Bembicine wasps (Hymenoptera: Crabronidae: Bembicinae: Bembicini, except Gorytina) of Rio de Janeiro State (southeast Brazil): inventory of species and notes on biology

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BUYS, S.C. **Bembicine wasps (Hymenoptera: Crabronidae: Bembicinae: Bembicini, except Gorytina) of Rio de Janeiro State (southeast Brazil): inventory of species and notes on biology.** Biota Neotrp. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn01712032012

Abstract: An inventory of the bembicine wasps (Hymenoptera: Crabronidae: Bembicinae: Bembicini, except Gorytina) found in Rio de Janeiro State is provided, based on the revision of the literature and on the examination of the entomological collections of the Instituto Oswaldo Cruz (CEIOC) and Museu Nacional – Universidade Federal do Rio de Janeiro (MNRJ). Original biological notes on *Rubrica nasuta* (Christ, 1791), *Stictia signata signata* (Linnaeus, 1758) and *Stictia punctata* (Fabricius, 1775) are also provided.
Keywords: *solitary wasps, Aculeata, Atlantic Forest, restinga, geographic distribution.*

BUYS, S.C. **Vespas bembicíneas (Hymenoptera: Crabronidae: Bembicinae: Bembicini, exceto Gorytina) do Estado do Rio de Janeiro (sudeste do Brasil): inventário de espécies e notas sobre biologia**. Biota Neotrp. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn01712032012

Resumo: Um inventário das vespas bembicíneas (Hymenoptera: Crabronidae: Bembicinae: Bembicini, exceto Gorytina) encontradas no Estado do Rio de Janeiro é fornecido, com base na revisão da literatura e exame das coleções entomológicas do Instituto Oswaldo Cruz (CEIOC) e Museu Nacional – Universidade Federal do Rio de Janeiro (MNRJ). Também são fornecidas notas biológicas originais sobre *Rubrica nasuta* (Christ, 1791), *Stictia signata signata* (Linnaeus, 1758) e *Stictia punctata* (Fabricius, 1775).
Palavras-chave: *vespas solitárias, Aculeata, Mata Atlântica, restinga, distribuição geográfica.*

Introduction

Bembicinae (Hymenoptera: Crabronidae) is a worldwide distributed group of solitary wasps, which dig nests in the ground, commonly in sandy soil, and store them with insects of several orders, as Diptera, Orthoptera, Hemiptera, Lepidoptera and Odonata (Bohart & Menke 1976, Evans & O'Neill 2007). The members of the subfamily Bembicinae have been classified into three tribes: Alyssontini (71 spp.), Bembicini (1,411 spp.) and Nyssonini (226 spp.) (Hanson & Menke 2006, Pulawski 2011a). Alyssontini was not recorded from Brazil and Nyssonini is poorly represented, with the most of its species occurring in the Amazonian region (Amarante 2002). On the other hand, Bembicini is widely represented in Brazil and throughout the Neotropical Region (Bohart & Menke 1976, Amarante 2002, Evans & O'Neill 2007). As part of an effort for producing a database on aculeate Hymenoptera of Rio de Janeiro State aiming subsequently to discuss ecological and biogeographic patterns, in the present paper an inventory of the bembicine wasps of the tribe Bembicini (Hymenoptera: Apoidea: Crabronidae: Bembicinae) found in this State is provided, except for the species of the subtribe Gorytina, which will be treated in a further paper. Original biological notes on *Rubrica nasuta* (Christ, 1791), *Stictia signata signata* (Linnaeus, 1758) and *Stictia punctata* (Fabricius, 1775) are also provided.

This study was based on the revision of the literature and on the examination of the entomological collections of the Instituto Oswaldo Cruz (CEIOC) and Museu Nacional – Universidade Federal do Rio de Janeiro (MNRJ). The identification of the species was based mainly on the papers by Parker (1929), Araújo (1939), Willink (1947) and Bohart (1996a, b). Specimens that do not perfectly match with the published descriptions were not included in the paper.

Results

Tribe Bembicini Latreille, 1802

SUBTRIBE BEMBICINA LATREILLE, 1802

Genus *Bembix* Fabricius, 1775

Bembix comantis Parker, 1929

Previous literature records. Parker (1929): Rio de Janeiro State; Amarante (2002): Rio de Janeiro State.

Genus *Bicyrtes* Lepeletier de Saint Fargeau, 1845

Bicyrtes discisus (Taschenberg, 1870)

Records. Itatiaia (500m), 1♂, 1♀, J.F. Zikán, 3.II.1933 (CEIOC); Niterói, 1♀, R. Arlé (MNRJ); Nova Friburgo, 1♀, 1♂, Melo Leitão (MNRJ); idem, 1♀, S. Lopes, 22.IV.1927 (MNRJ); Rio de Janeiro (Floresta da Tijuca), 1♀, C.A.C. Seabra, 26.III.1955 (MNRJ); Silva Jardim (Reserva Biológica de Poço das Antas), 1♀, S. C. Buys, IX.2001 (CEIOC).

Previous literature records. Taschenberg (1870): Rio de Janeiro State, Amarante (2002): Rio de Janeiro State.

Bicyrtes variegatus (Olivier, 1798)

Records. Cabo Frio, 8♀, Carvalho, 05.II.1984 (MNRJ); Itatiaia (700 m), 4♂, J.F. Zikán, 30.III.1938 (CEIOC); Niterói, 1♀, S.S.F.R., 10.XI.1946 (MNRJ); Rio de Janeiro, 3♀, R. Arlé, (MNRJ); Rio de Janeiro (Floresta da Tijuca), 1♀, C.A.C. Seabra, III.1954 (MNRJ); Rio de Janeiro (Guaratiba), 1♀, J.H. Guimarães, 1.1956 (MNRJ); Rio de Janeiro (Copacabana), 1♀, C. Moreira (MNRJ); Rio de Janeiro, 1♀, H.S. Lopes, V.1936 (MNRJ); Seropédica (BR 465, Km 47), 1♀, B. Ramos, 27.II.1945 (MNRJ).

Genus *Editha* J. Parker, 1929

Editha adonis Handlirsch (1890)

Previous literature record. Handlirsch (1890: *apud* Pulawski 2011b): Rio de Janeiro State, Rio de Janeiro [According to Pulawski (2011b), *E. adonis* was described based on specimens from "Ipanema, part of Rio de Janeiro"].

Editha fuscipennis (Lepeletier de Saint Fargeau, 1845)

Record. Itatiaia, 1♀, 16.I.1924 (CEIOC).

