:681–694.

BRACK, P., BUENO, R.M., FALKENBERG, D.B., PAIVA, M.R.C., SOBRAL, M., STEHMANN, J.R. 1985. Levantamento florístico do Parque Estadual do Turvo, Tenente Portela, Rio Grande do Sul, Brasil. Roessléria 7(1):69–94.

BEHLING, H. & PILLAR, V.D. 2007. Late Quaternary vegetation, biodiversity and fire dynamics on the southern Brazilian highland and their implication for conservation and management of modern Araucaria forest and grassland ecosystems. Philos. T. Roy. Soc. B 362:243–251, http://dx.doi.org/10.1098/rstb.2006.1984

BUENO, O.L., NEVES, M.T.M.B., OLIVEIRA, M.L.A.A., RAMOS, R.L.D. & STREHL T. 1987. Florística em áreas da margem direita do baixo Jacuí, RS, Brasil. Acta Bot. Bras. 1(2):101–121, http://dx.doi.org/10.1590/S0102-33061987000200003

BURKART, A. 1979. Leguminosas Mimosoideas. In Flora Ilustrada Catarinense. (Reitz, P.R., ed.). Herbário Barbosa Rodrigues, Itajaí, p. 1–304.

CAMPBELL, E.J.F. & NEWBERY, D. 1993. Ecological relationships between lianas and trees in lowland rain forest in Sabah, East Malaysia. J. Trop. Ecol. 9:469–490, http://dx.doi.org/10.1017/S0266467400007549

CARLUCCI, M.B., JARENKOW, J.A., DUARTE, L.D.S. & PILLAR, V.D. 2011a. Conservação da Floresta com Araucária no Extremo Sul do Brasil. Nat. Conservacao 9:11–114.

CARLUCCI, M.B., TEIXEIRA, F.Z., BRUM, F.T. & DUARTE, L.S. 2011b. Edge expansion of Araucaria forest over southern Brazilian grasslands relies on nurse plant effect. Community Ecol. 12:196–201, http://dx.doi.org/10.1556/ComEc.12.2011.2.7

CARNEIRO, J.S. & VIEIRA, A.O.S. 2012. Trepadeiras: florística da Estação Ecológica do Caiuá e chave de identificação vegetativa para espécies do Norte do Estado do Paraná. Acta Scientiarum. Biological Sciences 34(2):217–223, http://dx.doi.org/10.4025/actascibiolsci.v34i2.5892

CITADINI-ZANETTE, V., SOARES, J.J. & MARTINELLO, C.M. 1997. Lianas de um remanescente florestal da microbacia do Rio Novo, Orleans, Santa Catarina. Insula 26:45–63.

CRIA. 2014. Centro de Referência em Informação Ambiental - *species*Link. http://splink.cria.org.br/ (último acesso em 07/ago/2014).

DEWALT, S., SCHNITZER, S.A. & DENSLOW, J.S. 2000. Density and diversity of lianas along a chronosequence in a central Panamanian lowland forest. J. Trop. Ecol. 16:1–19, http://dx.doi.org/10.1017/S0266467400001231

DRAY, S. & DUFOUR, A.B. 2007. The ade4 package: implementing the duality diagram for ecologists. J. Stat. Softw. 22(4):1–20.

DUARTE, L.D.S., DOS SANTOS, M.M.G, HARTZ, S.M. & PILLAR, V.D. 2006. Role of nurse plants in Araucaria forest expansion over grasslands in south Brazil. Austral Ecol. 31:520–528, http://dx.doi.org/10.1111/j.1442-9993.2006.01602.x

DUARTE, L.D.S., PRIETO, P.V. & PILLAR, V.D. 2012. Assessing spatial and environmental drivers of phylogenetic structure in Brazilian Araucaria forests. Ecography 35:001–009, http://dx.doi.org/10.1111/j.1600-0587.2011.07193.x

DURIGON, J., CANTO-DOROW, T.S. & EISINGER, S.M. 2009. Composição florística de trepadeiras ocorrentes em fragmentos de floresta estacional, Santa Maria, Rio Grande do Sul, Brasil. Rodriguésia 60(2):415–422.

DURIGON, J. & WAECHTER, J.L. 2011. Floristic composition and biogeographic relations of a subtropical assemblage of climbing plants. Biodivers. Conserv. 20(5):1027–1044, http://dx.doi.org/10.1007/s10531-011-0012-5

DURIGON, J., DURÁN, S.M. & GIANOLI, E. 2013. Global distribution of root climbers is positively associated with precipitation and negatively associated with seasonality. J. Trop. Ecol. 29(4):357–360, http://dx.doi.org/10.1017/S0266467413000308

FALKENBERG, D.B. & VOLTOLINI, J.C. 1995. The montane cloud forest in southern Brazil. In Tropical Montane cloud forests (Lawrence, S.H., James, O.J. & Scatena, F.N., eds.). Springer, US, p. 138–149.

FUHRO, D., VARGAS, D., & LAROCCA, J. 2005. Levantamento florístico das espécies herbáceas, arbustivas e lianas da floresta de encosta da Ponta do Cego, Reserva Biológica do Lami (RBL), Porto Alegre, Rio Grande do Sul, Brasil. Pesquisas, ser. Botânica 56:239–256.

GENTRY, A.H. 1991. The distribution and evolution of climbing plants. In The Biology of Vines (Putz, F.E. & Mooney, H.A. eds.). Cambridge University Press, Cambridge, pp. 3–49.

HEGARTY, E.E. 1991. Vine-host interactions. In The Biology of Vines (Putz, F.E. & Mooney, H.A. eds.). Cambridge University Press, Cambridge, pp. 357–375.

HEGARTY, E.E. & G C.A.B.A.L.L.É. 1991. Distribution and abundance of vines in forest communities. In The Biology of Vines (Putz, F.E. & Mooney, H.A., eds.). Cambridge University Press, Cambridge, pp. 313–335.

HUECK, K. 1972. As florestas da América do Sul: ecologia, composição e importância econômica. Polígono, São Paulo.

IBGE. 2004. Mapa de vegetação do Brasil. Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro, Brasil.

IBGE. 2012. Manuais Técnicos em Geociências 1 - Manual Técnico da Vegetação Brasileira. 2 ed. Brasil: Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro.

INGWELL, L.L., WRIGHT, S.J., BECKLUND, K.K., HUBBELL, S.P. & SCHNITZER, S.A. 2010. The impact of lianas on 10 years of tree growth and mortality on Barro Colorado Island, Panama. J. Ecol. 98:879–887, http://dx.doi.org/10.1111/j.1365-2745.2010.01676.x

KNOB, A. 1978. Levantamento fitossociológico da formação mata do Morro do Coco, Viamão, Rio Grande do Sul. Iheringia. Série Botânica (23):65–108.

KOCH, I., RAPINI, A., KINOSHITA, L.S., SIMÕES, A.O. & SPINA A.P. 2013. Apocynaceae. In : Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB4699 (último acesso em 10/Jan/2014)

LAURANCE, W.F., PÉREZ-SALICRUP, D., DELAMÔNICA, P., FEARNSIDE, P.M., D'ANGELO, S., JEROZOLINSKI, A., POHL, L. & LOVEJOY, T.E. 2001. Rain forest fragmentation and the structure of Amazonian liana communities. Ecology 82:105–116, http://dx.doi.org/10.1890/0012-9658(2001)082[0105:RFFATS]2.0.CO;2

LOHMANN, L.G., BELL, C.D., CALIÓ, M.F. & WINKWORTH, R.C. 2013. Pattern and timing of biogeographical history in the Neotropical tribe Bignonieae (Bignoniaceae). Bot. J. Linn. Soc. 171:154–170, http://dx.doi.org/10.1111/j.1095-8339.2012.01311.x

LONDRÉ, R.A. & SCHNITZER, S.A. 2006. The distribution of lianas and their change in abundance in temperate forests over the past 45 years. Ecology 87:2973–2978.

LIMA, H.C., LIMA, M.P.M., Vaz, A.M.S. & PESSOA, S.V.A. 1997. Trepadeiras da reserva ecológica de Macaé de Cima. In Serra de Macaé de Cima: diversidade florística e conservação em Mata Atlântica (Guedes-Brunini, R.R. & Lima, H.C. eds.). Jardim Botânico do Rio de Janeiro, Rio de Janeiro, p. 75–87.

MARINERO, F.E.C., WILLIAM, A.R. & CERVI, A.C. 2012. Manettia (Rubiaceae) no estado do Paraná, Brasil. Rodriguésia 63(3):635–647, http://dx.doi.org/10.1590/S2175-78602012000300012

MATZENBACKER, N.I., LIMA, L.F.P., DETTKE, G.A., DURIGON, J., KIELING-RUBIO, M.A. & TREVISAN, R. 2011. Flórula da Fazenda São Maximiano, Guaíba, Rio Grande do Sul, Brasil. 1 ed. EDIURCAMP, Bagé.

ORIHUELA, R.L.L. & J.L, WAECHTER. 2010. Host size and abundance of hemiepiphytes in a subtropical stand of Brazilian Atlantic Forest. J. Trop. Ecol. 26:119–122, http://dx.doi.org/10.1017/S0266467409990496

PAVOINE, S., VALLET, J., DUFOUR, A.B., GACHET, S., & DANIEL, H. 2009. On the challenge of treating various types of variables: application for improving the measurement of functional diversity. Oikos 118(3):391–402.

PILLAR, V.D. 1999. How sharp are classifications? Ecology 80(8):2508–2516.

PUTZ, F.E. 1984. The natural history of lianas on Barro Colorado Island, Panama. Ecology 65:1713–1724.

PUTZ, F.E. & HOLBROOK, N.M. 1991. Biomechanical studies of vines. In The Biology of Vines (Putz, F.E. & H.A. Mooney, eds.). Cambridge University Press, Cambridge, pp. 73–97.

REITZ, R., KLEIN, R.M., & REIS, A. 1983. Projeto Madeira do Rio Grande do Sul. Sellowia 34/35:1–525.

R CORE TEAM. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C PONZONI, F.J & HIROTA, M.M. 2009. The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biol. Conserv. 142:1141–1153, http://dx.doi.org/10.1016/j.biocon.2009.02.021

RITTER, M.R. & WAECHTER, J.L. 2004. Biogeografia do gênero Mikania Willd. (Asteraceae) no Rio Grande do Sul, Brasil. Acta Bot. Bras. 8(3):643–652.

SANTOS, K., KINOSHITA, L.S. & REZENDE, A.A. 2009. Species composition of climbers in seasonal semideciduous forest fragments of Southeastern Brazil. Biota Neotrop. 9(4):175–188 http://www.biotaneotropica.org.br/v9n4/pt/abstract?inventory+bn02409042009 (last access at 12/03/2014)., http://dx.doi.org/10.1590/S1676-06032009000400018

SCHNITZER, S.A. & BONGERS, F. 2002. The ecology of lianas and their role in forests. Trends Ecol. Evol. 17:223–230, http://dx.doi.org/10.1016/S0169-5347(02)02491-6

SCHNITZER, S.A. & CARSON, W.P. 2010. Lianas suppress tree regeneration and diversity in treefall gaps. Ecol. Lett. 13:849–857, http://dx.doi.org/10.1111/j.1461-0248.2010.01480.x

SCHNITZER, S.A. & BONGERS, F. 2011. Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. Ecol. Lett. 14:397–406, http://dx.doi.org/10.1111/j.1461-0248.2011.01590.x

SEMA. 2006. Projeto conservação da Mata Atlântica do Rio Grande do Sul: Plano de manejo do Parque Estadual de Itapeva. Secretaria Estadual do Meio Ambiente do Rio Grande do Sul. Porto Alegre, Brasil.

SILVA FILHO, P.J.S, SILVA, C.C., FRANCO, F.P., CAVALLI, J., BERTHOLDO, L.M., SCHMITT, L.A., ILHA, R. & MONDIN, C.A. 2013. Levantamento florístico de um fragmento de Floresta Ombrófila Densa no litoral norte do Rio Grande do Sul, Brasil. Revista Brasileira de Biociências 11(2):163–183.

UDULUTSCH, R.G. 2010. Composição florística e chaves de identificação para as lianas da Estação Ecológica dos Caetetus, estado de São Paulo, Brasil. Rodriguésia 61(4):715–730.

VAN DER PIJL, L. 1982. Ecological Dispersal Classes, Established on the Basis of the Dispersing Agents. In Principles of Dispersal in Higher Plants (van der PijlL., ed.). Springer-Verlag, Berlin Heidelberg New York, pp.22–90.

VENTURI, S. 2000. Florística e fitossociologia do componente apoiante-escandente em uma floresta costeira subtropical. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul, Porto Alegre.

VILLAGRA, B.L.P. & NETO, S.R. 2010. Florística de trepadeiras no Parque Estadual das Fontes do Ipiranga, São Paulo, SP, Brasil. Revista Brasileira de Biociências 8(2):186-200. WAECHTER J.L. 2002. Padrões geográficos na flora atual do Rio Grande do Sul. Ciência & Ambiente 24:93–10.

Received 12/04/2014
Revised 04/10/2014
Accepted 06/10/2014

Biota Neotropica 14(4): e20140068, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
article

Interactions between frugivorous birds and plants in savanna and forest formations of the Cerrado

Keila Nunes Purificação[1,2,4], Márcia Cristina Pascotto[2], Fernando Pedroni[3], Jessiane Mayara Nogueira Pereira[2] & Naftali Alves Lima[2]

[1] Programa de Pós-graduação em Ecologia e Conservação, Universidade do Estado de Mato Grosso, Nova Xavantina, MT, Brazil.
[2] Laboratório de Ornitologia, Universidade Federal de Mato Grosso, Barra do Garças, MT, Brazil.
[3] Universidade Federal de Mato Grosso, Instituto de Ciências Biológicas e da Saúde, Pontal do Araguaia, MT, Brazil.
[4] Corresponding author: Keila Nunes Purificação, e-mail: keilanunesbio@gmail.com

PURIFICAÇÃO, K.N., PASCOTTO, M.C., PEDRONI, F., PEREIRA, J.M.N., LIMA, N.A. **Interactions between frugivorous birds and plants in savanna and forest formations of the Cerrado.** Biota Neotropica. 14(4): e20140068. http://dx.doi.org/10.1590/1676-06032014006814

Abstract: We recorded interactions between frugivorous birds and plants in the Cerrado and we assessed the role and importance of birds as potential seed dispersers. We analyzed the distribution of recorded feeding events, bird-plant interactions, and bird species composition between savanna and forest formations and between the dry and rainy seasons. Samplings were carried out from August 2009 to October 2010 and from November 2011 to August 2012 by means of line transects and focal observations. We recorded 348 feeding events and 187 interactions involving 44 plant species and 60 bird species. Most of the feeding events were observed in the forests and during the dry season ($\chi^2 = 39.529$; $gl = 1$; $p < 0.001$). However, no significant difference was found in the number of interactions ($\chi^2 = 15.975$; $gl = 1$; $p = 0.06$) between the two vegetation formations and between seasons. The bird species composition differed between savanna and forest formations (ANOSIM, $R = 0.238$; $p < 0.001$) and between the dry and rainy seasons (ANOSIM, $R = 0.223$; $p < 0.001$). Most of the potential seed dispersers were generalist birds that preferentially occupy forests during the dry season. Records of feeding events in forest formations increased in the dry season, indicating that birds use these sites as foraging areas during this period. We suggest that the preservation of forests in predominantly savanna-like ecosystems such as the Cerrado is extremely important for frugivorous birds and for frugivore-plant interactions.

Keywords: *Mutualistic interactions, Neotropical savanna, seasonality, seed dispersal.*

PURIFICAÇÃO, K.N., PASCOTTO, M.C., PEDRONI, F., PEREIRA, J.M.N., LIMA, N.A. **Interações entre aves frugívoras e plantas em formações savânicas e florestais do Cerrado.** Biota Neotropica. 14(4): e20140068. http://dx.doi.org/10.1590/1676-06032014006814

Resumo: Registramos interações entre aves frugívoras e plantas no Cerrado e avaliamos o papel e a importância das aves como potenciais dispersoras de sementes. Observamos como números de registros de alimentação e de interações e composição de espécies de aves se distribuem entre formações savânicas e florestais e entre as estações seca e chuvosa. Realizamos amostragens entre agosto/2009 e outubro/2010 e entre novembro/2011 e agosto/2012 por meio de transecções e observações focais. Observamos 348 registros de alimentação e 187 interações envolvendo 44 espécies de plantas e 60 espécies de aves. A maioria dos registros de alimentação foi observada nas florestas e durante a estação seca ($\chi^2 = 39{,}529$; $gl = 1$; $p < 0{,}001$). Já em relação ao número de interações não encontramos diferença significativa ($\chi^2 = 15{,}975$; $gl = 1$; $p = 0{,}06$) entre as duas formações vegetacionais e entre as estações. A composição de espécies de aves diferiu entre formações savânicas e florestais (ANOSIM, $R = 0{,}238$; $p < 0{,}001$) e entre as estações seca e chuvosa (ANOSIM, $R = 0{,}223$; $p < 0{,}001$). A maioria das espécies potencialmente dispersoras foi aves generalistas que ocupam preferencialmente florestas durante a estação seca. Durante a estação seca há aumento de registros de alimentação nas formações florestais, indicativo de que as aves usam estes locais como área de forrageio nesse período. Sugerimos que a manutenção de florestas em ecossistemas predominantemente savânicos como o Cerrado é extremamente importante para a avifauna frugívora e para as interações frugívoro-planta.

Palavras-chave: *Interações mutualísticas, savana Neotropical, sazonalidade, dispersão de sementes.*

Introduction

One of the main positive interactions between plants and animals is seed dispersal by frugivores. Plants benefit from the dispersal of their propagules away from the parent plant because this reduces competition and predation (Howe & Smallwood 1982) and increases gene flow between populations. In return, animals that consume fruits receive nutritional benefits (Howe & Primack 1975, Snow 1981).

The interactions between fruiting plants and frugivorous birds in a community define a pattern comprising a few bird species that interact with many plant species and a few plants that interact with many birds. This makes the dependence between bird and plants species essential to the stability of the ecological processes of a community (Fadini & De Marco 2004).

Birds stand out as seed dispersers due to the high abundance and frequency with which they feed on fruits and their great ability to move between environments (Jordano 1994). Frugivorous birds represent 56% of the world's avian families and, in Neotropical forests, 25 to 30% of the avifauna includes fruits in their diet (Pizo & Galetti 2010). According to Jordano (1987), studies of frugivory by birds in tropical forests are relatively well reported (e.g., Snow 1981, Jordano 1987, Galetti & Pizo 1996, Medellín & Gaona 1999, Silva & Tabarelli 2000, Bascompte et al. 2003, Saracco et al. 2005, Galetti et al. 2013). It is estimated that 50 to 90% of tree species in tropical forests produce zoochorous fruit (Howe & Smallwood 1982). In contrast, in tropical savannas, despite the wide geographical distribution and rich biodiversity, few studies have addressed the frugivory and seed dispersal by birds (e.g., Dean et al. 1999, Hovestadt et al. 1999, Wütherich et al. 2001, Faustino & Machado 2006, Christianini & Oliveira 2009, Pascotto et al. 2012, Maruyama et al. 2013).

Savannas are defined primarily by their seasonal climate and fire regime, with vegetation characterized by an herbaceous stratum dominated by grasses and a discontinuous woody shrub stratum (Skarpe 1992). The Brazilian Cerrado, the largest savanna in the world, is represented by a mosaic of phytophysiognomic formations such as Fields, Cerrado *sensu stricto*, Semideciduous Forests and Gallery Forests (Silva & Bates 2002). The climate is represented by two well-defined seasons (one warm and wet and the other cool and dry), due to the changes in temperature and precipitation over the year (Eiten 1972).

With about 12000 plant species (Mendonça et al. 2008) and 837 bird species (Myers et al. 2000) catalogued, it is estimated that about half of the plant species in the Cerrado need animals to disperse their seeds, and birds are the main group of dispersers (Gottsberger & Silberbauer-Gottsberger 1983, Pinheiro & Ribeiro 2001, Kuhlmann 2012). The proportion of zoochorous plant species is high in both savanna and forest physiognomies of the Cerrado. In the Cerrado *sensu stricto* of Central Brazil, for example, the proportion of zoochorous plant species ranges from 51 to 68% (Vieira et al. 2002). On the other hand, in the Gallery Forests of Central and Southeastern Brazil, 63 to 89% of the plants have zoochorous dispersion and more than half of them are *ornithochorous* (Pinheiro & Ribeiro 2001, Motta-Junior & Lombardi 2002).

The fruit production of most Cerrado *sensu stricto* zoochorous species follows a seasonal pattern, with a peak in fruit ripening in the rainy season (Silberbauer-Gottsberger 2001, Lenza & Klink 2006, Pirani et al. 2009, Camargo et al. 2013). The same pattern has been observed in Gallery Forests (Oliveira & De Paula 2001). However, the fruit of most abundant species in the two phytophysiognomies ripen in the dry season (Gouveia & Felfili 1998).

Knowing that seed dispersal is an important ecological process that acts in the maintenance of diversity and that frugivory is the first step in studying this event (Cordeiro & Howe 2001), our objectives were (i) to identify the interactions between frugivorous birds and plants and the most important species in the community (*sensu* importance Murray 2000), and (ii) to evaluate the potential of seed dispersal, number of feeding records, number of interactions and composition of frugivorous bird species in savanna and forest formations of the Cerrado, considering the dry and rainy seasons. We tested the hypothesis that forest formations have higher numbers of feeding records and interactions, since most of the zoochorous plants of the Cerrado are concentrated in forests (Pinheiro & Ribeiro 2001, Kuhlmann 2012), and that the records of feeding and interactions show higher values during the rainy season, because there is greater availability of ripe fruit in the Cerrado during this season (Silberbauer-Gottsberger 2001, Lenza & Klink 2006, Pirani et al. 2009, Camargo et al. 2013). Our second hypothesis is that the composition of frugivorous bird species does not differ between savanna and forest formations or between the dry and rainy seasons, since most of the bird species of the Cerrado occur in both vegetation formations (Silva 1997, Bagno & Marinho-Filho 2001).

Material and Methods

Study area – This study was conducted in Serra Azul State Park (15°52'S and 51°16'W), located in the municipality of Barra do Garças, in the region of the Araguaia Valley, in the eastern part of the state of Mato Grosso. With an area of about 11,000 ha, this is an important Conservation Unit in the Cerrado containing a variety of phytophysiognomies typical to this biome, including savanna and forest formations (Ribeiro & Walter 2008). The average altitudes in the region range from 600 to 700 m and its soils are classified as clayey dystrophic red-yellow latosol (oxisol) (Pirani et al. 2009).

According to the Köppen classification the region has an Aw type climate, hot and humid, with two well-defined seasons, a rainy summer (October to March) and dry winter (April to September). The average annual temperature is 25.5°C and annual average rainfall is 1,528 mm (Pirani et al. 2009).

Data collection – Sampling was conducted from August 2009 to October 2010 (first period) and from November 2011 to August 2012 (second period). In the first period, we used four preestablished trails, each approximately 2 km in length, two of which passed through savanna formations (rocky outcrop Cerrado - *Cerrado Rupestre* and Typical Cerrado - *Cerrado Típico*) and two through forest formations (Gallery Forest and Semideciduous Forest). In the second period we sampled the module that follows the RAPELD model (Magnusson et al. 2005), in which two parallel 5-km-long trails, one kilometer apart from each other, pass through different Cerrado phytophysiognomies, such as Shrubby Grassland Cerrado (*Cerrado Ralo*), Typical Cerrado, Semideciduous Forest and Gallery Forest (*sensu* Ribeiro & Walter 2008).

The interactions were recorded using the line transect method (Bibby et al. 2000), with adaptations for frugivory studies (Pizo & Galetti 2010). In addition to the line transect method, focal observations were made involving twelve plant species chosen mainly because of their large individual fruit production and the easy visibility of the crown (*Byrsonima sericea* DC. – Malpighiaceae, *Cecropia pachystachya* Trécul – Urticaceae, *Copaifera langsdorffii* Desf. – Fabaceae, *Lasiacis ligulata* Hitchc. & Chase – Poaceae, *Miconia staminea* (Desr.) DC. – Melastomataceae, *Myrcia multiflora* (Lam.) DC. – Myrtaceae, *Myrsine umbellata* Mart. – Primulaceae, *Norantea guianensins* Aubl. – Marcgraviaceae, *Rudgea viburnoides* (Cham.) Benth. – Rubiaceae, *Schefflera morototoni* (Aubl.) Maguire et al. – Araliaceae, *Xylopia aromatica* (Lam.) Mart. e *Xylopia sericea* A. St.-Hil. – Annonaceae). Focal observations of the same plant were made on non-consecutive days, with an average of three observers per sampling. Three hours of focal observations were made for each plant species and only complete observations were considered, in which a frugivore was observed from its arrival on the plant until its departure, without losing sight of the bird during its entire visit (Silva et al. 2002).

Each time a bird was observed eating fruit the feeding event was recorded, regardless of the number of fruits consumed and the duration of the visit. In the case of flocks of birds foraging at the same time on the same plant, an individual feed record was made of the fruit consumed by each bird in the flock (Pizo & Galetti 2010). Records of feeding events by a bird species on a plant species corresponded to an interaction. Thus, an interaction indicated that a particular bird species consumed fruits of a particular plant species, regardless of the number of recorded feeding events.

In each recorded feeding event, we noted the consumer bird species, the plant species whose fruits were consumed, the phytophysiognomy and the date of the record. The mode of fruit consumption by the birds was also evaluated, including the portion of fruit consumed (pulp, aril, seed, and/or entire fruit) and the fruit's ripeness. Birds observed consuming whole propagules or taking them away from the parent plant were considered potential seed dispersers. The species that ate unripe fruits or that shredded the seeds were considered seed predators (Howe & Smallwood 1982, Moermond & Denslow 1985).

Weekly visits to the field were made in the first period, so that each phytophysiognomy was sampled at least once a month by the line transect method. Two to three weekly field visits were made in the second period, so that each vegetation type would also be sampled at least once a month by the line transect method, ensuring that the number of samplings in savanna and forest formations would be as similar as possible. Samplings were conducted between 6:00 AM and 1:00 PM., totaling 284 hours of sampling work by the line transect (248 hours) and focal methods (36 hours).

A frugivore was considered based on the criteria of Moermond & Denslow (1985), according to which a frugivorous bird is one that includes fruits in its diet at least during some season or stage of life, but does not feed exclusively on fruits. To separate the frugivorous birds into feeding guilds, we used the criteria adopted by Vieira et al. (2013) for the avifauna of Serra Azul State Park. The taxonomic classification and nomenclature of bird species was based on the proposal of the Brazilian Ornithological Records Committee (CBRO 2014) and of plant species on the List of Brazilian Flora Species (2014).

Data analysis – The importance index (*I*) was calculated for each bird species considered a potential seed disperser. This index denotes the contribution of a bird species compared with the other bird species to each of the plants with which it interacts. The index is characterized by assigning a weight to the species with many interactions, which include many exclusive interactions (Murray 2000), and is given by the following formula: $I_j = \Sigma[(C_{ij}/T_i)/S]$ where T_i is the total number of bird species that fed on the fruit of plant i, S is the total number of sampled plants species, and C_{ij} is equal to 1 if the bird species j consumed the fruits of the plant species i or 0 if it did not. The value of I varies between 0 and 1, with 0 corresponding to avian species that did not interact with any plant and 1 corresponding to those that consumed fruits from all the plants contained in the sample. The same index was use to calculate the plant species whose fruits were eaten by the birds. In this case, i corresponded to the bird species and j to the plant species.

We used the chi-square test (χ^2) by means of contingency tables (Zar 1999) to test our first hypothesis, i.e., to ascertain if there are more records of feeding events and interactions (consumed/did not consume) in forest formations than in savanna formations, and to determine how these values are distributed between the dry and rainy seasons. The composition of frugivorous bird species between savanna and forest formations and between the dry and rainy seasons (second hypothesis) was compared based on a multivariate analysis of similarity (ANOSIM) (Clarke & Green 1988), using the Jaccard similarity coefficient. The significance of the test (p) was obtained after 9,999 permutations and sequential Bonferroni correction (Legendre & Legendre 1998). The analyses were performed using the R-2.13.0 software program (R Development Core Team 2011).

Results

A total of 348 feeding events were recorded (average of 1.22 events per hour) and 187 interactions involving 44 plant species (26 families) and 60 bird species (19 families). Of the 60 bird species observed consuming fruit, 47 belong to the order Passeriformes, and are distributed in 12 families. Among them, the most numerous in terms of species were Thraupidae (16) and Tyrannidae (11). Among the non-passerines (13 species), the Psittacidae family was the most well represented (5 species) (Figure 1A). The plant families with the highest species richness were Myrtaceae (4), Melastomataceae (3) and Malpighiaceae (3) (Figure 1B).

The bird species that interacted with the largest number of plants were *Turdus leucomelas* Vieillot, 1818 (15 interactions) and *Dacnis cayana* (Linnaeus, 1766) (n = 12), followed by *Tangara cayana* (Linnaeus, 1766) (n = 9) and *Cyanocorax cyanopogon* (Wied, 1821) (n = 9). Considering only forest formations, *Turdus leucomelas* (n = 12), *Dacnis cayana* (n = 8) and *Saltator maximus* (Statius Muller, 1776) (n = 8) were the bird species that interacted with the largest number of plant species. In the savanna formations, *Dacnis cayana* and *Tangara sayaca* (Linnaeus, 1766) stood out with five interactions each, and *Hemithraupis guira* (Linnaeus, 1766) and *Elaenia chiriquensis* Lawrence, 1865, with four interactions each.

The plant species that interacted with the largest number of bird species were *Miconia staminea* (23 interactions), *Cecropia pachystachya* (n = 12) and *Dilodendron bipinnatum* Radlk. (n = 12). In the forest formations, 35% of the observed interactions involved *Miconia staminea* (n = 23), *Dilodendron bipinnatum* (n = 12) and *Schefflera morototoni* (n = 10). On the other hand,

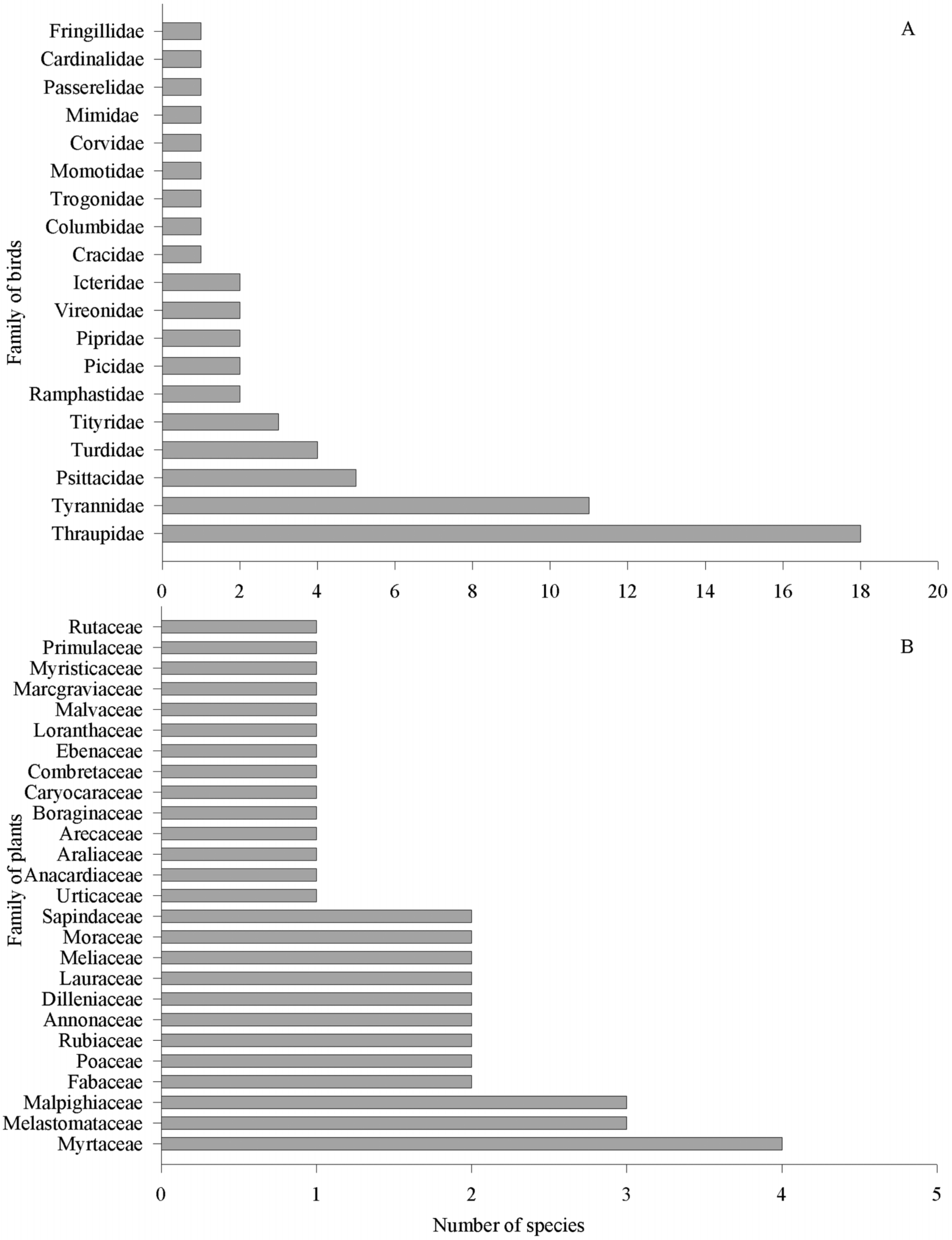

Figure 1. Specific richness of the avian (A) and plant (B) families that presented interactions in frugivory events in Serra Azul State Park, Mato Grosso, Brazil.

about 40% of the interactions in the savanna formations involved *Cecropia pachystachya* (9 interactions), *Curatella americana* L. (n = 9) and *Copaifera langsdorffii* (n = 7).