Genus *Microbembex* Patton, 1979

Microbembex ciliata (Fabricius, 1804)

Record. Rio de Janeiro, 3♀, Arlé (MNRJ).

Genus *Rubrica* Parker, 1929

Rubrica adumbrata (Handlirsch, 1890)

Previous literature record. Amarante (2002): Rio de Janeiro State.

Rubrica gravida (Handlirsch, 1890)

Record. Petrópolis (Pedro do Rio), 3♀, 1♂, C.A.C. Seabra, III.1954 (MNRJ).

Rubrica nasuta (Christ, 1791)

Records. Araruama, 2♀, H. Schubart, 3.XII.1961 (MNRJ); Duque de Caxias (São Bento), 1♀, P.A. Teles, 18.II.1951 (MNRJ); idem, 3♀, P.A. Teles, XII.1973 (MNRJ); Itaguaí, 1♀, L. Fernandes, 01.I.1957 (MNRJ); Itatiaia (700 m), 1♀, J.F. Zikán, 24.II.1940 (CEIOC); idem, 1♀, J.F. Zikán, 16.III.1941 (CEIOC); Maricá (Restinga de Barra de Maricá), 1♀, S.C. Buys, 13.III.2001 (CEIOC); Rio de Janeiro, 9♀, H.S. Lopes, 07.V.1936 (MNRJ); idem, 3♀, 1♂, R, Arlé (MNRJ); idem, 1 exemplar, II.1926 (MNRJ); Rio de Janeiro (Floresta da Tijuca), 7♀, C.A.C. Seabra, I.1951 (MNRJ); Rio de Janeiro (Deodoro), 1♀ (MNRJ); idem, 1♀, W. Zikán, 09.V.1940 (MNRJ); idem, 1♀, W. Zikán,10.X.1937 (MNRJ); Seropédica (Universidade Federal Rural do Rio de Janeiro), 1♀, J.H. Guimarães, 1957 (MNRJ); Seropédica (BR 465, Km 47), 1♀, J.F. Zikán, 15.II.1957 (MNRJ).

Previous literature records. Bradley (1921, p. 54); Amarante (2002): Rio de Janeiro State.

Biological notes. This species was commonly observed in the summer of 2001 in the Restinga de Barra de Maricá (city of Maricá). The nests were found near margins of an unpaved road in compacted soil composed of sand and clay. One female spent about 20-30 minutes to dig a burrow of 7 cm in depth and 1 cm in diameter. Another observed nest was about 10.5 cm in depth. Specimens of *Ornidia obesa* (Fabricius, 1775) (Diptera: Syrphidae) and an unidentified horse-fly (Diptera: Tabanidae) were found as prey inside the nests. *Rubrica nasuta* is relatively well studied and the herein presented observations generally agree with observations made in other places (review in Evans & O'Neill 2007).

Genus *Stictia* Illinger, 1807

Stictia maccus (Handlirch, 1895)

Records. Angra dos Reis, 1♀, L. Travassos, XII.1932 (MNRJ); Rio de Janeiro, 2♀ (no further dates) (MNRJ).

Stictia punctata (Fabricius, 1775)

Records. Angra dos Reis, 1♀, L. Travassos, XII.1932 (MNRJ); Cabo Frio, 5♀, Carvalho, 05.II.1984 (MNRJ); idem, 3♀, Carvalho, 03.XI.1984 (MNRJ); Itaperuna, 2♀, Alceir Castro (MNRJ); Niterói (Jurujuba), 2♀; Rio de Janeiro (Marambaia) (CEIOC), 2♀, Alceir Castro, I.1953 (MNRJ); Seropédica (BR 465, Km 47), 1♀ (MNRJ).

Previous literature record. Amarante (2002): Rio de Janeiro State.

Biological notes. The biology of this species is known only for the notes by Evans & Matthews (1974), based on 10 nests observed in Colombia, and short observations by Amarante (1996) on hunting tactics (review on biology in Evans & O'Neill 2007). Herein additional observations on habitat are provided as follows: dense and large nesting aggregations with dozen of specimens were observed in flattened sandy soil in areas of restinga vegetation and in the superior portion of beaches from west zone of Rio de Janeiro city in the summer of 2002. Nesting females were also observed in the superior portion of beaches in the city of Niterói sparsely distributed in vertical sandy banks severely exposed to the sun. One nest was excavated, but cells were not found. This nest consisted of a long tunnel, at least of 50 cm in depth.

Stictia signata signata (Linnaeus, 1758)

Records. Duque de Caxias (São Bento), 4♀, P.A. Teles, VI.1953 (MNRJ); idem, 2♀, P.A. Teles, XI.1953 (MNRJ); idem, 4♀, P.A. Teles, 30.V.1954 (MNRJ); Maricá (Restinga de Barra de Maricá), 1♀, S. C. Buys, 13.III.2001 (CEIOC); Rio de Janeiro (Guaratiba), 1♀, J.H. Guimarães, I.1956 (MNRJ); Seropédica (BR 465, Km 47), 1♀, Antenor, 15.IV.1945 (MNRJ).

Previous literature record. Amarante (2002): Rio de Janeiro State.

Biological notes. Nesting females were observed in Restinga de Barra de Maricá (city of Maricá) in the summer of 2001. One observed nest was an oblique burrow of 19 cm in depth, excavated in a sandy site exposed to the sun; one specimen of *Biopyrellia bipuncta* (Wiedemann, 1830) (Diptera: Muscidae) was found inside the nest as prey. Adult specimens were observed

Table 1. Richness of bembicine wasps (tribe Bembicini), excluding the subtribe Gorytini, in the Neotropical Region, Brazil, Southeast Region of Brazil and Rio de Janeiro State. Classification by Pulawski (2011a); number of species based on Amarante (2002, 2005), adding the new records provided in the present paper.

Tabela 1. Riqueza de vespas bembicíneas (tribe Bembicini), excluindo a subtribo Gorytina, na Região Neotropical, Brasil, Região Sudeste do Brasil e Estado do Rio de Janeiro. Classificação de Pulawski (2011a); número de espécies baseado em Amarante (2002, 2005), adicionando os novos registros fornecidos no presente artigo.