As for the importance index, *Turdus leucomelas* (*I* = 0.107), *Cyanocorax cyanopogon* (*I* = 0.066) and *Trogon curucui* Linnaeus, 1766 (*I* = 0.054) were the most important bird species in the entire community (Figure 2A). The most important bird species in the forests were *Turdus leucomelas* (*I* = 0.116), *Trogon curucui* (*I* = 0.078) and *Saltator maximus* (*I* = 0.071). In the savanna formations, the bird species with the highest levels of importance were *Volatinia jacarina* (Linnaeus, 1766) (*I* = 0.080), *Turdus leucomelas* (*I* = 0.065), *Tangara sayaca* (*I* = 0.065) and *Myiodynastes maculatus* (Statius Muller, 1776) (*I* = 0.065).

Among plants, *Miconia staminea* (*I* = 0.162), *Cecropia pachystachya* (*I* = 0.083) and *Rudgea viburnoides* (*I* = 0.063) were the most important in the community (Figure 2B). The plants that stood out in the forest formations were *Miconia staminea* (*I* = 0.255), *Rudgea viburnoides* (*I* = 0.089) and *Xylopia sericea* (*I* = 0.084). The most important plants in the savanna formations were *Cecropia pachystachya* (*I* = 0.170), *Curatella americana* (*I* = 0.165) and *Copaifera langsdorffii* (*I* = 0.111).

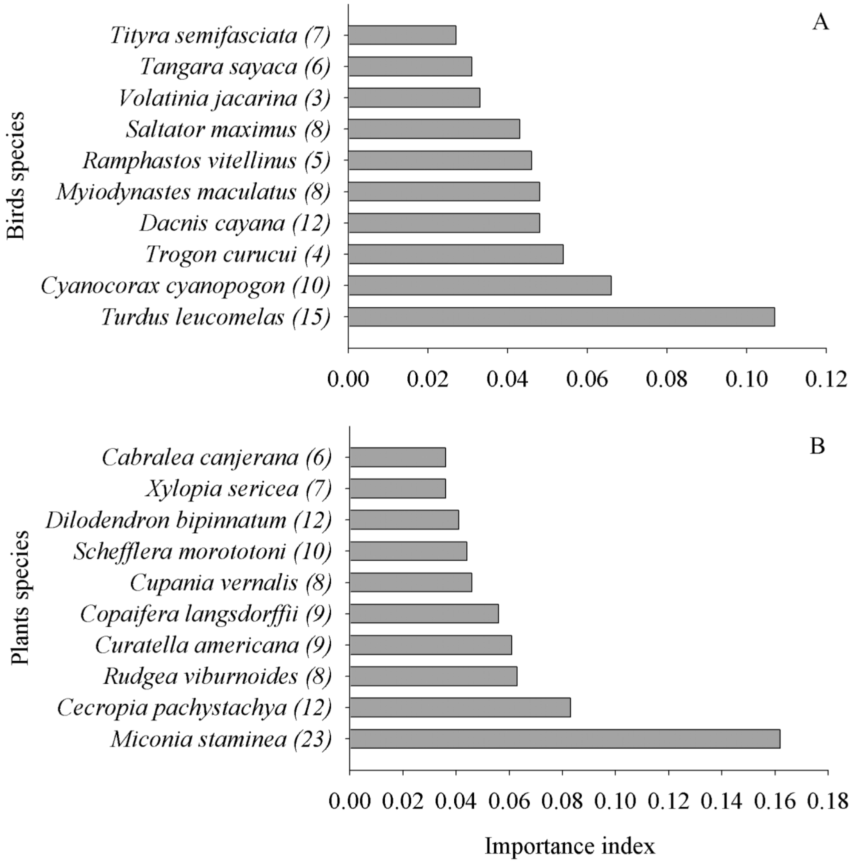

Figure 2. Indices of importance of the ten avian (A) and plant (B) species that presented the highest values in Serra Azul State Park, Mato Grosso, Brazil. The number of recorded interactions are shown in parentheses.

Among the observed interactions, 77% showed a potential for dispersal. Of the 60 bird species, 49 (82%) were considered potential dispersers of all the plant species with which they interacted. Seed predators, represented mainly by species of the Psittacidae family, accounted for 12% of the observed bird species. Besides parrots, only *Cyclarhis gujanensis* (Gmelin, 1789), *Nemosia pileata* (Boddaert, 1783), *Neothraupis fasciata* (Lichtenstein, 1823), *Tersina viridis* (Illiger, 1811), *Zonotrichia capensis* (Statius Muller, 1776) and *Gnorimopsar chopi* (Vieillot, 1819) were not considered potential seed dispersers of any plant species (Table 1).

The seeds of nine plant species were not dispersed by any bird species. The seeds of four of these plant species [*Brosimum gaudichaudii* Trécul, *Caryocar brasiliense* Cambess., *Cordia sellowiana* Cham. and *Pseudobombax tomentosum* (Mart. & Zucc.)] were shredded by parrots. Added to these plant species, the fruits of *Mezilaurus crassiramea* (Meisn.) Taub. ex Mez and Indeterminate 1 were consumed only in the unripe stage. The consumption of pulp was observed only in *Buchenavia tomentosa* Eichler, *Diospyros brasiliensis* Mart. ex Miq. and *Mangifera indica* L. (Table 1).

Most of the feeding events (70% of total) were recorded in forest formations and during the dry season (73%) ($\chi^2 = 39.529$; *gl*= 1; $p < 0.001$). As for the number of interactions (consumed/did not consume), about 70% of them were recorded in the forest formations and also during the dry season (75%). However, this result was not significant ($\chi^2 = 15.975$; $gl = 1$; $p = 0.06$). Of total number of frugivorous birds recorded, 75% occurred in forest formations and 52% in savanna formations, indicating that the composition of frugivorous bird species differed between the two types of vegetation (ANOSIM, $R = 0.238$, $p < 0.001$). The bird species composition also differed between seasons (ANOSIM, $R = 0.223$, $p < 0.001$). About 80% of the species were recorded during the dry season, while approximately 50% were recorded eating fruits in the rainy season. Twenty- nine bird species were recorded consuming fruits exclusively in forests, 15 exclusively in savanna formations, and 16 in both environments (Table 1).

Discussion

Bird species of the Thraupidae and Tyrannidae families (Passeriformes) were found to be the main potential seed dispersers. In frugivory studies conducted in the Cerrado (Francisco & Galetti 2002, Cazetta et al. 2002, Melo et al. 2003, Marcondes-Machado & Rosa 2005, Pascotto 2006, 2007, Francisco et al. 2007, Christianini & Oliveira 2009, Allenspach & Dias 2012, Pascotto et al. 2012, Maruyama et al. 2013), species of the aforementioned families also stood out as the main potential seed dispersers, with *Tangara sayaca*, *Tangara cayana* (Thraupidae), *Pitangus sulphuratus* (Linnaeus, 1766) and *Myiodynastes maculatus* (Tyrannidae) standing out as the most frequently recorded species.

Species of the tanager family are very important to seed dispersal in the Cerrado, as well as throughout the Neotropics (Snow & Snow 1971). According to Francisco & Galetti (2002),

Table 1. Avian species observed consuming fruit during 284 hours of observations in forest and savanna formations in Serra Azul State Park, municipality of Barra do Garças, Mato Grosso, Brazil. [1]**Dispersal potential (DP):** (PD) Potential disperser, (ND) Non-disperser. [2]**Diet (D)** (Vieira et al. 2013.): (Fru) Frugivorous, (Omn) Omnivorous, (Ins) Insectivorous, (Nec) Nectivorous, (Gra) Granivorous. [3]**Vegetation formation (VF):** (F) Forest, (S) Savanna. [4]**Season (S):** (D) Dry, (R) Rainy. *Seed shredder species. §Species carrying fruit in their beak/nails.

Birds	Plants	DP[1]	D[2]	VF[3]	S[4]	Portion consumed
Cracidae						
Penelope superciliaris Temminck, 1815	*Rudgea viburnoides* (Cham.) Benth (Rubiaceae)	PD	Fru	F	D	Whole fruit
Columbidae						
Patagioenas speciosa (Gmelin, 1789)	*Schefflera morototoni* (Aubl.) Maguire *et al.* (Araliaceae)	PD	Fru	F	D	Whole fruit
	Indeterminada 1	ND		F	R	Unripe fruit
Trogonidae						
Trogon curucui Linnaeus, 1766	*Byrsonima* sp. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Byrsonima sericea DC. (Malpighiaceae)	PD		F	R	Whole fruit
	Dilodendron bipinnatum Radlk. (Sapindaceae)	PD		F	D	Seeds
	Guarea guidonia (L.) Sleumer (Meliaceae)	PD		F	D	Seeds
Momotidae						
Momotus momota (Linnaeus, 1766)	*Cabralea canjerana* (Vell.) Mart. (Meliaceae)	PD	Omn	F	D	Seeds
	Xylopia aromatica (Lam.) Mart. (Annonaceae)	PD		F	D	Seeds
Ramphastidae						
Ramphastos toco Statius Muller, 1776	*Cecropia pachystachya* Trécul (Urticaceae)	PD	Fru	S	D	Pulp/Seeds
Ramphastos vitellinus Lichtenstein, 1823	*Calyptranthes* cf. *lucida* Mart. *ex* DC. (Myrtaceae)	PD	Fru	F	D	Whole fruit
	Campomanesia eugenioides (Cambess.) D.Legrand *ex* Landrum (Myrtaceae)	PD		F	R	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		F	R	Pulp/Seeds
	Ocotea corymbosa (Meisn.) Mez (Lauraceae)	PD		F	R	Whole fruit
	Myrsine umbellata Mart. (Primulaceae)	PD		F	D	Whole fruit
Picidae						
Celeus flavescens (Gmelin, 1788)	*Xylopia aromatica* (Lam.) Mart. (Annonaceae)	PD	Ins	F	D	Seeds
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
Dryocopus lineatus (Linnaeus, 1766)	*Myrcia multiflora* (Lam.) DC. (Myrtaceae)	PD	Ins	S	R	Whole fruit
Psittacidae						
Ara chloropterus Gray, 1859	*Caryocar brasiliense* Cambess. (Caryocaraceae)	ND	Fru	S	D	Pulp/Seeds*
Diopsittaca nobilis (Linnaeus, 1758)	*Cordia sellowiana* Cham. (Boraginaceae)	ND	Fru	F	R	Pulp/Seeds*
Psittacara leucophthalmus (Statius Muller, 1776)	*Cordia sellowiana* Cham. (Boraginaceae)	ND	Fru	S	R	Pulp/Seeds*
Eupsittula aurea (Gmelin, 1788)	*Brosimum gaudichaudii* Trécul (Moraceae)	ND	Fru	S	D	Pulp/Seeds*
Brotogeris chiriri (Vieillot, 1818)	*Brosimum gaudichaudii* Trécul (Moraceae)	ND	Fru	S	D	Pulp/Seeds*
	Pseudobombax tomentosum (Mart. & Zucc.) A.Robyns (Malvaceae)	ND		F	D	Pulp/Seeds*
Pipridae						
Pipra fasciicauda Hellmayr, 1906	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Fru	F	D	Whole fruit
Antilophia galeata (Lichtenstein, 1823)	*Rudgea viburnoides* (Cham.) Benth (Rubiaceae)	PD	Fru	F	D	Whole fruit
Tityridae						
Tityra inquisitor (Lichtenstein, 1823)	*Rudgea viburnoides* (Cham.) Benth (Rubiaceae)	PD	Ins	F	D	Whole fruit

Continued on next page

Table 1. Continued.

Birds	Plants	DP^1	D^2	VF^3	S^4	Portion consumed
Tityra semifasciata (Spix, 1825)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Ins	F	R	Whole fruit
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Ocotea corymbosa (Meisn.) Mez (Lauraceae)	PD		F	D	Whole fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
	Virola sebifera Aubl. (Myristicaceae)	PD		F	D	Seeds/Aril
	Xylopia aromatica (Lam.) Mart. (Annonaceae)	PD		F	D	Seeds
Pachyramphus viridis (Vieillot, 1816)	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Omn	F	D	Whole fruit
Tyrannidae						
Camptostoma obsoletum (Temminck, 1824)	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Ins	F	D	Whole fruit
Elaenia flavogaster (Thunberg, 1822)	*Byrsonima pachyphylla* A.Juss. (Malpighiaceae)	PD	Omn	S	D	Whole fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Xylopia aromatica (Lam.) Mart. (Annonaceae)	PD		S	D	Seeds
Elaenia mesoleuca (Deppe, 1830)	*Xylopia sericea* A.St.-Hil. (Annonaceae)	PD	Omn	F	D	Seeds
Elaenia chiriquensis Lawrence, 1865	*Brosimum gaudichaudii* Trécul (Moraceae)	ND	Omn	S	D	Pulp
	Byrsonima pachyphylla A.Juss. (Malpighiaceae)	PD		S	D	Whole fruit
	Byrsonima sericea DC. (Malpighiaceae)	PD		S	R	Whole fruit
	Cupania vernalis Cambess. (Sapindaceae)	ND		F	D	Aril
	Miconia albicans (Sw.) Triana (Melastomataceae)	ND		S	D	Unripe fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
Myiarchus swainsoni Cabanis & Heine, 1859	*Cabralea canjerana* (Vell.) Mart. (Meliaceae)	PD	Ins	F	D	Seeds
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Virola sebifera Aubl. (Myristicaceae)	PD		F	D	Seeds/Aril
Sirystes sibilator (Vieillot, 1818)	*Cabralea canjerana* (Vell.) Mart. (Meliaceae)	PD	Ins	F	D	Seeds
Pitangus sulphuratus (Linnaeus, 1766)	*Copaifera langsdorffii* Desf. (Fabaceae)	PD	Omn	F	D	Seeds/Aril
Myiodynastes maculatus (Statius Muller, 1776)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Byrsonima sp. (Malpighiaceae)	PD		F		Whole fruit
	Cabralea canjerana (Vell.) Mart. (Meliaceae)	PD		F	D	Seeds
	Copaifera langsdorffii Desf. (Fabaceae)	PD		F/S	D	Seeds/Aril
	Cupania vernalis Cambess. (Sapindaceae)	PD		F	D	Seeds/Aril
	Curatella americana L. (Dilleniaceae)	PD		S	D	Seeds/Aril
	Davilla elliptica A.St.-Hil. (Dilleniaceae)	PD		S	D	Seeds/Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
Megarynchus pitangua (Linnaeus, 1766)	*Byrsonima* sp. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Cabralea canjerana (Vell.) Mart. (Meliaceae)	PD		F	D	Seeds
	Curatella americana L. (Dilleniaceae)	PD		S	R	Seeds/Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
Empidonomus varius (Vieillot, 1818)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Ins	F	R	Whole fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit

Continued on next page

Table 1. Continued.

Birds	Plants	DP[1]	D[2]	VF[3]	S[4]	Portion consumed
Cnemotriccus fuscatus (Wied, 1831)	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Ins	F	D	Whole fruit
Vireonidae						
Cyclarhis gujanensis (Gmelin, 1789)	*Cupania vernalis* Cambess. (Sapindaceae)	ND	Ins	F	D	Aril
Vireo chivi (Linnaeus, 1766)	*Cupania vernalis* Cambess. (Sapindaceae)	PD	Omn	F	D	Seeds/Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Zanthoxylum rhoifolium Lam. (Rutaceae)	PD		F	D	Seeds
Corvidae						
Cyanocorax cyanopogon (Wied, 1821)	*Acrocomia aculeata* (Jacq.) Lodd. *ex* Mart. (Arecaceae)	PD§	Omn	F	R	Pulp
	Buchenavia tomentosa Eichler (Combretaceae)	ND		S	D	Pulp
	Copaifera langsdorffii Desf. (Fabaceae)	PD		S	D	Seeds/Aril
	Diospyros brasiliensis Mart. *ex* Miq. (Ebenaceae)	ND		F	D	Pulp
	Mangifera indica L. (Anacardiaceae)	ND		F	R	Pulp
	Miconia albicans (Sw.) Triana (Melastomataceae)	PD		F	C	Whole fruit
	Miconia macrothyrsa Benth. (Melastomataceae)	PD		F	D	Whole fruit
	Tocoyena formosa (Cham. & Schltdl.) K.Schum. (Rubiaceae)	PD		S	D	Seeds/Pulp
	Virola sebifera Aubl. (Myristicaceae)	PD		F	D	Seeds/Aril
Turdidae						
Turdus leucomelas Vieillot, 1818	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Cabralea canjerana (Vell.) Mart. (Meliaceae)	PD		F	D	Seeds
	*Calyptranthes*cf. *lucida* Mart. *ex* DC. (Myrtaceae)	PD		F	D	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		S	R/D	Pulp/Seeds
	Copaifera langsdorffii Desf. (Fabaceae)	PD		S	D	Seeds/Aril
	Lasiacis ligulata Hitchc. & Chase (Poaceae)	PD		F	D	Whole fruit
	Miconia macrothyrsa Benth. (Melastomataceae)	PD		F	D	Whole fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Myrcia tomentosa (Aubl.) DC. (Myrtaceae)	PD		S	R	Whole fruit
	Indeterminada 2	PD		F	D	Whole fruit
	Rudgea viburnoides (Cham.) Benth (Rubiaceae)	PD		F	D	Whole fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
	Xylopia aromatica (Lam.) Mart. (Annonaceae)	PD		F	D	Seeds
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
	Zanthoxylum rhoifolium Lam. (Rutaceae)	PD		F	D	Seeds
Turdus amaurochalinus Cabanis, 1850	*Copaifera langsdorffii* Desf. (Fabaceae)	PD	Omn	S	D	Seeds/Aril
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Turdus subalaris (Seebohm, 1887)	*Cupania vernalis* Cambess. (Sapindaceae)	PD	Omn	F	D	Seeds/Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Turdus albicollis Vieillot, 1818	*Myrsine umbellata* Mart. (Primulaceae)	PD	Omn	F	D	Whole fruit
	Rudgea viburnoides (Cham.) Benth (Rubiaceae)	PD		F	D	Whole fruit

Continued on next page

Table 1. Continued.

Birds	Plants	DP[1]	D[2]	VF[3]	S[4]	Portion consumed
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Mimidae						
Mimus saturninus (Lichtenstein, 1823)	*Copaifera langsdorffii* Desf. (Fabaceae)	PD	Omn	S	D	Seeds/Aril
Passerelidae						
Zonotrichia capensis (Statius Muller, 1776)	*Curatella americana* L. (Dilleniaceae)	ND	Gra	S	D	Unripe fruit
Icteridae						
Icterus pyrrhopterus (Vieillot, 1819)	*Cecropia pachystachya* Trécul (Urticaceae)	PD	Omn	S	D	Pulp/Seeds
Gnorimopsar chopi (Vieillot, 1819)	*Curatella americana* L. (Dilleniaceae)	ND	Oni	S	D	Aril
Thraupidae						
Coereba flaveola (Linnaeus, 1758)	*Cecropia pachystachya* Trécul (Urticaceae)	PD	Nec	S	D	Pulp/Seeds
Saltator maximus (Statius Muller, 1776)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		F	D	Pulp/Seeds
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Lasiacis ligulata Hitchc. & Chase (Poaceae)	PD		F	D	Whole fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Pterodon pubescens (Benth.) Benth. (Fabaceae)	PD		F	D	Seeds
	Rudgea viburnoides (Cham.) Benth (Rubiaceae)	PD		F	D	Whole fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Saltator similis d'Orbigny & Lafresnaye, 1837	*Cupania vernalis* Cambess. (Sapindaceae)	PD	Omn	F	D	Seeds/Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Zanthoxylum rhoifolium Lam. (Rutaceae)	PD		F	D	Seeds
Nemosia pileata (Boddaert, 1783)	*Copaifera langsdorffii* Desf. (Fabaceae)	ND	Omn	F	D	Aril
	Davilla elliptica A.St.-Hil. (Dilleniaceae)	ND		S	D	Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
Tachyphonus rufus (Boddaert, 1783)	*Byrsonima pachyphylla* A.Juss. (Malpighiaceae)	PD	Omn	S	D	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		S	D	Pulp/Seeds
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Rudgea viburnoides (Cham.) Benth (Rubiaceae)	PD		F	D	Whole fruit
Ramphocelus carbo (Pallas, 1764)	*Cupania vernalis Cambess. (Sapindaceae)*	ND	Omn	F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	*Xylopia aromatica (*Lam.) Mart. (Annonaceae)	PD		F	D	Seeds
Lanio cristatus (Linnaeus, 1766)	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Omn	F	D	Whole fruit
Lanio penicillatus (Spix, 1825)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Fru	F	R	Whole fruit
	Cupania vernalis Cambess. (Sapindaceae)	ND		F	D	Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
Tangara sayaca (Linnaeus, 1766)	*Brosimum gaudichaudii* Trécul (Moraceae)	ND	Omn	S	D	Pulp
	Cecropia pachystachya Trécul (Urticaceae)	PD		S	D	Pulp/Seeds
	Copaifera langsdorffii Desf. (Fabaceae)	ND		S	D	Aril

Continued on next page

Table 1. Continued.

Birds	Plants	DP^1	D^2	VF^3	S^4	Portion consumed
	Norantea guianensis Aubl. (Marcgraviaceae)	PD		S	R	Pulp/Seeds
	Psittacanthus robustus (Mart.) Mart. (Loranthaceae)	PD		S	D	Whole fruit
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
Tangara palmarum (Wied, 1823)	*Miconia albicans* (Sw.) Triana (Melastomataceae)	PD	Omn	S	R/D	Whole fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Tangara cyanicollis (d'Orbigny & Lafresnaye, 1837)	*Miconia staminea* (Desr.) DC. (Melastomataceae)	PD	Fru	F	R	Whole fruit
Tangara cayana (Linnaeus, 1766)	*Campomanesia eugenioides* (Cambess.) D.Legrand *ex* Landrum (Myrtaceae)	PD	Omn	F	R	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		F	D	Pulp/Seeds
	Copaifera langsdorffii Desf. (Fabaceae)	ND		S	D	Aril
	Davilla elliptica A.St.-Hil. (Dilleniaceae)	ND		S	D	Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Indeterminada 2	ND		F	D	Unripe fruit
	Norantea guianensis Aubl. (Marcgraviaceae)	PD		S	R	Pulp/Seeds
	Rudgea viburnoides (Cham.) Benth (Rubiaceae)	PD		F	D	Whole fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
Neothraupis fasciata (Lichtenstein, 1823)	*Byrsonima pachyphylla* A.Juss. (Malpighiaceae)	ND	Omn	S	D	Pulp
Tersina viridis (Illiger, 1811)	*Davilla elliptica* A.St.-Hil. (Dilleniaceae)	ND	Omn	S	D	Aril
Dacnis cayana (Linnaeus, 1766)	*Byrsonima sericea* DC. (Malpighiaceae)	PD	Omn	F	R	Whole fruit
	Curatella americana L. (Dilleniaceae)	PD		S	R/D	Seeds/Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril
	Ficus sp. (Moraceae)	PD		F	D	Whole fruit
	Mezilaurus crassiramea (Meisn.) Taub. *ex* Mez (Lauraceae)	ND		S	R	Unripe fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Norantea guianensis Aubl. (Marcgraviaceae)	PD		S	R	Pulp/Seeds
	Psittacanthus robustus (Mart.) Mart. (Loranthaceae)	ND		S	R	Unripe fruit
	Schefflera morototoni (Aubl.) Maguire *et al.* (Araliaceae)	PD		F	D	Whole fruit
	Xylopia aromatica (Lam.) Mart. (Annonaceae)	PD		F/S	R/D	Seeds
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
	Zanthoxylum rhoifolium Lam. (Rutaceae)	PD		F	D	Seeds
Cyanerpes cyaneus (Linnaeus, 1766)	*Curatella americana* L. (Dilleniaceae)	PD	Fru	S	R/D	Seeds/Aril
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Norantea guianensis Aubl. (Marcgraviaceae)	PD		S	R	Pulp/Seeds
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
Hemithraupis guira (Linnaeus, 1766)	*Byrsonima pachyphylla* A.Juss. (Malpighiaceae)	PD	Omn	S	D	Whole fruit
	Byrsonima sericea DC. (Malpighiaceae)	PD		F	R	Whole fruit
	Cecropia pachystachya Trécul (Urticaceae)	PD		S	D	Pulp/Seeds
	Curatella americana L. (Dilleniaceae)	ND		S	R/D	Aril
	Dilodendron bipinnatum Radlk. (Sapindaceae)	ND		F	D	Aril

Continued on next page

Table 1. Continued.

Birds	Plants	DP^1	D^2	VF^3	S^4	Portion consumed
	Mezilaurus crassiramea (Meisn.) Taub. *ex* Mez (Lauraceae)	ND		S	R	Unripe fruit
	Miconia staminea (Desr.) DC. (Melastomataceae)	PD		F	D	Whole fruit
	Xylopia sericea A.St.-Hil. (Annonaceae)	PD		F	D	Seeds
Volatinia jacarina (Linnaeus, 1766)	*Brachiaria* sp. (Poaceae)	PD	Gra	S	R	Seeds
	Curatella americana L. (Dilleniaceae)	ND		S	R/D	Aril
	Miconia albicans (Sw.) Triana (Melastomataceae)	PD		S	R	Whole fruit
Cardinalidae						
Piranga flava (Vieillot, 1822)	*Cecropia pachystachya* Trécul (Urticaceae)	PD	Omn	S	D	Pulp/Seeds
	Curatella americana L. (Dilleniaceae)	PD		S	R	Seeds/Aril
Fringillidae						
Euphonia chlorotica (Linnaeus, 1766)	*Cecropia pachystachya* Trécul (Urticaceae)	PD	Omn	S	D	Pulp/Seeds
	Norantea guianensis Aubl. (Marcgraviaceae)	PD		S	R	Pulp/Seeds

tanagers stand out especially in the dispersal of seeds from plants with small fruit (< 0.4 cm). In the case of larger fruits, seed dispersal is compromised because the seeds fall under the parent plants (Levey 1987, Sick 1997, Francisco & Galetti 2002). Despite the importance of tanagers as potential seed dispersers in this study, we observed that in the case of larger seeds (> 0.5 cm, personal observation), the potential for seed dispersal was really compromised, confirming the findings of Francisco & Galetti (2002). Tanagers also were less efficient in the dispersal of arilled seeds (Table 1). According to Sick (1997), species of this group commonly eat only the aril and discard the seeds under the plant.

On the other hand, tyrant flycatchers, which are known for their predominantly insectivorous diet, include many species that feed on a mixed diet of insects and fruits (Sick 1997). Some studies have shown that species that supplement their diet with fruits, as in the case of this family, have stood out as major seed dispersers in forest (Melo et al. 2003, Pascotto 2006, 2007) and savanna formations (Faustino & Machado 2006, Pascotto et al. 2012, Maruyama et al. 2013) in the Cerrado. Generally, bird species with non-specialized diets also lack habitat specificity, making them important in seed dispersal among different environments (Melo et al. 2003). Thus, in environments characterized by a mosaic of vegetation types, such as the Cerrado (Silva & Bates 2002), opportunistic frugivores are extremely important from the standpoint of seed dispersal potential, at least with regard to plants that are little specialized and to the quantitative component (Schupp 1993). However, it is worth investigating how seeds are treated after being ingested by these birds.

Miconia staminea and *Cecropia pachystachya* stood out as the most important plants. These species are characterized by their abundant production of small fruits and seeds (Kuhlmann 2012). Like most of the plant species observed here, they belong in the low investment model (Howe & Smallwood 1982). In this model, plants produce copious amounts of fruits which are not very nutritious and small seeds, attracting a large variety of opportunistic birds willing to take advantage of a super-abundant resource, but of little nutritional value. Based on the bird species observed consuming fruits (Table 1), we suggest that our results strongly fit this model, since most of the interactions were performed by opportunistic frugivores.

We found that 82% of the frugivorous bird species were considered potential seed dispersers. This was expected, since ornithochory is the main seed dispersal syndrome of tree species in the Brazilian Cerrado, in both forest and savanna environments (Gottsberger & Silberbauer-Gottsberger 1983, Pinheiro & Ribeiro 2001). Species of the Psittacidae family, widely known as predators of seeds, which are usually shredded when ingested, stood out among the bird species that did not act as seed dispersers (Sick 1997). Plants with larger fruits (> 2.5 cm), such as *Buchenavia tomentosa* and *Diospyros brasiliensis*, were only visited by pulp-eaters or seed predators (Table 1).

An analysis of the records of feeding events, number of interactions and composition of frugivorous bird species indicated that higher numbers were recorded in forested areas, confirming our hypotheses. A recent study by Kuhlmann (2012) in the central portion of the Cerrado, involving 150 plant species with fruit attractive to fauna, revealed that about 80% were dispersed by birds and about 60% occurred in forested areas. Seed dispersal by animals in forest environments is more advantageous for plants than dispersal by abiotic processes, since animals, particularly birds, are more likely to disperse seeds over longer distances (Hovestadt et al. 1999).

Kuhlmann (2012) states that the majority of fruiting plants of the Cerrado ripen predominantly in the rainy season. Oliveira & De Paula (2001) reported a similar finding, stating that the fruit of most zoochorous plant species of gallery forests in central Brazil ripen in the rainy season. The same phenomenon has been observed in savanna formations (Silberbauer-Gottsberger 2001, Lenza & Klink 2006, Pirani et al. 2009, Camargo et al. 2013). Based on this information about fruiting phenology, we expected to record more numerous feeding events and interactions during the rainy season since, according to the above cited authors, more fruits ripen during this period. However, our assumption was not confirmed.

We believe that the large number of records of feeding events and of interactions during the dry season stems from the high production of fruits by species such as *Rudgea viburnoides*, *Schefflera morototoni* and *Miconia staminea*. According to Snow (1981), species of these three genera are very important in the diet of frugivorous birds in the Neotropics, because their fruits are eaten by specialist and generalist frugivores. Firstly, the three species have small fruits (< 1 cm), which enables them to be eaten by frugivores of all sizes. *Rudgea viburnoides* and *Miconia staminea* belong to the two most important families of plants for tropical frugivorous birds (Rubiaceae and Melastomataceae, respectively) and, because their fruits are succulent, they are appreciated by a variety of frugivorous birds, especially the small ones that feed in the lower strata of the vegetation (Snow 1981, Maruyama et al. 2013). On the other hand, the fruit of *Schefflera morototoni* is rich in lipids and proteins (Snow 1971), and therefore also attracts a wide variety of frugivores ranging from the smallest to the largest (Saracco et al. 2005, Parrini et al. 2013).

It should also be noted that highly abundant species such as *Turdus leucomelas*, which alone accounted for 25% of the recorded feeding events, may have influenced the high number of feeding events recorded in the forests during the dry season, which may explain the fact that we found no difference in the qualitative matrix of interactions. Thus, we emphasize that it is important to consider the abundance of frugivores, as well as the number of recorded feeding events, and not only the presence/absence of interactions. During the dry season, for example, the number of feeding events recorded for *Turdus leucomelas* in forest areas was about 90% higher than in the rainy season. Most of the species recorded in forests also showed a remarkable increase in recorded feeding events in the dry season. This may be due to temporal and spatial variations in food resources, such as lower abundance of invertebrates and ripe fruits in open areas in the dry season (Macedo 2002). These factors are extremely important and can influence the movement of birds between forest and savanna habitats.

We observed that the composition of frugivorous birds differs between savanna and forest formations. This contradicted our hypothesis since, according to Bagno & Marinho-Filho (2001), most bird species in the Cerrado occur in both savanna and forest formations. However, this does not seem to apply when only frugivorous birds are involved (Vieira et al. 2013), probably due to the dependence of mandatory frugivores [e.g., *Ramphastos vitellinus* Lichtenstein, 1823 and *Antilophia galeata* (Lichtenstein, 1823)] on forest environments.

Based on the composition of avian frugivores (Table 1), it was found that the diet of approximately 80% of the recorded bird species is not based on fruits, but that they simply complement their diet with this type of resource. Thus, we believe that during the dry season, when there is a scarcity of other food items [such as small arthropods (Macedo 2002, Manhães 2003)], there is an increase in fruit consumption. Moreover, in situations of water deficit, consuming fruit is one of the main ways to obtain water (Argel-de-Oliveira 1998). Thus, species that do not usually consume fruits begin to use this resource in the dry season, which may explain the increase in the records of feeding events and bird-plant interactions during this period.

Our findings suggest that there is a shift of frugivorous bird species and particularly of individuals between savanna and forest formations in response to fluctuations in food resources, which are influenced by the strong climate seasonality of the Cerrado (Macedo 2002, Manhães 2003). Future studies to evaluate temporal and spatial fluctuations in the composition and abundance of bird species in the different vegetation formations of the Cerrado, as well as the availability of food resources, may complement and strengthen our findings. However, we already have strong evidence that forests represent important foraging areas for frugivorous birds during the dry season. Thus, the conservation of forest areas in predominantly savanna-like ecosystems such as the Cerrado is extremely important for frugivorous birds, thus ensuring the preservation of frugivore-plant interactions.

Acknowledgments

The authors thank the *Secretaria de Estado de Meio Ambiente* (SEMA-MT) for authorizing the fieldwork in the *Parque Estadual da Serra Azul* (PESA). We also gratefully acknowledge the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), for granting a master scholarship to the first author; and *Fundação de Amparo à Pesquisa do Estado de Mato Grosso* (FAPEMAT) (Process Nos. 873/2006 and 738702/2008) and the project *SISBIOTA/Rede ComCerrado* (Proc. CNPq 563134/2010-0) for their financial support. In addition, we are indebted to the following people for their assistance: the team of the *Laboratório de Ornitologia* UFMT/CUA for their assistance in the field work; Leandro Maracahipes and Maryland Sanchez for their help in identifying several plant species; Renato Goldenberg for identifying *Miconia staminea* and *M. macrothyrsa*; and Dilermando P. Lima Junior and Rudi R. Laps for their insightful suggestions.