	Neotropical region	Brazil	Southeast region of Brazil	Rio de Janeiro state
Bembicina				
Bembix	16	8	6	1
Bicyrtes	23	10	6	2
Carlobembix	1	0	0	0
Editha	7	6	3	2
Hemidula	2	0	0	0
Microbembix	27	7	3	1
Rubrica	4	3	3	3
Selman	1	1	1	0
Stictia	26	11	7	3
Trichostictia	3	1	0	0
Zyzzyx	1	0	0	0
Exeirina				
Argogorytes	8	4	2	0
Clitemnestra	52	12	1	1
Neogorytes	6	0	0	0
Paraphilanthus	1	0	0	0
Handlirschiina				
Pterogorytes	3	3	1	0
Heliocausina				
Acanthocausus	1	0	0	0
Heliocausus	3	0	0	0
Tiguipa	4	0	0	0
Spheciina				
Sphecius	4	1	1	0
Tanyoprymnus	1	0	0	0
Stictiellina				
Glenostictia	4	0	0	0
Microstictia	5	0	0	0
Steniolia	3	0	0	0
Stictiela	2	0	0	0
Stizina				
Bembecinus	12	7	3	3
Total	220	74	37	16

Table 2. Comparison of the bembicine fauna from three regions of the Rio de Janeiro State with distinct vegetation and geographic aspects, based on the material examined in the present paper.

Tabela 2. Comparação entre a fauna de bembicíneos de três regiões do Estado do Rio de Janeiro com vegetação e aspectos geográficos distintos, baseada no material examinado no presente artigo.

Species/subspecies	Sandy coastal plains	Lowland areas on Serra do Mar, excluding sandy coastal areas	Highland areas on Serra dos Órgãos
Bicyrtes discisus		X	X
Bicyrtes variegatus	X	X	X
Editha adonis	X		
Editha fuscipennis			X
Rubrica gravida			X
Rubrica nasuta	X	X	X
Stictia punctata	X	X	
Stictia signata signata	X	X	
Bembecinus agilis		X	
Bembecinus bolivari	X	X	
Bembecinus quinquespinosus		X	
Total	6	8	5

feeding on flowers of *Borreria* sp. (Rubiaceae). Females were observed following walking people and hover near them in search for prey items. In such occasions, the females attack co-specific wasps that approximate. A similar behaviour of hunting near people was observed by Philippi & Eberhard (1986).

Subtribe Exeirina Dalla Torre, 1897

Genus *Clitemnestra* Spinola, 1851

Clitemnestra densa Bohart, 2000

Previous literature records. Amarante (2002): Rio de Janeiro State.

SUBTRIBE STIZINA A. COSTA, 1859

Genus *Bembecinus* A. Costa, 1859

Bembecinus agilis (Smith, 1873)

Records. Niterói, 1♀, R. Arlé (MNRJ); Rio de Janeiro, 2♀, R. Arlé (MNRJ); Rio de Janeiro, 3♀, H.S. Lopes, 01.1936 (MNRJ); Rio de Janeiro (Floresta da Tijuca - Gávea), 1♀, 1♂, L. Travassos, 09.1935 (MNRJ).

Bembecinus bolivari (Handlirsch, 1892)

Records. Angra dos Reis, 1♀, L.T., 12.1932 (MNRJ); Duque de Caxias (São Bento), 5♀, P.A. Teles, 11.1954 (MNRJ); Macaé (Barra de Sana), 1♀, Alceu, I.1957 (MNRJ); Niterói (Jurujuba), 1♀, 23.03.1933 (MNRJ); Rio de Janeiro, 1♀, R. Arlé (MNRJ).

Bembecinus quinquespinosus (Say, 1823)

Records. Duque de Caxias (São Bento), 1♀, P.A. Teles, 11.1953 (MNRJ).

Previous literature records. Amarante (2002): Rio de Janeiro State.

Concluding Remarks

Amarante (2002) recorded the occurrence of 74 species of Bembicini, excluding the Gorytina, to Brazil (Table 1). From these species, only seven were cited by this author to Rio de Janeiro State. In the present paper, 16 species are inventoried to Rio de Janeiro State. Certainly this number must be increased with further studies, since almost 40 species of bembicine wasps, other than Gorytina, has been recorded to the Southeast Region of Brazil (Table 1), in the vicinities of Rio de Janeiro State, and possibly several of these species also occur in this State.

The most of the specimens examined in the preset study came from coastal sandy plains and other lowland areas on the Serra do Mar (Table 2). This is an expected pattern based on the observation that bembicine wasps are conspicuous elements of the fauna of superior portions of not strongly anthropized sandy beaches and areas of restinga throughout the Rio de Janeiro State. In this context, one must consider that the anthropization of coastal areas of Rio de Janeiro State perhaps is favoring the colonization of new sites toward interior lands by bembicine. This is because open sites with sandy soil are favorite places for the nesting of bembicine and unpaved roads seems to be paths of dispersion to ground-nester wasps and bees. Besides this, bembicine do not have strongly specialized food habits (see for example Evans & O'Neill 2007) and they could search for prey items in stocks of vegetation that commonly are present in these devastated areas.

Acknowledgements

I thank Cinara de Andrade Silva for assisting in the field works; Marcia Couri for identifying the flies. I specially thank the "Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro" (FAPERJ) for the post-doctoral grant.

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Received 07/07/2011
Revised 22/05/2012
Accepted 09/08/2012

Medium and large sized mammals of a semideciduous forest remnant in southern Brazil

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PIRES, D.P.S. & CADEMARTORI, C.V. **Medium and large sized mammals of a semideciduous forest remnant in southern Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn01412032012

Abstract: Knowledge about mammals of the Atlantic Forest is still lacking, especially because some places remain poorly studied or inventoried, which makes conservation initiatives difficult. We aimed to determine the species richness and composition of medium and large sized mammals in a semideciduous forest remnant, Morro do Coco, thus contributing information about the occurrence of mammalian fauna in the metropolitan region of Porto Alegre, southern Brazil. The methods consisted of interviews with local inhabitants, visual records and sand plot analysis. The study took place from July 2008 to April 2009, with monthly expeditions of three days. Sixteen species of mammals were recorded, seven of which are threatened with extinction in Rio Grande do Sul and one nationally. The predominant trophic group was the frugivorous/herbivorous. The study area is situated in a prioritized zone for the conservation of mammals in Greater Porto Alegre, since it consists of one of the last remnants where the phytophysionomies that originally occupied the edge of Guaiba Lake and granite hills of the region are represented and preserved.

Keywords: *mammalian fauna, tracks, Atlantic Forest Domain, sand plots, visual records.*

PIRES, D.P.S. & CADEMARTORI, C.V. **Mamíferos de médio e grande porte de um remanescente de Floresta Estacional Semidecidual no sul do Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn01412032012

Resumo: O conhecimento sobre a mastofauna da Mata Atlântica é ainda insuficiente, especialmente porque restam locais pouco estudados ou mal inventariados, o que dificulta iniciativas de conservação. Teve-se, como objetivos, conhecer a riqueza e a composição de espécies de mamíferos de médio e grande porte em um remanescente de Floresta Estacional Semidecidual, o Morro do Coco, contribuindo, assim, com informações sobre a ocorrência da mastofauna na região metropolitana de Porto Alegre, sul do Brasil. A metodologia consistiu de entrevistas com moradores locais, registros visuais e parcelas de areia. O estudo transcorreu de julho de 2008 a abril de 2009, com expedições mensais de três dias. Foram registradas 16 espécies de mamíferos, sete das quais estão ameaçadas de extinção no Rio Grande do Sul e uma nacionalmente. O grupo trófico predominante foi o de frugívoros/herbívoros. A área de estudo situa-se em uma zona prioritária à conservação da mastofauna na Grande Porto Alegre, por ser um dos últimos remanescentes onde estão representadas e preservadas as fitofisionomias que originalmente ocupavam a orla do Lago Guaíba e os morros graníticos da região.

Palavras-chave: *mastofauna, pegadas, Domínio da Mata Atlântica, parcelas de areia, registros visuais.*

Introduction

The search for conservationist actions has led scientists throughout the world to understand and discuss the main environmental impacts of the unbridled actions of humanity, and also to find ways of confronting and reducing the loss of biodiversity. One of the principal impacts of anthropic activities on biodiversity is the loss and reduction of habitats, which contributes to the extinction of species of the world's fauna (Primack & Rodrigues 2001).

The conservation of an ecosystem and its utilization in a sustainable manner depends on fauna inventories (Primack & Rodrigues 2001, Pardini et al. 2003, Rocha & Dalponte 2006). Information on abundance and distribution are very important to evaluate the state of conservation of a taxa (Butchart et al. 2006), and one of the difficulties in this evaluation, at the national level, is the scarcity of published data on the composition and abundance of species at local and regional levels (Machado et al. 2008).

The Atlantic Forest was the biome most affected by the settling of Brazil (Tabarelli et al. 2005, Tonhasca Junior 2005, Lagos & Muller 2007). Still, it is believed that the region encompasses 8% of the world's biodiversity and a large number of endemic species (Lagos & Muller 2007), sustaining 261 species of mammals, 61% of which are endemic (Costa 2001, Lagos & Muller 2007). However, knowledge of the fauna of this biome is still lacking, including the areas close to big cities, where it is not uncommon that there are animals essential to the maintenance of the ecological systems, such as medium and large sized mammals (Tonhasca Junior 2005, Penter et al. 2008, Abreu Junior & Köhler 2009).

The mammals are a representative group of the tropical fauna (Costa 2001). Mammalian species respond differently to alterations in their habitats, where some communities are more sensitive than others to environmental perturbations over time. Mammals are especially affected by the loss and alteration of habitats, since they are important components of terrestrial ecosystems, whether in terms of biomass, trophic interactions or their essential role in the maintenance and regeneration of tropical forests through the dispersal of seeds and predation of seedlings (Redford & Eisenberg 1992, Silva 1994, Tonhasca Junior 2005, Carvalho Junior & Luz 2008).

The fauna of mammals in Rio Grande do Sul comprises 166 species already recorded (Fontana et al. 2003). This total accounts for almost 25% of the 701 species mentioned by Paglia et al. (2012) for Brazil. However, many ecological and biological aspects of medium and large sized mammals are still little known, due to the difficulties in their observation and study (Silva 1994, Pardini et al. 2003).

The metropolitan region of Porto Alegre is made up of a vegetational mosaic composed of fields and forests, predominant especially in the hills, which results from the combination of geomorphological diversity and transitional climatic conditions, because it is situated between temperate and tropical regions (Menegat et al. 1998). Such conditions, although having revealed a high richness and diversity of species for other faunistic groups (Lema et al. 1983, Scherer et al. 2006, Santos & Cademartori 2010), have been little explored with respect to the mammalian fauna. The species richness of mammals has been insufficiently studied in the forest remnants of the region (Antonio 1996, Sestren-Bastos 2006, Penter et al. 2008), where there is a need for information from more long-term inventories.

Therefore, with the aim of contributing to the conservation and maintenance of the constituent natural processes of forest remnants in the state of Rio Grande do Sul, we studied the species richness and composition of mammals of medium and large size in Morro do Coco and also updated the information on the occurrence of the mammalian fauna in the metropolitan region of Porto Alegre.

Materials and Methods

The study area is situated in Morro do Coco, a remnant of a seasonal semideciduous forest of about 142 ha that belongs to the Atlantic Forest Domain (Figure 1). It is located in the municipality of Viamão, state of Rio Grande do Sul, between 30° 16' 15" S and 51° 02' 54" W, 50 km to the south of Porto Alegre and about 15 km from the lighthouse of Itapuã (Menegat et al. 1998). It has an elongated shape, east to west, where the eastern point projects into Guaíba Lake (Backes 2000). It is situated in a matrix with a predominance of rural activity, with substantial farming, intertwined with urban centers. The landscape consists of isolated hills and low lands that extend up to Guaíba Lake, whose banks are broken up by points and coves (Hickel et al. 1998). In this region, there are still patches of vegetation that interconnect important forest remnants such as Morro São Pedro, Morro da Extrema, Morro do Coco and Parque Estadual de Itapuã, among others (Figure 1).

The climatic and edaphic factors have a strong influence on the vegetation of this area, determined by the occurrence of a clean field, dirty field, shrub field, forest fragments and continuous forest (Backes 2000). The forest of Morro do Coco is not continuous in all directions. According to Knob (1978), the vegetation of the hills of Greater Porto Alegre has already been almost totally destroyed or modified, but the vegetation of Morro do Coco is in an advanced stage of ecological succession.

The climate in the region is of the Cfa type, according to the Koeppen classification, that is, subtropical climate with dominant influence of the territorial configuration (C), with cool winters (f) and a minimal temperature of 3 °C recorded in June and July. The summer is hot, with a maximal absolute temperature of 41 °C recorded in December, and mean of the warmest month higher than 22 °C (a).

Samplings were carried out monthly in a period of 10 months, from July 2008 to April 2009.The time spent in the area at each expedition was three days, totaling a period of 30 days of field activities.