References

ALLENSPACH, N. & DIAS, M.M. 2012. Frugivory by birds on *Miconia albicans* (Melastomataceae), in a fragment of cerrado in São Carlos, southeastern Brazil. Braz. J. Biol. 72(2):407–413, http://dx.doi.org/10.1590/S1519-69842012000200024

ARGEL-DE-OLIVEIRA, M.M. 1998. Aves que plantam: frugivoria e dispersão de sementes por aves. Boletim CEO 13(1):9–21.

BAGNO, M.A. & MARINHO-FILHO, J. 2001. A avifauna do Distrito Federal: uso de ambientes abertos e florestais e ameaças. In Cerrado: caracterização e recuperação de Matas de Galeria (Ribeiro J.F., Fonseca C.E.L. & Sousa-Silva J.C., eds). Embrapa Cerrados, Planaltina, p. 493–528.

BASCOMPTE, J., JORDANO, P., MELIÁN, J. & OLESEN, J.M. 2003. The nested assembly of plant-animal mutualistic networks. PNAS 100(16):9383–9387, http://dx.doi.org/10.1073/pnas.1633576100

BIBBY, C.J., BURGESS, N.D., HILL, D.A. & MUSTOE, S.H. 2000. Bird census techniques. 2 ed. Academic Press, London.

CAMARGO, M.G.G., CAZETTA, E., SCHAEFER, H.M. & MORELLATO, L.P.C. 2013. Fruit color and contrast in seasonal habitats - a case study from a cerrado savanna. Oikos 122(9):1335–1342, http://dx.doi.org/10.1111/j.1600-0706.2013.00328.x

CAZETTA, E., RUBIM, P., LUNARDI, V.O., FRANCISCO, M.R. & GALETTI, M. 2002. Frugivoria e dispersão de sementes de *Talauma ovata* (Magnoliaceae) no sudeste brasileiro. Ararajuba 10(2):199–206.

CHRISTIANINI, A. & OLIVEIRA, P.S. 2009. The relevance of ants as seed rescuers of a primarily bird-dispersed tree in the Neotropical cerrado savanna. Oecologia 160(4):735–745, http://dx.doi.org/10.1007/s00442-009-1349-2

CLARKE, K.R. & GREEN, R.H. 1988. Statistical design and analysis for a 'biological effects' study. Mar. Ecol. Prog. Ser. 46(1):213–226, http://dx.doi.org/10.3354/meps046213

COMITÊ BRASILEIRO DE REGISTROS ORNITOLÓGICOS - CBRO. 2014. Lista das aves do Brasil. 11ª ed. http://www.cbro.org.br/CBRO/pdf/AvesBrasil2014.pdf (último acesso em 02/05/2014).

CORDEIRO, N.J. & HOWE, H.F. 2001. Low recruitment of trees dispersed by animals in African forest fragments. Conserv. Biol. 15(6):1733–1741, http://dx.doi.org/10.1046/j.1523-1739.2001.99579.x

DEAN, W.R.J., MILTON, S.J. & JELTSCH, F. 1999. Large trees, fertile islands, and birds in arid savanna. J. Arid Environ. 41(1):61–78, http://dx.doi.org/10.1006/jare.1998.0455

EITEN, G. 1972. The cerrado vegetation of Brazil. Bot. Rev. 38(2):201–341, http://dx.doi.org/10.1007/BF02859158

FADINI, R.F. & DE MARCO, P. 2004. Interações entre aves frugívoras e plantas em um fragmento de Mata Atlântica de Minas Gerais. Ararajuba 12(2):97–103.

FAUSTINO, T.C. & MACHADO, C.G. 2006. Frugivoria por aves em uma área de campo rupestre na Chapada Diamantina, BA. Rev. Bras. Ornitol. 14(2):137-143.

FRANCISCO, M.R. & GALETTI, M. 2002. Aves como potenciais dispersores de sementes de *Ocotea pulchella* Mart. (Lauraceae) numa área de vegetação de cerrado do sudeste brasileiro. Rev. Bras. Bot. 25(1):11–17.

FRANCISCO, M.R., LUNARDI, V.O. & GALETTI, M. 2007. Bird attributes, plant characteristics, and seed dispersal of *Pera glabrata* (Schott, 1858), (Euphorbiaceae) in a disturbed cerrado area. Braz. J. Biol. 67(4):627–634, http://dx.doi.org/10.1590/S1519-69842007000400006

GALETTI, M. & PIZO, M.A. 1996. Fruit eating by birds in a forest fragment in southeastern Brazil. Ararajuba 4(2):71–79.

GALETTI, M.R., GUEVARA, R., CÔRTES, M.C., FADINI, R., VON MATTER, S., LEITE, A.B., LABECCA, F., RIBEIRO, T., CARVALHO, C.S., COLLEVATTI, R.G., PIRES, M.M., GUIMARÃES JR, P.R., BRANCALION, P.H., RIBEIRO, M.C. & JORDANO, P. 2013. Functional extinction of birds drives rapid evolution changes in seed size. Science 340(6136):1086–1090, http://dx.doi.org/10.1126/science.1233774

GOTTSBERGER, G. & SILBERBAUER-GOTTSBERGER, I. 1983. Dispersal and distribuition the Cerrado vegetation of Brazil. Sonderb. Naturwiss. Ver. Hamburg 7(1):315–352.

GOUVEIA, G.P. & FELFILI, J.M. 1998. Fenologia de comunidades de cerrado e de Mata de Galeria no Brasil Central. Rev. Árvore 22(4):443–450.

HOVESTADT, T., YAO, P. & LINSENMAIR, K.E. 1999. Seed dispersal mechanisms and the vegetation of forest islands in a West African forest-savanna mosaic (Comoé National Park, Ivory Coast). Plant Ecol. 144(1):1–25, http://dx.doi.org/10.1023/A:1009764031116

HOWE, H.F. & PRIMACK, R.B. 1975. Differential seed dispersal by birds of the tree *Casearia nitida* (Flacourtiaceae). Biotropica 7(4):278–283, http://dx.doi.org/10.2307/2989740

HOWE, H.F. & SMALLWOOD, J. 1982. Ecology of seed dispersal. Annu. Rev. Ecol. Syst. 13(1):201–228, http://dx.doi.org/10.1146/annurev.es.13.110182.001221

JORDANO, P. 1987. Patterns of mutualistic interactions in pollination and seed dispersal: connectance, dependence asymmetries, and coevolution. Am. Nat. 129(5):657–677, http://dx.doi.org/10.1086/284665

JORDANO, P. 1994. Spatial and temporal variation in the avian-frugivore assemblage of *Prunus mahaleb*: patterns and consequences. Oikos 71(3):479–471, http://dx.doi.org/10.2307/3545836

KUHLMANN, M. 2012. Frutos e sementes do Cerrado atrativos para fauna: guia de campo. Rede de Sementes do Cerrado, Brasília.

LEGENDRE, P. & LEGENDRE, E. 1998. Numeral Ecology. Elsevier Science B.V., Amsterdam.

LENZA, E. & KLINK, C.A. 2006. Comportamento fenológico de espécies lenhosas em um cerrado sentido restrito de Brasília, DF. Rev. Bras. Bot. 29(4):627–638, http://dx.doi.org/10.1590/S0100-84042006000400013

LEVEY, D. 1987. Seed size and fruit-handling techniques of avian frugivores. Am. Nat. 129(4):471–485, http://dx.doi.org/10.1086/284652

LISTA DE ESPÉCIES DA FLORA DO BRASIL. 2014. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/ (último acesso em: 02/05/ 2014).

MACEDO, R.H.F. 2002. The avifauna: ecology, biogeography, and behavior. In The Cerrados of Brazil: ecology and natural history of a Neotropical savanna (Oliveira, P.S. & Marquis, R.J. eds). Columbia University Press, New York, p. 242–265.

MAGNUSSON, W.E., LIMA, A.P., LUIZÃO, R., LUIZÃO, F., COSTA, F.R.C., CASTILHO, C.V. & KINUPP, V.F. 2005. RAPELD: a modification of the Gentry method for biodiversity surveys in long-term ecological research sites. Biota Neotrop. 5(2):1–6. http://www.biotaneotropica.org.br/v5n2/pt/abstract?point-of-view+bn01005022005 (último acesso em 02/05/2014), http://dx.doi.org/10.1590/S1676-06032005000300002

MANHÃES, M.A. 2003. Variação sazonal da dieta e do comportamento alimentar de traupíneos (Passeriformes: Emberezidae) em Ibitipoca, Minas Gerais, Brasil. Ararajuba 11(1):45–55.

MARCONDES-MACHADO, L.O. & ROSA, G.A.B. 2005. Frugivoria por aves em *Cytharexyllum myrianthum* Cham. (Verbenaceae) em áreas de pastagens de Campinas, SP. Ararajuba 13(1):113–115.

MARUYAMA, P.K., BORGES, M.R., SILVA, P.A., BURNS, K.C. & MELO, C. 2013. Avian frugivory in *Miconia* (Melastomataceae): contrasting fruiting times promote habitat complementary between savanna and palm swamp. J. Trop. Ecol. 29(2):99–109, http://dx.doi.org/10.1017/S0266467413000138

MEDELLÍN, R.A. & GAONA, O. 1999. Seed dispersal by bats and birds in forest and disturbed habitats of Chiapas, México. Biotropica 31(3):478–485, http://dx.doi.org/10.1111/j.1744-7429.1999.tb00390.x

MELO, C., BENTO, E.C. & OLIVEIRA, P.E. 2003. Frugivory and dispersal of *Faramea cyanea* (Rubiaceae) in cerrado woody plant formations. Braz. J. Biol. 63(1):75–82, http://dx.doi.org/10.1590/S1519-69842003000100010

MENDONÇA, R.C., FELFILI, J.M., WALTER, B.M., SILVA-JUNIOR, M.C., REZENDE, A.B., FILGUEIRAS, T.S., NOGUEIRA, P.E. & FAGG, C.W. 2008. Flora vascular do bioma Cerrado: *checklist* com 12.356 espécies. In Cerrado: ecologia e flora (Sano, S.M., Almeida, S.P. & Ribeiro J.F., eds). Embrapa Informação Tecnológica, Brasília, v 2, p. 421–1279.

MOERMOND, T.C. & DENSLOW, J.S. 1985. Neotropical avian frugivores: patterns of behavior, morphology, and nutrition, with consequences for fruit selection. Ornithological Monographs 36(1):865–897, http://dx.doi.org/10.2307/40168322

MOTTA-JUNIOR, J.C & LOMBARDI, J.A. 2002. Ocorrência de zoocoria em florestas de galeria no Complexo do Cerrado, Brasil. Biotemas 15(1):59–81.

MURRAY, K.G. 2000. The importance of different bird species as seed dispersers. InMonteverde: ecology and conservation of a tropical cloud forest (Nadkarni, N.M, & Wheelwright, N.T. eds) Oxford University Press, New York, p. 294–295.

MYERS N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.F. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403(6772):853–858, http://dx.doi.org/10.1038/35002501

OLIVEIRA, P.E.A.M. & DE PAULA, F.R. 2001. Fenologia e biologia reprodutiva de plantas de Matas de Galeria. In Cerrado: caracterização e recuperação de Matas de Galeria (Ribeiro, J.F, Fonseca, C.E.L. & Sousa-Silva, J.C., eds). Embrapa Cerrados, Planaltina, p. 303–332.

PARRINI, R., RAPOSO, M.A., DEL HOYO, J. & SILVA, A.R. 2013. *Schefflera morototoni* (Araliaceae) como importante recurso alimentar para as aves durante a estação seca na Amazônia central. Cotinga 35(1):1–4.

PASCOTTO, M.C. 2006. Avifauna dispersora de sementes de *Alchornea glandulosa* (Euphorbiaceae) em uma área de mata ciliar no estado de São Paulo. Rev. Bras. Ornitol. 14(3):291–296.

PASCOTTO, M.C. 2007. *Rapanea ferruginea* (Ruiz & Pav.) Mez. (Myrsinaceae) como uma importante fonte alimentar para as aves em uma mata de galeria no interior do Estado de São Paulo. Rev. Bras. Zool. 24(3):735–741.

PASCOTTO, M.C., CATEN, H.T. & OLIVEIRA, J.P.F. 2012. Birds as potential seed dispersers of *Curatella americana* L. in the Brazilian Cerrado. Ornitol. Neotrop. 23(1):583–593.

PINHEIRO, F. & RIBEIRO, J.F. 2001. Síndromes de dispersão de sementes em Matas de Galeria do Distrito Federal. In Cerrado: caracterização e recuperação de Matas de Galeria (Ribeiro, J.F., Fonseca, C.E.L. & Sousa-Silva, J.C, eds). Embrapa Cerrados. Planaltina, p. 333–376.

PIRANI, F.R., SANCHEZ, M. & PEDRONI, F. 2009. Fenologia de uma comunidade arbórea em cerrado sentido restrito, Barra do Garças, MT, Brasil. Acta Bot. Bras. 23(4):1096–1109, http://dx.doi.org/10.1590/S0102-33062009000400019

PIZO, M.A. & GALETTI, M. 2010. Métodos e perspectivas do estudo da frugivoria e dispersão de sementes por aves. In Ornitologia e conservação: ciência aplicada, técnicas de pesquisa e levantamento (Accordi, I., Straube, F.C & Von Matter, S. orgs). *Technical Books* Rio de Janeiro, p. 492–504.

R DEVELOPMENT CORE TEAM. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. ISBN 3-900051-07-0, http://www.R-project.org/.

RIBEIRO, J.F. & WALTER, B.M.T. 2008. As principais fitofisionomias do Bioma Cerrado. In Cerrado: ecologia e flora (Sano, S.M., Almeida, S.P. & Ribeiro, J.F., eds). Embrapa Informação Tecnológica, Brasília, p. 151–212.

SARACCO, J.F., COLLAZO, J.A., GROOM, M.J. & CARLO, T.A. 2005. Crop size and fruit neighborhood effects on bird visitation to fruiting *Schefflera morototoni* trees in Puerto Rico. Biotropica 37(1):81–87, http://dx.doi.org/10.1111/j.1744-7429.2005.04040.x

SCHUPP, E.W. 1993. Quantity, quality and the effectiveness of seed dispersal by animals. Vegetatio 107/108(1):15–29.

SICK, H. 1997. Ornitologia Brasileira: uma introdução. Nova Fronteira, Rio de Janeiro.

SILBERBAUER- GOTTSBERGER, I. 2001. A hectare of Cerrado. II. Flowering and fruiting of thick-stemmed woody species. Phyton 41(1):129–158.

SILVA, J.M.C. & BATES, J.M. 2002. Biogeographic patterns and conservation in the South American Cerrado: a tropical savanna hotspot. BioScience 52(3):225–233, http://dx.doi.org/10.1641/0006-3568(2002)052[0225:BPACIT]2.0.CO;2

SILVA, J.M.C. & TABARELLI, M. 2000. Tree species impoverishment and the future flora of the Atlantic forest of northeast Brazil. Nature 404(6773):72–74, http://dx.doi.org/10.1038/35003563

SILVA, J.M.C. 1997. Endemic bird species and conservation in the Cerrado Region, South America. Biodivers. Conserv. 6(3):435–450, http://dx.doi.org/10.1023/A:1018368809116

SILVA, W.R., DE MARCO, P., HASUI, E. & GOMES, V.S.M. 2002. Patterns of fruit-frugivore interactions in two Atlantic forest bird communities of south-eastern Brazil: implications for conservation. In Seed dispersal and frugivory: ecology, evolution and conservation (Levey, D.J., Silva, W.R. & Galetti, M. eds). CABI Publising, Oxon, p. 423–436.

SKARPE, C. 1992. Dynamics of savanna ecosystems. J. Veg. Sci. 3(3):293–300, http://dx.doi.org/10.2307/3235754

SNOW, B.K. & SNOW, D.W. 1971. The ecology of tanagers and honeycreepers in Trinidad. The Auk 88(2):291–322.

SNOW, D.W. 1981. Tropical frugivorous birds and their food plants: a world survey. Biotropica 13(1):1–14.

VIEIRA, D.L.M., AQUINO, F.G., BRITO, M.A., FERNANDES-BULHÃO, C. & HENRIQUES, R.P.B. 2002. Síndromes de dispersão de espécies arbustivo-arbóreas em cerrado *sensu stricto* do Brasil Central e savanas amazônicas. Rev. Bras. Bot. 25(2):215–220, http://dx.doi.org/10.1590/S0100-84042002000200009

VIEIRA, F.M., PURIFICAÇÃO, K.N., CASTILHO, L.S. & PASCOTTO, M.C. 2013. Estrutura trófica da avifauna de quatro fitofisionomias do Cerrado no Parque Estadual da Serra Azul. Ornithologia 5(2):43–57.