In this study, the mammals considered were of medium and large size, with a body weight over 1 kg when adults (Chiarello 2000).

For the screening of tracks, 20 sand plots were placed in two transects, each at a distance of 20 m from the other, 10 on the edge of and the other 10 inside the forest. The sand plots consisted of wooden frames with a size of 50 cm in length × 50 cm in width × 5 cm in height, without bottom. The plots were examined daily, moistened with a sprinkler, leveled and the bait was replaced when it was taken. The choice of baits for the herbivorous animals (banana) and for the carnivorous animals (bacon) was according to Pardini et al. (2003). To increase the probability of capturing different species in the areas sampled, the types of bait utilized were switched with each expedition. Therefore, bacon was used in one transect and banana in the other, reversing the type of bait in transects every month. The sampling sites were studied simultaneously, with the same effort for both, totaling 300 plots for each transect (75 m^2.day per transect).

Besides the use of sand plots placed in the two transects already described, screening of tracks on the lake bank was carried out by excursions on foot during the day and eventually at night. The effort allotted was two hours per day, totaling 60 hours.

Besides the tracks, the occurrence of the mammals was determined by sightings. The sightings were recorded while covering trails and transects in the study area. Daily walks of about two hours were taken, totaling an effort of 60 hours. The recordings obtained in 120 hours of effort, including tracks and visual, were counted per day, that is, species per day, taking into account a single daily recording per species. The tracks were identified based on the previous experience of the observer, using field guides (Becker & Dalponte

Figure 1. Location of the study area and main hills and patches of forest that compose the landscape on the edge of Guaíba Lake (Google Earth 2012). 1. Ponta Grossa, 2. Ponta da Cuíca, 3. Ponta do Arado, 4. Ponta das Canoas, 5. Morro São Pedro, 6. Morro da Extrema, 7. Ponta do Cego, 8. Reserva Biológica do Lami José Lutzenberger, 9. Morro do Coco, 10. Parque Estadual de Itapuã, 11. Morro da Fortaleza, 12. Ponta de Itapuã, 13. Morro da Grota.

1991, Borges & Tomaz 2008, Carvalho Junior & Luz 2008) and by consulting specialists. Ten local inhabitants were interviewed with the aim of confirming and complementing the visual and track recordings, utilizing a questionnaire adapted from Santos (2001). Recordings were considered valid only if confirmed by at least two inhabitants in a period of five years, accompanied by a detailed description, followed by the identification of the animal from a photograph.

The species accumulation curve was obtained based on the number of species recorded per month. The program EstimateS 8.5 was used to estimate the species richness of the study area, and the results were submitted to the estimators Chao 1, Jacknife 1 and Bootstrap. The first estimator is based on abundance and considers exclusively the species with a low number of recordings, while the second is based on incidence and considers only rare species, found in only one or two samples; the third estimates total richness, using data of all species, not just rare species (Colwell 2009).

The occurrence constancy of the species was evaluated by the index developed by Silveira-Neto et al. (1976), based on the scale proposed by Santos et al. (2008): species encountered in more than 50% of the samplings are considered constant, those present between 25 and 50% are accessory, and those with a level less than 25% are considered occasional. For constancy analysis, only sand plots and visual recordings were considered. Each species was assigned to a trophic category according to Paglia et al. (2012) and the degree of threat followed Fontana et al. (2003) and Machado et al. (2008).

Results

In the period of ten months, 16 species of mammals were recorded in Morro do Coco, distributed into 15 families and eight orders (Table 1), including the exotic species *Lepus europaeus* Pallas, 1778. The estimator of species richness Jacknife 1 determined 17 species for the locality, while the estimators Chao 1 and Bootstrap estimated 16 species (Figure 2). Seven of the 16 species detected are threatened with extinction in Rio Grande do Sul, all included in the category Vulnerable (Table 1).

The method that was the most efficient for the detection of the mammalian fauna of medium and large size was that of trails (14 species), followed by interviews (13 species) and sightings (6 species).

Considering the total recordings, the most frequent species in Morro do Coco was *Alouatta guariba* Cabrera, 1940, with 31% of the total, followed by *Didelphis albiventris* Lund 1840, with 30%. The other species combined comprised 39% of the recordings.

An analysis of the trophic categories revealed that six species (37.5%) are herbivorous, six (37.5%) are omnivorous, three (19%) are carnivorous or piscivorous and one (6%) is myrmecophagous (Table 1). The constancy index revealed that two species were accessory in the area and 13 occasional (Table 1).

Discussion

Based on the similar results of the three estimators of species richness used, the locality was well sampled. However, according to Santos (2003), the majority of the methods utilized for estimating species richness generally underestimate the richness of the community, because it is very difficult if not impossible to assess how close estimations are to the true richness of the community. According to this author, the suitability of these methods for studies of biological diversity is still poorly known, and their application in ecology is relatively recent, which requires caution in the interpretation of the results. Considering that the surrounding region has been little studied and that the period of study was not of long duration, new species can probably be recorded in Morro do Coco and surroundings. Felines of the genus *Leopardus* and cervids of the genus *Mazama*, for example, often appear in reports by inhabitants around the study area (D.P.S. Pires, personal observation), suggesting that new species could be recorded. Knowing that the detection of all species of an area is practically unattainable, especially in complex ecosystems, and that the species accumulation curve did not reach a plateau, it cannot be stated that Morro do Coco is completely inventoried.

Species richness in Morro do Coco differs more or less from that of the surrounding regions and of the other hills of Porto Alegre. The

Table 1. Medium and large sized mammals recorded in Morro do Coco, RS, from July 2008 to April 2009.

ORDER/Family/*Species*	Trophic category	n	CI	Form of recording	Conservation status
DIDELPHIMORPHIA					
Didelphidae					
Didelphis albiventris (Lund, 1840)	Frugivorous/Omnivorous	30	A	T, I	NT
PILOSA					
Myrmecophagidae					
Tamandua tetradactyla (Linnaeus, 1758)	Myrmecophagous	1	O	T, I	V
CINGULATA					
Dasypodidae					
Dasypus novemcinctus (Linnaeus, 1758)	Insectivorous/Omnivorous	2	O	V, T, I	NT
PRIMATES					
Atelidae					
Alouatta guariba Cabrera, 1940	Folivorous/Frugivorous	29	A	V, T, I	V
CARNIVORA					
Canidae					
Cerdocyon thous (Linnaeus, 1766)	Insectivorous/Omnivorous	5	A	T,I	NT
Procyonidae					
Procyon cancrivorus (G. Cuvier, 1798)	Frugivorous/Omnivorous	7	O	T	NT
Mephitidae					
Conepatus chinga (Molina, 1782)	Insectivorous/Omnivorous	1	O	T	NT
Mustelidae					
Lontra longicaudis (Olfers, 1818)	Piscivorous	3	O	V, T, I	V
Felidae					
Puma yagouaroundi (E. Geoffroyi) Saint-Hilaire, 1803)	Carnivorous	1	O	T, I	V
Leopardus pardalis (Linnaeus, 1758)	Carnivorous	-	-	I	V
ARTIODACTYLA					
Cervidae					
Mazama sp. (Rafinesque, 1817)	Frugivorous/Herbivorous	2	O	T,I	V
RODENTIA					
Erethizontidae					
Coendou spinosus (F. Cuvier, 1823)	Frugivorous/Folivorous	3	O	V, T, I	NT
Caviidae					
Hydrochoerus hydrochaeris (Linnaeus, 1766)	Herbivorous	4	O	T, I	NT
Dasyproctidae					
Dasyprocta azarae (Lichtenstein, 1823)	Frugivorous/Granivorous	1	O	T	V
Myocastoridae					
Myocastor coypus (Molina, 1782)	Frugivorous/Omnivorous	4	O	V	NT
LAGOMORPHA					
Leporidae					
Lepus europaeus (Pallas, 1778)	Herbivorous	4	O	V, T, I	*

n (number of records, considering species per day). CI – Constancy index (A – Accessory, C – Constant, O – Occasional). V – Visual recording, T – Recording by trails, I – Recording by interviews. Conservation status according to Fontana et al. (2003) and Machado et al. (2008): V – Vulnerable, NT – Not threatened, * Exotic species. The trophic categories according to Paglia et al. (2012).

list of species of the Parque Estadual de Itapuã, a conservation unit of approximately 5,500 ha and close to Morro do Coco, consists of 21 species of medium and large sized mammals (Antonio 1996). A survey of mammals carried out by Penter et al. (2008) in Morro Santana, an area of about 1000 ha, noted the presence of 17 species of medium and large sized mammals, a large part being learned through interviews. In fact, only nine of these species were considered with occurrence confirmed by the authors, two of which were not recorded in Morro do Coco, *Cavia aperea* (Erxleben, 1777) and *Cebus nigritus* (Goldfuss, 1809). Sestren-Bastos (2006) recorded only four species of mammals of medium and large size in Morro do Osso, in Porto Alegre, one of which was not detected in Morro do Coco, *C. aperea*, a characteristic species of open formations (Redford & Eisenberg 1992). The biotic and abiotic characteristics of these hills are similar to those of Morro do Coco; however, Morro Santana and Morro do Osso are much more impacted than Morro do Coco, since the first two are isolated and surrounded by the urban network of Porto Alegre. Parque Estadual de Itapuã, on the contrary, is a more conserved area and far from the urban sprawl, suggesting that the richness of mammals of medium and large size have some relation to the conservation status and degree of isolation of the area. Kasper et al. (2007b), on the other hand, found 28 species in their study in Vale do Taquari. In the Parque Estadual do Turvo, an area of about 17,500 ha, Kasper et al. (2007a) recorded 29 species of mammals of medium and large size. Therefore, there is

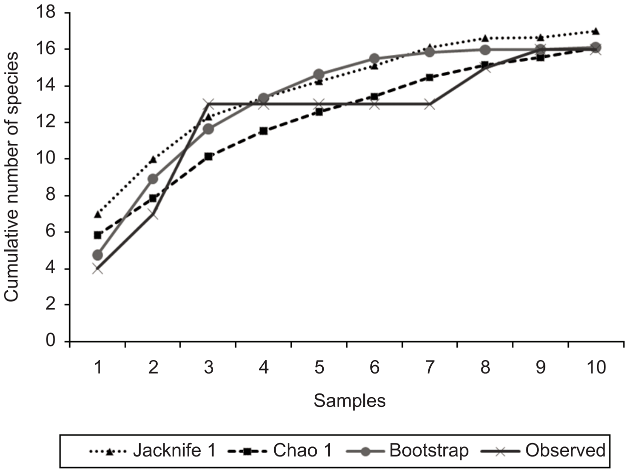

Figure 2. Observed and estimated species accumulation curves for medium and large sized mammals recorded in Morro do Coco, southern Brazil, from July 2008 to April 2009.

a greater difference in species richness in Morro do Coco compared to localities that are much more conserved and continuous, such as Parque Estadual do Turvo, where the number of medium and large sized mammals is much greater.

Although some species have not been recorded in Morro do Coco, their occurrence is expected, especially because they have been detected in nearby areas, such as Parque Estadual de Itapuã and Reserva Biológica do Lami, a conservation unit of 204 ha (Witt 2008). This is the case for *C. aperea* and *Dasypus hybridus* (Desmarest, 1804), since there are open formations in the vicinity, and for *Galictis cuja* (Molina, 1782), capable of occupying forest formations and open areas (Yensen & Tarifa 2003). It is also the situation for *Cabassous tatouay* (Desmarest, 1804), recorded by C.V. Cademartori (personal observation) in June 2006 in Lar Nazaré, a social assistance home of approximately 50 ha and about 5 km from the study area. *Cebus nigritus*, despite evidence of its presence in granite hills more to the north, in the municipality of Porto Alegre (Gomes 2006, Penter et al. 2008), does not occur in the study area or in Parque Estadual de Itapuã or Reserva Biológica do Lami. This species, easy to detect because of its diurnal habits and conspicuous behavior (Emmons & Feer 1997), was never mentioned by the interviewees, not even in reference to more remote times. Data on the distribution of *C. nigritus*, as well as its population densities and use of space are rare in Rio Grande do Sul, and although the species is tolerant to the presence of human and is able to occupy fragmented landscapes, its occurrence and size of groups depend on factors such as dimensions, state of conservation and connectivity between forest fragments, presence of farmland and food offerings by humans (Gonçalves 2006).