WÜTHERICH, D., AZÓCAR, A., GARCÍA-NUÑEZ, C. & SILVA, J.F. 2001. Seed dispersal in *Palicourea rigida*, a common treelet species from Neotropical savannas. J. Trop. Ecol. 17(3):449–458, http://dx.doi.org/10.1017/S0266467401001304

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

Received 04/05/2014
Revised 20/08/2014
Accepted 20/10/2014

Biota Neotropica 14(4): e20140099, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

Coloration of the testicular peritoneal sheath as a synapomorphy of triatomines (Hemiptera, Reduviidae)

Kaio Cesar Chaboli Alevi[1,3], *Jader de Oliveira*[2], *João Aristeu da Rosa*[2] & *Maria Tercília Vilela de Azeredo Oliveira*[1]

[1] *Instituto de Biociências, Letras e Ciências Exatas, Universidade Estadual Paulista Júlio de Mesquita Filho, São José do Rio Preto, SP, Brazil.*
[2] *Faculdade de Ciências Farmacêuticas, Departamento de Ciências Biológicas, Universidade Estadual Paulista Júlio de Mesquita Filho, Araraquara, SP, Brazil.*
[3] *Corresponding author: Kaio Cesar Chaboli Alevi, e-mail: kaiochaboli@hotmail.com*

ALEVI, K.C.C., OLIVEIRA, J., ROSA, J.A., AZEREDO-OLIVEIRA, M.T.V. **Coloration of the testicular peritoneal sheath as a synapomorphy of triatomines (Hemiptera, Reduviidae).** Biota Neotropica. 14(4): e20140099. http://dx.doi.org/10.1590/1676-06032014009914

Abstract: Recently, were described some morphological characteristics of 18 species of terrestrial hemipteran grouped in the Alydidae, Coreidae, Corimelaenidae, Lygaeidae, Rhopalidae, Scutelleridae, Tingidae and Reduviidae family that presented found variation in coloration of testicular peritoneal sheath (Reddish, Orange, Yellowish or Transparent). Thus, this study aims to analyzed the coloration of the peritoneal sheath in 44 species of triatomines grouped in nine different genera, with the aim of analyze whether the insects of the Triatominae subfamily also show variations in coloration. By means of analysis of the sheath was possible to observe that members of this subfamily have no interspecific differences, because all species have a transparent sheath. Thus, this paper describes the coloring of the peritoneal sheath in 44 species of the subfamily Triatominae and mainly suggests that the transparent color is one synapomorphy of this important group of insect vectors.
Keywords: *testicle, Heteroptera, Triatominae subfamily.*

ALEVI, K.C.C., OLIVEIRA, J., ROSA, J.A., AZEREDO-OLIVEIRA, M.T.V. **Coloração da bainha peritoneal testicular como uma sinapomorfia dos triatomíneos (Hemiptera, Reduviidae).** Biota Neotropica. 14(4): e20140099. http://dx.doi.org/10.1590/1676-06032014009914

Resumo: Recentemente, foram descritas algumas características morfológicas de 18 espécies de hemípteros terrestres agrupados nas famílias Alydidae, Coreidae, Corimelaenidae, Lygaeidae, Rhopalidae, Scutelleridae, Tingidae e Reduviidae que apresentaram grandes variações na coloração da bainha peritonial testicular (avermelhada, alaranjada, amarelada ou transparente). Assim, este estudo teve como objetivo analisar a coloração da bainha peritoneal em 44 espécies de triatomíneos agrupadas em nove gêneros diferentes, com o intuito de analisar se os insetos da subfamília Triatominae também apresentam variações na coloração da bainha. Por meio da análise da bainha, foi possível observar que os membros desta subfamília não apresentaram diferenças interespecíficas, pois todas as espécies analisadas possuem bainha transparente. Assim, o presente trabalho descreve a coloração da bainha peritoneal em 44 espécies da subfamília Triatominae e, principalmente, sugere que a cor transparente é uma sinapomorfia deste importante grupo de insetos vetores.
Palavras-chave: *testículo, Heteroptera, subfamília Triatominae.*

Introduction

Triatomines are hematophagous insects of medico-sanitary importance because they are considered as the main vector of Chagas disease in the human population. These vectors are included in the Hemiptera order, Heteroptera suborder, Reduviidae family and Triatominae subfamily (Lent & Wygodzinsky 1979).

The knowledge of the biology of these vectors is of great importance to public health, because the main way to minimize the incidence of Chagas disease is by controlling populations (Dias & Schofield 1998, Alevi et al. 2012a). The reproductive biology of hemipterans was extensively studied by many aspects, such as anatomical (Barth 1956, Freitas et al. 2008), morphological (Gomes et al. 2013, Rosa et al. 2014), structural (Freitas et al. 2010, Silistino-Souza et al. 2012), ultrastructural (Morielle-Souza et al. 2010, Freitas et al. 2010, Silistino-Souza et al. 2012) and cytogenetic (Alevi et al. 2012a, b, 2013a, b, c, d, 2014a, b).

Recently, Gomes et al. (2013) described some morphological traits of 18 species of terrestrial hemipteran grouped in the

Table 1. Genus and species of Triatominae who had the peritoneal sheath analyzed.

Genus	Species
Cavernicola	*C. pilosa*
Psammolestes	*P. tertius*
Rhodnius	*R. brethesi*, *R. colombiensis*, *R. domesticus*, *R. montenegrensis*, *R. nasutus*, *R. neglectus*, *R. neivai*, *R. palescens*, *R. pictipes*, *R. prolixus*, *R. robustus*
Dipetalogaster	*D. maximus*
Eratyrus	*E. cuspidatus*
Meccus	*M. pallidipennis*, *M. longipennis*
Mepraia	*M. spinolai*
Panstrongylus	*P. lignarius* (= *P. herreri*), *P. megistus*
Triatoma	*T. baratai*, *T. brasiliensis*, *T. b. macromelasoma*, *T. carcavalloi*, *T. costalimai*, *T. infestans*, *T. guazu*, *T. juazeirensis*, *T. klugi*, *T. lectularia*, *T. lenti*, *T. maculata*, *T. melanica*, *T. melanocephala*, *T. platensis*, *T. protracta*, *T. pseudomaculata*, *T. rubrovaria*, *T. rubrofasciata*, *T. sordida*, *T. tibiamaculata*, *T. vandae*, *T. vitticeps*, *T. williami*

Alydidae, Coreidae, Corimelaenidae, Lygaeidae, Rhopalidae, Scutelleridae, Tingidae and Reduviidae family. Among the characteristics, the color of the peritoneal sheath covering the seminiferous tubules was analyzed. The authors found variation in coloration of sheath (Reddish, Orange, Yellowish or Transparent). Thus, this study aims to analyze the peritoneal sheath in 44 species of triatomines grouped in nine different genera (Table 1), with the aim of analyze whether the insects of the Triatominae subfamily also show variations in coloration.

Material and Methods

Exemplars males of 44 species (Table 1) were provided by ''Triatominae Insectarium'' within the Department of Biological Sciences, in the College of Pharmaceutical Sciences, at Sao Paulo State University's Araraquara campus, Brazil (FCFAR/UNESP). The testicles were removed and photographed according to the methodology of Gomes et al. (2013).

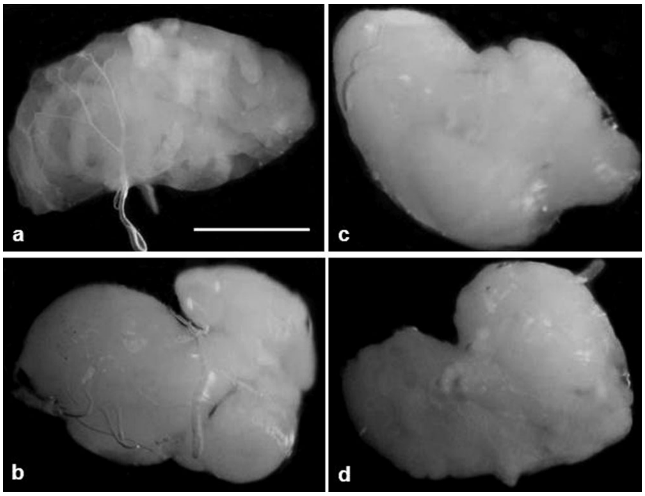

Figure 1. Peritoneal sheath of different genus of the subfamily Triatominae analyzed. Note that in all genus the sheath is transparent. (a) *T. infestans*. (b) *M. pallidipennis*. (c) *P. megistus*. (d) *D. maximus*. Bar: 10 mm.

Results and Discussion

The analysis of the peritoneal sheath of 44 species possible to observe that members of Triatominae subfamily have no interspecific differences, as described by Gomes et al (2013) for phytophagous hemipterans, because all species have a transparent sheath. Like all species of nine genera analyzed show the same coloring, we represent with image the testicle of one species of each genus (Figures 1 and 2).

The insects of the subfamily Triatominae share synapomorphies related to reproductive biology, such as the presence of chromosomes holocentric (Panzera et al. 1996), inverted meiosis for sex chromosomes (Gómez-Palacio et al. 2008), the phenomenon of nucleolar persistence during meiosis (Tartarotti & Azeredo-Oliveira 1999, Alevi et al. 2014c), nucleolar inactivation during spermiogenesis (Alevi et al. 2014b), presence seven testicular follicles (Schreiber et al. 1968) and testicular peritoneal sheath transparent (this paper), demonstrating that during the evolution and speciation of the triatomines, the reproductive aspects undergone few modifications.

Thus, this paper describes the coloring of the peritoneal sheath in 44 species of the subfamily Triatominae and mainly suggests that the transparent color is one synapomorphy of this important group of insect vectors.

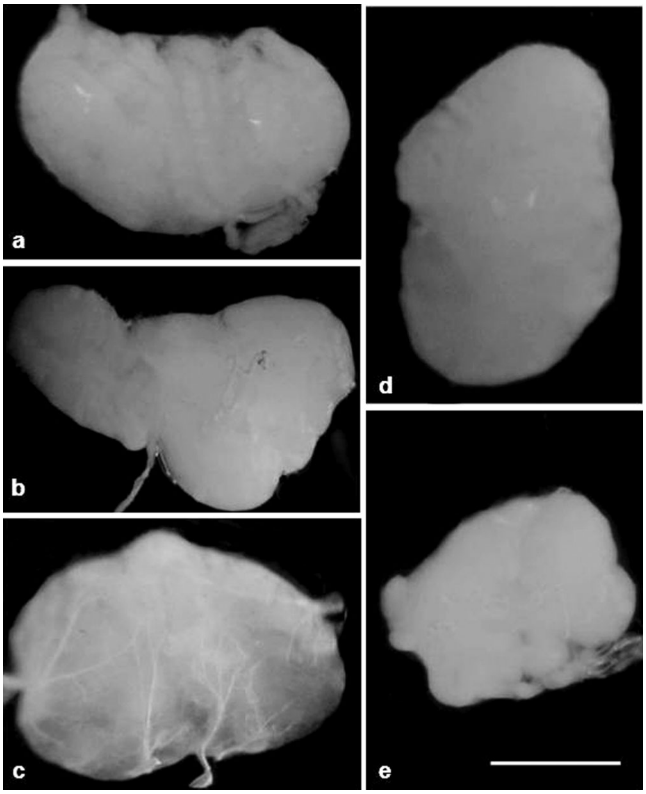

Figure 2. Peritoneal sheath of different genus of the subfamily Triatominae analyzed. Note that in all genus the sheath is transparent. (a) *M. spinolai*. (b) *E. cuspidatus*. (c) *P. tertius*. (d) *R. montenegrensis*. (e) *C. pilosa*. Bar: 10 mm.

http://dx.doi.org/10.1590/1676-06032014009914

Acknowledgments

This work was supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) (Process number 2013/19764-0) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

References

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P., ROSA, J.A. & AZEREDO-OLIVEIRA, M.T.V. 2012a. Karyotype of *Triatoma melanocephala* Neiva and Pinto (1923). Does this species fit in the Brasiliensis subcomplex? Infect. Gen. Evol. 12:1652–1653, http://dx.doi.org/10.1016/j.meegid.2012.06.011

ALEVI, K.C.C., MENDONÇA, P.P., SUCCI, M., PEREIRA, N.P., ROSA, J.A. & AZEREDO-OLIVEIRA, M.T.V. 2012b. Karyotype and spermatogenesis in *Triatoma lenti* (Hemiptera, Triatominae), a potentical Chagas vector. Gen. Mol. Res. 11:4278–4284, http://dx.doi.org/10.4238/2012.December.17.3

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P, GUERRA, A.L, FACINA, C.H,ROSA, J.A. & AZEREDO-OLIVEIRA, M.T.V. 2013a. Distribution of constitutive heterochromatin in two species of triatomines: *Triatoma lenti* Sherlock and Serafim (1967) and *Triatoma sherlocki* Papa, Jurberg, Carcavallo, Cerqueira & Barata (2002). Infect. Gen. Evol. 13:301–303, http://dx.doi.org/10.1016/j.meegid.2012.11.011

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P., FERNANDES, A.L.V.Z., ROSA, J.A., AZEREDO-OLIVEIRA, M.T.V. 2013b. Analysis of spermiogenesis like a tool in the study of the triatomines of the Brasiliensis subcomplex. C. R. Biologies. 336:46–50, http://dx.doi.org/10.1016/j.crvi.2013.01.005

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P., ROSA, J.A & AZEREDO-OLIVEIRA, M.T.V. 2013c. Heteropyknotic filament in spermatids of *Triatoma melanocephala* and *T. vitticeps* (Hemiptera, Triatominae). Inv. Rep. Dev. 58:9–12, http://dx.doi.org/10.1080/07924259.2013.793623

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P., ROSA, J.A & AZEREDO-OLIVEIRA, M.T.V. 2013d. Spermatogenesis in *Triatoma melanocephala* (Hemiptera, Triatominae). Gen. Mol.Res. 12:4944-4947, http://dx.doi.org/10.4238/2013.October.24.5

ALEVI, K.C.C., ROSA, J.A & AZEREDO-OLIVEIRA, M.T.V. 2014a. Spermatogenesis in *Triatoma melanica* Neiva and Lent, 1941 (Hemiptera, Triatominae) J. Vec. Ecol. 39:231–233, http://dx.doi.org/10.1111/j.1948-7134.2014.12094.x

ALEVI, K.C.C., MENDONÇA, P.P., PEREIRA, N.P., ROSA, J.A & AZEREDO-OLIVEIRA, M.T.V. 2014b. Is there post-meiotic transcriptional activity during hemiperan spermiogenesis? Inv. Rep. Dev. 58:193–198, http://dx.doi.org/10.1080/07924259.2014.889767

ALEVI, K.C.C., CASTRO, N.F.C., LIMA, A.N.C., RAVAZI, A., MORIELLE-SOUZA, A., OLIVEIRA, J., ROSA, J.A. & AZEREDO-OLIVEIRA, M.T.V. 2014c. Nucleolar persistence during spermatogenesis of the Rhodnius (Hemiptera, Triatominae). Cell Biol. Int. 38:977–980, http://dx.doi.org/10.1002/cbin.10297

BARTH, R. 1956. Estudos anatômicos e histológicos sôbre a subfamília Triatominae (Heteroptera, Reduviidae). VI parte: Estudo comparativo sôbre a espermiocitogênese das espécies mais importantes. Mem. Inst. Oswaldo Cruz 54:599–616, http://dx.doi.org/10.1590/S0074-02761956000300009

DIAS, J.C.P & SCHOFIELD, C.J. 1998. Controle da transmissão transfusional da doença de Chagas na Iniciativa do Cone Sul. Rev. Soc. Bras. Med. Trop. 31:373–383.

FREITAS, S.P.C., SANTOS-MALLET, J.E., COSTA, J., SOUZA, A.L.B., SERRÃO J.E. & GONÇALVES, T.C.M. 2008. A comparative study of testis follicles in species of *Triatoma* (Hemiptera, Triatominae). An. Biol. 58:227–233, http://dx.doi.org/10.1163/157075608X328062

FREITAS, S.P.C., GONÇALVES, T.C.M., SERRÃO, J.E., COSTA, J. & SANTOS-MALLET, J.R. 2010. Male reproductive system structure and accessory glands ultrastructure of two species of *Triatoma* (Hemiptera, Reduviidae, Triatominae). Micron 41:518–525, http://dx.doi.org/10.1016/j.micron.2010.01.008

GOMES M.O., CASTANHOLE, M.M.U., SOUZA, H.V., MURAKAMI, A.S., FIRMINO, T.S.S., SARAN, P.S., BANHO, C.A., MONTEIRO, L.S., SILVA, J.C.P. & ITOYAMA, M.M. 2013. Morphological aspects of the testes of 18 species of terrestrial of Heteroptera from Northwestern São Paulo (Brazil). Biota Neotrop. 13:132–135.

GÓMEZ-PALACIO, A., JARAMILLO-OCAMPO, N., TRIANA-CHÁVEZ, O., SALDAÑA, A., CALZADA, J., PÉREZ, R. & PANZERA, F. 2008. Chromosome variability in the Chagas disease vector *Rhodnius pallescens* (Hemiptera, Reduviidae, Rhodniini). Mem. Inst. Oswaldo Cruz 103:160–164, http://dx.doi.org/10.1590/S0074-02762008000200006

LENT, H. & WYGODZINSKY, P. 1979. Revision of the Triatominae (Hemiptera: Reduviidae) and their significance as vector of Chagas's disease. Bull. Am. Mus. Nat. Hist. 163:123–520.