In relation to methods used, the combination of the methods was shown to be more effective in detecting the local mammalian fauna than any one of the methods alone. Despite the high number of species obtained with interviews, it should be pointed out that in this case, these were based on only three families, who although living in the area did not venture into the interior of the forest or to areas farther from their homes. Still, the inhabitants had lived in the area for many years and were familiar with the wild fauna, which was accustomed to foraging close to their homes, which guaranteed greater reliability of the reports. Penter et al. (2008) noted that in urban fragments, the interviews can be the best alternative for the recording of species. However, the combined use of various sampling methods appears to be the most efficacious strategy for the detection of a greater number of species (Kasper et al. 2007a).

The high percentage of recordings of *D. albiventris* and *A. guariba* in relation to the other species suggests that both are common in the study area. This result has also been reported by other authors in studies carried out in the region, which indicates that the two species are easily encountered (Antonio 1996, Sestren-Bastos 2006, Penter et al. 2008). It should also be noted that the high percentage of *A. guariba* is due to its diurnal habits and conspicuous behavior, compared to other species of mammals recorded.

With respect to the trophic categories, similar results were obtained by Abreu Junior & Köhler (2009), who also found a preponderance of omnivorous and frugivorous/herbivorous mammals. The carnivorous and piscivorous groups recorded in Morro do Coco – *Puma yagouaroundi* (E. Geoffroy, 1803), *Leopardus pardalis* (Linnaeus, 1758) and *Lontra longicaudis* (Olfers, 1818) – represent the environmentally more demanding trophic group. Although it is a representative category in Morro do Coco, this does not mean that the area is capable of sustaining these species in the medium and long-term, which can be inferred by the low number of recordings of carnivores, compared to other studies (Santos et al. 2004, Kasper et al. 2007a, Marques et al. 2011). Because of the large living areas required by carnivores, a greater sampling effort is necessary to obtain more precise information of their distribution and abundance in Morro do Coco and other nearby hills and forest patches. In agreement with Becker & Dalponte (1991), the tracks of *P. yagouarondi* are very similar to those of felines of the genus *Leopardus*, where the simple observation of the tracks for the distinction between the species can be hasty and prone to errors. However, the track still provides unique characteristics of the species, such as the impression of four rounded toes in a semicircle and well distanced from the pad (Morro-Rios et al. 2008). Such characteristics, along with the confirmation of the species by inhabitants, show consistent evidence of the presence of *P. yagouarondi* in the study area.

The inhabitants reported the occurrence of the only specialized insectivore encountered, *Tamandua tetradactyla* (Linnaeus, 1758), about five years ago. Kasper et al. (2007b) affirmed that the species is still relatively common in the Vale do Taquari, located in the central region of the state of Rio Grande do Sul, on the slope of the Serra Geral, despite the intense fragmentation of the landscape. However, because of the lack of consistent recordings of *T. tetradactyla* in the regions close to Morro do Coco, it is necessary to make a greater effort in the field to confirm the occurrence of the species.

With the use of only sand plots, the presence of a species of the genus *Mazama* was detected, which could not be determined to the species level only by analysis of the tracks. However, by the type of environment, state of conservation and distribution of cervid species, this was probably *Mazama gouazoubira* (G. Fischer, 1814), a well-distributed and well-adapted species, which can utilize these forests, fields and regenerating forests (Redford & Einsenberg 1992, Silva 1994, Reis et al. 2006).

Among the 16 species found, seven (44%) are threatened with extinction in Rio Grande do Sul, in the vulnerable category (Fontana et al. 2003). *Leopardus pardalis* is also considered threatened at the national level in the vulnerable category (Machado et al. 2008). Among the main threats to these species are habitat loss and fragmentation, hunting and being run over (Fontana et al. 2003).

The results of constancy analysis revealed a similar pattern with studies of disturbed areas (Sestren-Bastos 2006, Penter et al. 2008), where the most frequent species are those that have the capacity for adaptation to anthropogenic presence. The most constant species in the area were *A. guariba*, *Cerdocyon thous* (Linnaeus, 1766) and *D. albiventris*. Unlike *A. guariba*, a threatened species in Rio

Grande do Sul, especially due to the fragmentation of the Atlantic Forest (Marques 2003), the last two species are usually found in altered environments (Fernandez & Pires 2006, Magalhães 2007). The constancy of *A. guariba* in the study area can be explained by its conspicuous behavior and by the fact that monkey groups are currently restricted to the forest remnants of the region

Among the species listed, the presence of threatened species as well as widely distributed species and generalist and specialist species were recorded. *Alouatta guariba*, *D. albiventris*, *C. thous*, *Hydrochoerus hydrochaeris* (Linnaeus, 1766), *Coendou spinosus* (F. Cuvier, 1823) (= *Sphiggurus villosus*, according to Voss 2011), *Dasypus novemcinctus* Linnaeus, 1758, *Procyon cancrivorous* (G. Cuvier, 1798) and *Myocastor coypus* (Molina, 1782) are generally species more often found in anthropized places (Peres 1997, Ramos Junior et al. 2003, Dias & Mikich 2006, Negrão & Valladares-Pádua 2006, Pedó et al. 2006, Kasper et al. 2007b, Araújo et al. 2008, Abreu Junior & Köhler 2009). *Lepus europaeus* is considered an invasive species that occupies open areas and pastures, whose first recordings in Rio Grande do Sul date from the beginning of the XXth century (Instituto... 2012). However, the occurrence of more specialized carnivores such as *P. yagouaroundi* and *L. pardalis*, whose populations have declined in the state due to the loss of natural habitats (Indrusiak & Eizirik, 2003), demonstrates the regional importance of the study area. The richness and composition of medium and large sized mammals found in Morro do Coco, with a predominance of generalist species and occasional recordings of rare and specialist species, suggest that the area is in a medium state of conservation. Despite the anthropic influence, Morro do Coco plays an important role in the conservation of medium and large sized mammals in the regional context, together with other forest remnants that comprise the landscape. However, by itself, it will not be able to contribute to the persistence of the mammalian fauna in the region, which requires studies in other remnants and evaluations on the landscape scale.

Final Considerations

Morro do Coco has been preserved by the Irmãos Lassalistas (a religious order) for more than 50 years. As a consequence, this area of native forest still maintains in part its original characteristics, serving as a refuge for various species of mammals and other faunal groups threatened with extinction in Rio Grande do Sul or which were already locally extinct in a large part of the metropolitan region of Porto Alegre. The marked species richness recorded for medium and large sized mammals, including various threatened species in the state of Rio Grande do Sul, as well as their considerable diversity of feeding habits (seven trophic categories), demonstrates the importance of the area for the conservation of the local mammalian fauna. Preserving Morro do Coco could contribute to conserving the community of medium and large sized mammals, and probably the ecological functions that they perform. Morro do Coco is situated in a zone prioritized for conservation of mammals in Greater Porto Alegre, since it consists of one of the last remnants where the phytophysionomies that originally occupied the edge of Guaiba Lake and granite hills of the region are represented and preserved.