MORIELLE-SOUZA A., TABOGA, S.R. & AZEREDO-OLIVEIRA, M.T.V. 2010. Ultrastructural analysis of the nucleolar aspects at spermiogenesis in triatomines (Heteroptera, Triatominae). Micron 41:791–796, http://dx.doi.org/10.1016/j.micron.2010.05.009

PANZERA, F., PÉREZ, R., HORNOS, S., PANZERA, Y., CESTAU, R., DELGADO, V. & NICOLINI, P. 1996. Chromosome numbers in the Triatominae (Hemiptera-Reduviidade): a Review. Mem. Inst. Oswaldo Cruz 91:515–518, http://dx.doi.org/10.1590/S0074-02761996000400021

ROSA, J.A., MENDONÇA, V.J., GARDIM, S., DE CARVALHO DB, DE OLIVEIRA J., NASCIMENTO, JD, PINOTTI, H, PINTO, MC, CILENSE, M, GLAVÃO, C & BARATA, J.M. 2014. Study of the external female genitalia of 14 *Rhodnius* species (Hemiptera, Reduviidae, Triatominae) using scanning electron microscopy. Paras. Vect. 7:17, http://dx.doi.org/10.1186/1756-3305-7-17

SCHREIBER, G., PENALVA, F. & CARVALHO HC. 1968. Morfologia comparada dos folículos testiculares e sistemática dos Triatominae (Hemiptera, Reduviidae). Cien. Cult. 20:640–641.

SILISTINO-SOUZA, R., PERUQUETTI, R.L., TABOGA, S.R. & AZEREDO-OLIVEIRA, M.T.V. 2012. Chromatoid body: Remnants of nucleolar proteins during spermatogenesis in triatomine (Heteroptera, Triatominae). Micron 43:954–960, http://dx.doi.org/10.1016/j.micron.2012.03.017

TARTAROTTI, E. & AZEREDO-OLIVEIRA, M.T.V. 1999. Patterns of nucleolar activity during spermatogenesis of two triatomines, *Panstrongylus megistus* and *P. herreri*. Caryologia 52:177–184, http://dx.doi.org/10.1080/00087114.1998.10589171

Received 07/07/2014
Revised 25/08/2014
Accepted 10/10/2014

Biota Neotropica 14(4): e20140007, 2014
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)

short communication

Bony fishes (Teleostei) caught by small-scale fisheries off central to south coast of São Paulo State, Southeastern Brazil

***Fabio Santos Motta*[1,4,5], *Marcos Rogério Rosa*[2], *Rafael Cabrera Namora*[3] & *Otto Bismarck Fazzano Gadig*[4]**

[1]*Departamento de Ciências do Mar, Universidade Federal de São Paulo, Santos, SP, Brazil.*
[2]*Instituto Linha D' Água, Pinheiros, São Paulo, SP, Brazil.*
[3]*Instituto de Pesca, Programa de Monitoramento da Atividade Pesqueira, Santos, SP, Brasil.*
[4]*Laboratório de Pesquisa em Elasmobrânquios, Universidade Estadual Paulista Júlio de Mesquita Filho, São Vicente, SP, Brazil.*
[5]*Corresponding author: Fabio Santos Motta, e-mail: limbatus@gmail.com*

MOTTA, F.S., ROSA, M.R., NAMORA, R.C., GADIG, O.B.F. **Bony fishes (Teleostei) caught by small-scale fisheries off central to south coast of São Paulo State, Southeastern Brazil.** Biota Neotropica. 14(4): e20140007. http://dx.doi.org/10.1590/1676-06032014000714

Abstract: Small-scale fisheries have a great socioeconomic importance in Brazil. Different regional characteristics along the coast, mostly related to landing sites, equipment used, and targeted species, renders its assessment and monitoring difficult. The aim of this paper is to present a list of species of bony fishes (Teleostei) caught by artisanal fisheries along the São Paulo coast, southeastern Brazil and to provide comments on the relative abundance and conservation status of those species. A total of 315 fishing fleet landings were surveyed, and 106 species distributed among 38 families were recorded. Sciaenidae and Carangidae were the most frequent families in species number. The southern king weakfish, *Macrodon atricauda*, was the most abundant species, representing 28.03% of the total number of specimens caught. Eleven of the most abundant species are classified as Overexploited in the country or as Near Threatened in the state of São Paulo. These findings reinforce the relevance of assessing and managing artisanal fisheries.

Keywords: *artisanal fisheries, ichthyofauna, species list, western Atlantic.*

MOTTA, F.S., ROSA, M.R., NAMORA, R.C., GADIG, O.B.F. **Peixes ósseos (Teleostei) capturados pela pesca de pequena escala na costa centro-sul de São Paulo, Sudeste do Brasil.** Biota Neotropica. 14(4): e20140007. http://dx.doi.org/10.1590/1676-06032014000714

Resumo: A pesca de pequena escala tem uma grande importância socioeconômica no Brasil. Diferenças regionais ao longo da costa, relacionadas principalmente aos locais de desembarque, artes de pesca e espécies- alvo tornam a sua avaliação e monitoramento difíceis. O objetivo do presente estudo foi apresentar uma lista das espécies de peixes ósseos capturadas pela pesca artesanal na costa de São Paulo, sudeste do Brasil, com comentários sobre a sua abundância relativa e estado de conservação. Foram monitorados 315 desembarques da frota pesqueira, registrando 106 espécies, distribuídas em 38 famílias. As famílias Sciaenidae e Carangidae foram as mais representativas em número de espécies. A pescada amarela, *Macrodon atricauda*, foi a espécie mais abundante, correspondendo a 28,03% do número total de peixes capturados. Onze das espécies mais abundantes são classificadas como Sobre-explotadas no país ou Próximo de Ameaça de Extinção no estado de São Paulo. Esses resultados reforçam a relevância de avaliar e manejar as pescarias artesanais.

Palavras-chave: *pesca artesanal, ictiofauna, lista de espécies, Atlântico Ocidental.*

Introduction

Despite a lack of government support, small-scale fisheries still have high socioeconomic relevance along the Brazilian coast, with about one million people involved in this activity (Vasconcellos et al. 2011). Even in the southeast region, where industrial fisheries account for most landings, the artisanal sector is still responsible for almost 40% of production (Vasconcellos et al. 2007). This situation reinforces the importance of understanding, assessing and effectively managing coastal fisheries (Salas et al. 2011). However, statistical data and basic information, including the species richness of fishes caught, are both still scarce and incomplete (Alves et al. 2009, Salas et al. 2011).

In São Paulo state, southern Brazil, most of the fish species inventories conducted have occurred along the northern and central coasts (Braga & Goitein 1984, Lopes et al. 1993, Giannini & Paiva-Filho 1995, Muto et al. 2000, Gibran & Moura 2012). Few surveys have focused on the southern to central portion of the São Paulo coast (e.g. Zani-Teixeira &

Paiva-Filho 1981). All of the studies cited were also based on scientific collecting and are therefore not adequate for evaluating the interaction between artisanal fisheries and coastal fish assemblages. This paper provides a checklist of the species of bony fishes (Actinopterygii: Teleostei) caught by small-scale fisheries along the central to south coast of São Paulo state. Comments on the relative abundance and conservation status of the species recorded are also included.

Materials and Methods

This report is associated with a long-term research on the fishery biology of coastal elasmobranchs off southeastern Brazil (PROJETO CAÇÃO), started in 1996 (Gadig et al. 2002). Species were recorded based on weekly sampling from artisanal fisheries that operate along the central to south coast of São Paulo state. The samplings were taken from landings on the ''Praia dos Pescadores'' (Fishermen's Beach), city of Itanhaém (24°11'S; 46°48'W).

The fishing operations in question cover an area of approximately 600 km^2, with the cities of Mongaguá and Peruibe making up the northern and southern limits, respectively (Figure 1). This region lies within the inner continental shelf, with a mean water temperature of 24°C and an average salinity of 34.5 (Freitas & Muelbert, 2004). The substrate is largely composed of fine sand, with less than 30% calcium carbonate (Figueiredo & Tessler, 2004). Primary productivity in the region is mainly driven by seasonal upwellings of nutrient-rich, cold subtropical waters caused by alongshore winds and by cyclonic vortices that come from the Brazil Current (Bakun & Parrish 1990, Matsuura 1995, Vasconcellos & Gasalla 2001).

This fishery fleet consists of approximately 28 small-motorized boats (4-10 m long), which fish mainly with gillnets and single shrimp otter trawl nets. Gillnets are made of nylon

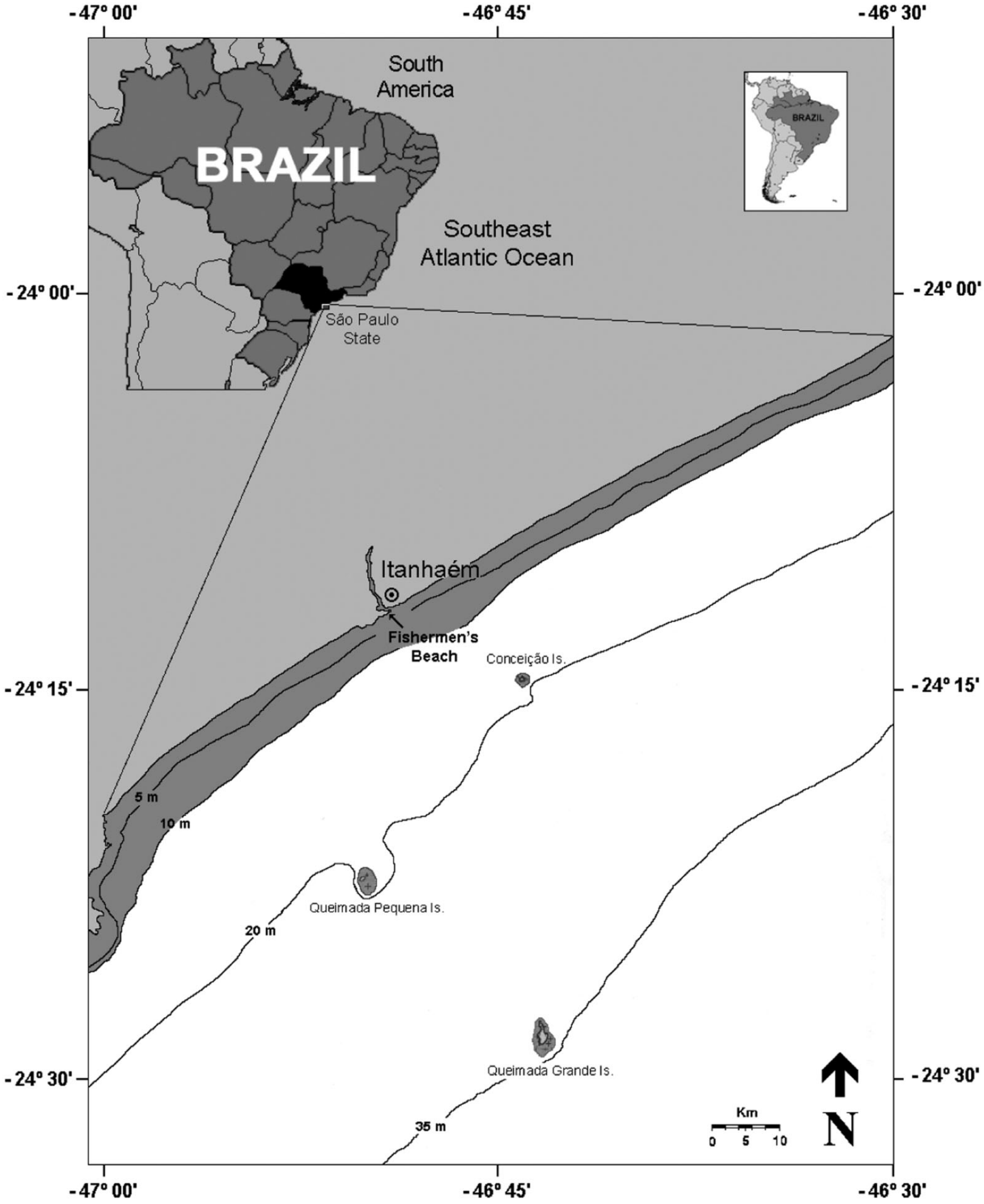

Figure 1. Map of study area, indicating the landing point of the small-scale fishery fleet in Itanhaém, southeastern Brazil.

Table 1. Checklist of species of the Teleostei captured by small-scale fisheries in the central to south coast of São Paulo State, Southeastern Brazil. Conservation status according to different level assessments: Needing Management Actions (NMA), Overexploited (OE), Data-Deficient (DD), Least-Concern (LC), Near-Threatened (NT), Vulnerable (VU); Endangered (EN), not evaluated species (-).

Order	Family	Species	State	Brazil	IUCN
Elopiformes					
	Elopidae				
		Elops smith McBride, Rocha, Ruiz-Carus & Bowen 2010	---	---	LC
Anguilliformes					
	Ophichthidae				
		Myrophis punctatus Lütken, 1852	---	---	---
Clupeiformes					
	Clupeidae				
		Brevoortia aurea (Spix & Agassiz, 1829)	---	---	---
		Brevoortia pectinata (Jenyns, 1842)	---	---	---
		Harengula clupeola (Cuvier, 1829)	DD	---	---
		Opisthonema oglinum (Lesueur, 1818)	NT	---	---
		Pellona harroweri (Fowler, 1917)	--	--	--
	Engraulidae				
		Anchoa spinifer (Valenciennes, 1848)	DD	---	---
		Anchoviella lepidentostole (Fowler, 1911)	NT	---	---
		Lycengraulis grossidens (Spix & Agassiz, 1829)	--	--	--
Siluriformes					
	Ariidae				
		Bagre bagre (Linnaeus, 1766)	DD	---	---
		Bagre marinus (Mitchill, 1815)	NT	---	---
		Cathorops spixii (Agassiz, 1829)	--	--	--
		Genidens barbus (Lacepede, 1803)	NMA	OE	---
		Genidens genidens (Cuvier, 1829)	DD	---	LC
		Notarius grandicassis (Valenciennes, 1840)	DD	---	---
Aulopiformes					
	Synodontidae				
		Synodus foetens (Linnaeus, 1766)	---	---	---
Gadiformes					
	Phycidae				
		Urophycis brasiliensis (Kaup, 1858)	NMA	---	---
Batrachoidiformes					
	Batrachoididae				
		Porichthys porosissimus (Cuvier, 1829)	NT	---	---
Syngnathiformes					
	Fistulariidae				
		Fistularia petimba Lacepède, 1803	---	---	---
		Fistularia tabacaria Linnaeus, 1758	---	---	---
	Dactylopteridae				
		Dactylopterus volitans (Linnaeus, 1758)	---	---	---
Scombriformes					
	Pomatomidae				
		Pomatomus saltatrix (Linnaeus, 1766)	NT	OE	---
	Scombridae				
		Auxis thazard (Lacepède, 1800)	DD	---	LC
		Scomberomorus brasiliensis Collette, Russo & Zavala-Camin, 1978	DD	---	LC
		Scomberomorus cavalla (Cuvier, 1829)	---	---	LC
	Stromateidae				
		Peprilus paru (Linnaeus, 1758)	DD	---	LC
	Trichiuridae				
		Trichiurus lepturus Linnaeus, 1758	---	---	---
Carangiaria					
	Centropomidae				

Continued on next page

Table 1. Continued.

Order	Family	Species	State	Brazil	IUCN
		*Centropomus parallelu*s Poey, 1860	NT	---	---
		Centropomus undecimalis (Bloch, 1792)	NT	---	---
	Polynemidae				
		Polydactylus virginicus (Linnaeus, 1758)	--	--	--
	Sphyraenidae				
		Sphyraena barracuda (Edwards, 1771)	DD	---	---
		Sphyraena guachancho Cuvier, 1829	DD	---	---
Carangiformes					
	Carangidae				
		Carangoides bartholomaei (Cuvier, 1833)	---	---	---
		Caranx crysos (Mitchill, 1815)	---	---	LC
		Caranx hippos (Linnaeus, 1766)	---	---	---
		Caranx latus Agassiz, 1831	--	--	--
		Chloroscombrus chrysurus (Linnaeus, 1766)	--	--	--
		Hemicaranx amblyrhynchus (Cuvier, 1833)	--	--	--
		Oligoplites palometa (Cuvier, 1832)	--	--	--
		Oligoplites saliens (Bloch, 1793)	--	--	--
		Oligoplites saurus (Bloch & Schneider, 1801)	--	--	--
		Parona signata (Jenyns, 1841)	--	--	--
		Selene setapinnis (Mitchill, 1815)	NT	--	--
		*Selene vome*r (Linnaeus, 1758)	NT	--	--
		Trachinotus carolinus (Linnaeus, 1766)	--	--	--
		Trachinotus falcatus (Linnaeus, 1758)	--	--	--
		Trachinotus goodei Jordan & Evermann, 1896	--	--	LC
		Trachinotus marginatus Cuvier, 1832	--	--	--
	Coryphaenidae				
		Coryphaena hippurus Linnaeus, 1758	DD	--	LC
	Rachycentridae				
		Rachycentron canadum (Linnaeus, 1766)		--	--
Pleuronectiformes					
	Achiridae				
		Trinectes microphthalmus (Chabanaud, 1928)	DD	--	--
		Trinectes paulistanus (Miranda Ribeiro, 1915)	DD	--	--
	Cynoglossidae				
		Symphurus tessellatus (Quoy & Gaimard, 1824)	--	--	--
	Paralichthyidae				
		Citharichthys spilopterus Günther, 1862	DD	--	--
		Syacium papillosum (Linnaeus, 1758)	DD	--	--
		Paralichthys brasiliensis (Ranzani, 1842)	NT	--	--
		Paralichthys patagonicus Jordan, 1889	NT	--	--
Mugiliformes					
	Mugilidae				
		Mugil lisa Valenciennes, *1836*	NMA	--	--
		Mugil curema Valenciennes, 1836	DD	--	--
Eupercaria					
	Gerreidae				
		Diapterus rhombeus (Cuvier, 1829)	--	--	--
		Eucinostomus argenteus Baird & Girard, 1855	--	--	--
		Eugerres brasilianus (Cuvier, 1830)	DD	--	--
	Haemulidae				
		Anisotremus surinamensis (Bloch, 1791)	--	--	--
		Anisotremus virginicus (Linnaeus, 1758)	--	--	--
		Boridia grossidens Cuvier, 1830	DD	--	--
		Conodon nobilis (Linnaeus, 1758)	DD	--	--
		Haemulon steindachneri (Jordan & Gilbert, 1882)	--	--	LC
		Orthopristis ruber (Cuvier, 1830)	NT	--	--
		Pomadasys corvinaeformis (Steindachner, 1868)	--	--	--

Continued on next page

Table 1. Continued.

Order	Family	Species	State	Brazil	IUCN
	Lutjanidae				
		Lutjanus analis (Cuvier, 1828)	NMA	OE	VU
		Lutjanus synagris (Linnaeus, 1758)	--	--	--
	Sciaenidae				
		Bairdiella ronchus (Cuvier, 1830)	DD	--	--
		Cynoscion acoupa (Lacepède, 1801)	DD	--	LC
		Cynoscion guatucupa (Cuvier, 1830)	NMA	OE	--
		Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	NT	--	--
		Cynoscion leiarchus (Cuvier, 1830)	DD	--	--
		Cynoscion microlepidotus (Cuvier, 1830)	DD	--	--
		Cynoscion virescens (Cuvier, 1830)	NT	--	--
		Isopisthus parvipinnis (Cuvier, 1830)	--	--	--
		Larimus breviceps Cuvier, 1830	--	--	--
		Macrodon atricauda (Günther, 1880)	NMA	OE	--
		Menticirrhus americanus (Linnaeus, 1758)	NT	--	--
		Menticirrhus littoralis (Holbrook, 1847)	NT	--	--
		Micropogonias furnieri (Desmarest, 1823)	NMA	OE	--
		Nebris microps Cuvier, 1830	DD	--	--
		Paralonchurus brasiliensis (Steindachner, 1875)	NT	--	--
		Stellifer brasiliensis (Schultz, 1945)	--	--	--
		Stellifer rastrifer (Jordan, 1889)	--	--	--
		Stellifer stellifer (Bloch, 1790)	DD	--	--
		Umbrina coroides Cuvier, 1830	--	--	--
Lobotiformes					
	Lobotidae				
		Lobotes surinamensis (Bloch, 1790)	DD	--	--
Ephippiformes					
	Ephippidae				
		Chaetodipterus faber (Broussonet, 1782)	--	--	--
Spariformes					
	Sparidae				
		Diplodus argenteus (Valenciennes, 1830)	--	--	--
Lophiiformes					
	Ogcocephalidae				
		Ogcocephalus vespertilio (Linnaeus, 1758)	--	--	--
Tetraodontiformes					
	Diodontidae				
		Chilomycterus reticulatus (Linnaeus, 1758)	--	--	--
	Tetraodontidae				
		Lagocephalus laevigatus (Linnaeus, 1766)	--	--	--
		Sphoeroides testudineus (Linnaeus, 1758)	DD	--	--
	Balistidae				
		Balistes capriscus Gmelin, 1789	NMA	--	--
		Stephanolepis hispidus (Linnaeus, 1766)	--	--	--
Perciformes					
	Serranidae				
		Epinephelus marginatus (Lowe, 1834)	NMA	OE	EN
		Hyporthodus niveatus (Valenciennes, 1828)	NMA	OE	VU
		Mycteroperca acutirostris (Valenciennes, 1828)	--	--	LC
		Diplectrum radiale (Quoy & Gaimard, 1824)	--	--	--
	Scorpaenidae				
		Scorpaena isthmensis Meek & Hildebrand, 1928	--	--	--
	Triglidae				
		Prionotus punctatus (Bloch, 1793)	--	--	--

Vouchers used as reference: *Rachycentron canadum* AZUSC 165, *Hyporthodus niveatus* AZUSC 424, *Synodus foetens* AZUSC 431, *Stephanolepis hispidus* AZUSC 898, *Parona signata* AZUSC 3654 monofilament with 1500 m in length and stretched mesh sizes varying between 7 and 14 cm. The height of the nets varies between 1.7 and 3.5 m. Nets were set up between 12 to 24 hours, within an area of 0.5 to 12 nautical miles from the shore, in waters between 5 and 35 m deep. Other fishing gear used seasonally include driftnet, trammel nets and large-sized gillnets. More detailed descriptions of those fisheries are presented by Namora et al. (2009). There are two marine protected areas in the region, the "Tupiniquins" Ecological Station (corresponding to IUCN Category Ia), created in 1986, with an area of 20 km^2, and the "Litoral Centro" Environmental Protected Area (corresponding to IUCN Category V), established in 2008 and comprising an area of 4,531km^2.

This checklist was based on 315 fishery fleet landings monitored between July 1996 and March 2007. To evaluate the relative abundance of species, 33 field campaigns were carried out in order to count the specimens landed between April 2004 and October 2006. The orders and families were listed in phylogenetic order according to Betancur-R et al. (2014), and the species were organized within each family in alphabetical order. The conservation status of the species were based on global (IUCN 2013), national (Machado et al. 2005), and regional (São Paulo State 2014) levels. Voucher specimens of the some species collected during the study were deposited in the ichthyology collection of the "Acervo Zoológico da Unisanta" (AZUSC), in the city of Santos, São Paulo.

Results and Discussion

A total of 106 species, distributed among 78 genera, 38 families and 20 orders of the Teleostei were recorded (Table 1) over 10 years. The most speciose family recorded was Sciaenidae (19 species = 17.9%), followed by Carangidae (16 = 15.1%), Haemulidae (7 = 6.6%), Ariidae (6 = 5.7%), Clupeidae (5 = 4.7%), and Serranidae (4 = 3.8%).

The number of species recorded is higher than the amounts recorded during previous experimental studies conducted with beach or otter trawl nets in other regions off the coast of São Paulo state. Braga & Goitein (1984), for instance, recorded 57 species, whereas Lopes et al. (1993), Giannini & Paiva-Filho (1995) and Muto et al. (2000) recorded 78, 98 species, and 83 species, respectively. When compared to monitoring of fishing activities in adjacent areas, the number of species recorded in this study is approximately 2.5 times higher than that of Bertozzi & Zerbini (2002), which recorded 42 species off the city of "Praia Grande". The difference in terms of number of recorded species in this study is likely related to several factors, including the total area of operation of the fleet surveyed, the fishing gear selectivity, the magnitude of both sampling and fishing effort, and the spatial and temporal distribution of species. In the current study, for instance the fishing operation area and the magnitude of sampling and fishing effort were higher than those previous studies.

Between April 2004 and October 2006, 11,443 fish specimens of 74 species, 59 genera and 31 families were recorded. The southern king weakfish, *Macrodon atricauda* (Günther, 1880), and the gulf kingcroaker, *Menticirrhus littoralis* (Holbrook, 1847), were the most abundant species, representing 28.03% and 12.48% of the total number of specimens recorded, respectively (Table 2). Among the 20 most abundant species, 10 (50%) belonged to Sciaenidae. This finding highlight the abundance of the group in the coastal waters and its relevance to artisanal fisheries. Previous studies conducted off the coast of São Paulo state also reported a relative dominance of Sciaenidae species (Braga & Goitein 1984, Lopes et al. 1993, Giannini & Paiva-Filho 1995, Muto et al. 2000).

Table 2. Relative abundance (> 0.5% of the total catch) of species caught by small-scale fisheries in the central to south coast of São Paulo State, Southeastern Brazil, between April 2004 and October 2006. Number of specimens (N); Percentage of the total catch (%).

Species	N	%
Macrodon atricauda	3208	28.03
Menticirrhus littoralis	1428	12.48
Larimus breviceps	781	6.83
Bagre bagre	701	6.13
Oligoplites saliens	673	5.88
Stellifer rastrifer	670	5.86
Micropogonias furnieri	621	5.43
Nebris microps	351	3.07
Trichiurus lepturus	262	2.29
Scomberomorus brasiliensis	252	2.20
Genidens barbus	249	2.18
Bagre marinus	226	1.98
Notarius grandicassis	221	1.93
Paralonchurus brasiliensis	182	1.59
Chloroscombrus chrysurus	156	1.36
Menticirrhus americanus	139	1.21
Cynoscion virescens	127	1.11
Stellifer brasiliensis	122	1.07
Peprilus paru	119	1.04
Genidens genidens	104	0.91
Cynoscion jamaicencis	92	0.80
Isopisthus parvipinnis	72	0.63
Selene setapinnis	67	0.59
Centropomus undecimalis	60	0.52

Out of the total number of species recorded, 59 (55.6%) have had their conservation statuses assessed on at least one geographic scale. At the global level, one species was evaluated as Endangered (*Epinephelus marginatus*), two species were considered Vulnerable (*Hyporthodus niveatus* and *Lutjanus analis*) and 12 were considered to be of Least Concern (Table 1). Regional and national assessments have adopted other categories in addition to those provided by the IUCN. At the national level (on the Brazilian list), eight species were considered Overexploited (Table 1), whereas in the São Paulo state list, ten species were evaluated as Needing Management Actions, 17 were considered to be Near Threatened, and 27 were categorized as Data Deficient (Table 1). There is particular concern over the fact that 11 of the most frequently captured species are considered "Overexploited" (*Macrodon atricauda*, *Micropogonias furnieri*, *Genidens barbus*) or "Near Threatened" (*Bagre marinu*s, *Paralonchurus brasiliensis*, *Cynosciun virescens*, *Cynoscion jamaicencis, Paralonchurus brasiliensis*, *Menticirrhus americanus, Menticirrhus littoralis, Paralonchurus brasiliensis*), reinforcing the importance of assessment programs and management actions for these fisheries.

Acknowledgements

The authors thank the fishermen of Itanhaém for their collaboration with PROJETO CACÃO, for their friendship, and for their permission to examine all fish specimens landed, and to grant # 1999/04085-1, São Paulo Research Foundation (FAPESP) and the Brazilian Council for Scientific Research (CNPq) for the grants to F. S. Motta and O. B. F. Gadig, respectively. The authors are also grateful to reviewers for comments that greatly improved the manuscript.

References

ALVES, P.M.F., ARFELLI, C.A. & TOMÁS, A.R.G. 2009. Caracterização da pesca de emalhe do litoral do Estado de São Paulo, Brasil. Bol. Inst. Pesca. 35(1):17-27.

BAKUN, A. & PARRISH, R. 1990. Comparative studies of coastal pelagic fish reproductive habitat: the Brazilian sardine (*Sardinella aurita*). J. Cons. Int. Explor. Mer. 46:269-283, http://dx.doi.org/10.1093/icesjms/46.3.269

BERTOZZI, C.P. & ZERBINI, A.N. 2002. Incidental mortality of franciscana (*Pontoporia blainvillei*) in the artesanal fishery of Praia Grande, São Paulo State, Brazil. LAJAM. 1(1):153-160, http://dx.doi.org/10.5597/lajam00019

BETANCUR-R, R., WILEY, E., BAILLY, N., MIYA, M., LECOINTRE, G., ORTÍ, G. 2014. Phylogenetic Classification of Bony Fishes --Version 3 (http://www.deepfin.org/Classification_v3.htm) (accessed on 20 October 2014).

BRAGA, F.M.S. & GOITEIN, R. 1984. Lista prévia das espécies de peixes demersais na região da Ilha Anchieta (Lat. 23° 33′S – Long. 45° 05), Ubatuba, litoral norte do Estado de São Paulo, Brasil. Naturalia. 9:61-72.

FIGUEIREDO, A.G. & TESSLER, M.G. 2004. Topografia e composição do substrato marinho da região Sudeste-Sul do Brasil. São Paulo, Instituto Oceanográfico, USP – Série Documentos do Revizee: Score Sul, 64p.

FREITAS, D.M. & MUELBERT, J.H. 2004. Ichthyoplankton distribution and abundance off southeaster and Southern Brazil. Braz. Arch. Biol. Techn. 47(4):601-612, http://dx.doi.org/10.1590/S1516-89132004000400014

GADIG, O.B.F., MOTTA, F.S. & NAMORA, R.C. 2002. Projeto Cação: a study on small coastal sharks in São Paulo, southeast Brazil. In: Duarte, P. (ed.) Proceedings fo the International Conference on Sustainable Management of Coastal Ecosystems. Universidade Fernando Pessoa, Porto, Portugal. p. 239-246.

GIANNINI, R. & PAIVA-FILHO, A.M. 1995. Análise comparativa da ictiofauna da zona de arrebentação de praias arenosas do Estado de São Paulo, Brasil. Bol. Inst. Ocean. 43(2):141-152.

GIBRAN, F.Z. & MOURA, R.L. 2012. The structure of rocky reef fish assemblages across a nearshore to coastal islands'gradient in Southeastern Brazil. Neotrop. Ichthyol. 10(2):369-382, http://dx.doi.org/10.1590/S1679-62252012005000013

INTERNATIONAL UNION FOR CONSERVATION OF NATURE – IUCN. 2013. IUCN Red List of Threatened Species. http://www.iucnredlist.org/ (Accessed on 10 December 2013).

LOPES, R.G., RODRIGUES, E.S., PUZZI, A., PITA, J.B., COELHO, J.A.P. & FREITAS, M.L. 1993. Levantamento ictiofaunistico em um ponto fixo na baia de santos, Estado de São Paulo. Brasil. Bol. Inst. Pesca. 20:7-20.

MACHADO, A.B.M., MARTINS, C.S., DRUMMOND, G.M. 2005. Lista da fauna brasileira ameaçada de extinção: incluindo as espécies quase ameaçadas e deficientes em dados. Belo Horizonte: Fundação Biodiversitas.

MATSUURA, Y. 1995. Os ecossistemas brasileiros e os principais macrovetores de desenvolvimento. Subsídio ao Planejamento da Gestão Ambiental. Projeto Cenários para o Planejamento da Gestão Ambiental (MMA/PNMA), Brasília, DF, p. 39-104.

MUTO, E.Y., SOARES, E.S.H. & ROSSI-WONGTSCHOWSKI, C.L.D.B. 2000. Demersal fish assemblages Off São Sebastião, southeastern Brazil: Structure and environmental conditioning factors (summer 1994). Rev. Bras. Ocean. 48(1):9-27.

NAMORA, R.C., MOTTA, F.S. & GADIG, O.B.F. 2009. Caracterização da pesca artesanal da Praia dos Pescadores, Município de Itanhaém, costa centro-sul do Estado de São Paulo. Arq. Ciên. Mar. 42(2):60-67.

SALAS, S., CHUENPAGDEE, R., CHARLES, A. & SEIJO, J.C. 2011. Coastal fisheries of Latin America and the Caribbean. FAO Fisheries and Aquaculture Technical Paper. No. 544. Rome, FAO. p. 430.

SECRETARIA DO MEIO AMBIENTE DO ESTADO DE SÃO PAULO - SEMA/ SP. 2014. Decreto n° 60.133, de 7 de fevereiro de 2014. Declara as espécies da fauna silvestre ameaçadas de extinção, as quase ameaçadas e as deficientes de dados para avaliação no Estado de São Paulo e dá providências correlatas. Diário Oficial do Estado de São Paulo, São Paulo, Poder Executivo, 8 fev. 2014. Seção 1.

VASCONCELLOS, M., GASALLA, M.A. 2001. Fisheries catches and the carrying capacity of marine ecosystems in southern Brazil. Fish. Res. 50:279-295, http://dx.doi.org/10.1016/S0165-7836(00)00217-4

VASCONCELLOS, M., DIEGUES, A.C.S.A. & SALES, R.R. 2007. Limites e possibilidades na gestão da pesca artesanal costeira. In: Costa, A.L. (Org.) Nas Redes da Pesca Artesanal. Brasília: IBAMA - MMA, p. 15-83.

VASCONCELOS, M., DIEGUES, A.C. & KALIKOSKI, D.C. 2011. Coastal fisheries of Brazil. In: Salas, S., Chuenpagdee, R., Charles, A., Seijo, J.C. (eds.) Coastal fisheries of Latin America and the Caribbean. *FAO* Fisheries and Aquaculture Technical Paper. No. 544. Rome, FAO, p. 73–116.

ZANI-TEIXEIRA, M.L. & PAIVA-FILHO, A.M. 1981. Contribuição ao conhecimento da fauna íctica costeira de região de Peruíbe, SP. II: Diversidade faunística. Rev. Bras. Biol. 41(2):291-294.

Received 24/01/2014
Revised 03/11/2014
Accepted 07/11/2014