Acknowledgements

We thank the team who helped us in field surveys and to Rosane Vera Marques for scientific contributions. We are also very grateful to Irmãos Lassalistas for the permission to carry out our field work in Morro do Coco. Dr. A. Leyva helped with the English translation and editing of the manuscript. Finally, we thank CNPq for financial support.

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Received 03/11/2011
Revised 30/06/2012
Accepted 03/08/2012

Head triangulation as anti-predatory mechanism in snakes

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Abstract: Anti-predator mechanisms in snakes are diverse and complex, including mimetic behavior. Some snakes triangulate their head, probably mimicking other more dangerous snakes. However, there is a lack of studies that demonstrate the effectiveness of this behavior with natural predators. The aim of this study was to verify, using artificial snakes, if snakes with triangular heads are less susceptible to attack by predators, and if predatory attack is targeted to the head of serpents. Artificial snakes were systematically arranged on a road border. The rate of attacked models was 48.71%. Number of attacks on models with rounded head was significantly higher than in models with triangular head. There was a significant difference between the places of attack on the snakes in relation to different head shapes. Therefore, snakes that have head triangulation may be a less frequent target of attacks by predators than those without such behavior.
Keywords: *artificial models, defensive behavior, mimicry, predation rate, reptiles.*

DELL'AGLIO, D.D., TOMA, T.S.P., MUELBERT, A.E., SACCO, A.G. & TOZETTI, A.M. **Triangulação da cabeça como mecanismo anti-predação em serpentes**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?short-communication+bn01912032012

Resumo: Mecanismos anti-predação em serpentes são diversos e complexos, incluindo comportamentos miméticos. Algumas serpentes triangulam a cabeça, possivelmente mimetizando outras serpentes mais perigosas. No entanto, são escassos os estudos demonstrando a eficiência deste comportamento frente a predadores naturais. O objetivo deste estudo foi verificar, utilizando serpentes artificiais, se os indivíduos com cabeça triangular são menos suscetíveis ao ataque de predadores e, se o ataque predatório é direcionado à cabeça das serpentes. Serpentes artificiais foram dispostas sistematicamente na margem de uma estrada. A taxa de modelos atacados foi 48,71%. O número de ataques em modelos de cabeça arredondada foi significativamente maior do que nos modelos com cabeça triangular. Houve diferença significativa entre as partes atacadas nas serpentes quando comparados aos diferentes formatos de cabeça. Portanto, as serpentes que possuem triangulação da cabeça podem ser um alvo menos frequente de ataques por predadores do que as que não possuem esse tipo de comportamento.
Palavras-chave: *modelos artificiais, comportamento defensivo, mimetismo, taxa de predação, répteis.*

Introduction

Species' ability to defend themselves from a predator is intrinsically associated to their survival, increasing ability to explore the environment as well as to obtain resources (Lima & Dill 1990, Downes 2001). Reptiles exhibit extremely diverse anti-predator mechanisms, including cryptic coloration and behavior, mimicry, aposematism and also several ways to intimidate attackers (Pough et al. 2004). Many of these anti-predator mechanisms are assumed to be a visual intimidation for predators (Tozetti et al. 2009). Snakes are interesting models for defense mechanisms studies because besides having developed defensive behaviors, they are potential prey for many animals such as mammals, birds, other reptiles and invertebrates (Greene 1988).

Capacity of head triangulation is one of many tactics of defense. This ability can be observed in some species of *Dipsas*, which associated with coloration make them mimetic of *Bothrops jararaca*, a Viperidae snake widely distributed in Brazil (Tozetti et al. 2009). The mimetic behaviors displayed by these snakes, head triangulation and threatening posture, are known for many species of Colubrid snakes (Marques et al. 2001a), however, there are controversial data in studies showing their effectiveness against natural predators (Guimarães & Sawaya 2012, Valkonen & Mappes 2012).

Artificial models have been used in several studies as a tool to test anti-predation responses, for example fishes (Kelley & Magurran 2003), amphibians (Saporito et al. 2007), birds (Gottfried 1979, Gottfried et al. 1985), lizards (Leal & Rodriguez-Robles 1997), mammals (Barros et al. 2002, Vignieri et al. 2010) and particularly snakes (Brodie & Janzen 1995, Wilgers & Horne 2007, Niskanen & Mappes 2005, Guimarães & Sawaya 2011). Thus, using artificial snakes for studies with mimetic behavior and natural enemies' response seems to be an interesting, valid and effective method.

Therefore, the aim of this study was to verify, through an experiment using artificial snakes, if snakes with triangular head are less susceptible to attack by predators, and if predatory attack is targeted at the snake's head. Guimarães & Sawaya (2011) conducted a similar experiment which had negative results related to the effectiveness of having a triangular head. However, these results were contested by Valkonen & Mappes (2012). Our hypotheses are: (1) snakes with triangular head suffer less predation pressure; (2) as the snake's head is an important target, the head has higher attack rate (Langkilde et al. 2004, Niskanen & Mappes 2005); and (3) snakes with triangular head, supposedly to intimidate visual predators (Tozetti et al. 2009), suffer higher attack rate on the head than on other parts of the body, setting up more accurate attacks.

Materials and Methods

This study was performed at Research and Nature Conservation Center Pró-Mata (CPCN Pró-Mata) located in Araucaria Plateau, at approximately 900 m elevation (29° 27' S and 50° 08' W), in Rio Grande do Sul State, Brazil. The experiment was conducted in an area characterized by a mosaic of grasslands and Araucaria forest in different successional stages.

The experiment was conducted on January 2011 and consisted of 80 artificial snake models made of non-toxic modeling plasticine, 40 triangular head and 40 round head. Artificial models measured about 20 cm long and 1 cm wide, grayish color (Figure 1a, b). The coloration and size was similar to the color pattern of species commonly found in the region (e.g. *Liophis poecilogyrus* or juveniles of *Philodryas patagoniensis*, Di-Bernardo 1998). Snake models were disposed on a margin of a country road every 20 m following a sequence of 10 round models and 10 triangular models. There were four sections of 400 m by 500 m apart to ensure both autonomy between samples and spatial homogeneity of the surrounding vegetation. The models were exposed for 17 hours, overnight, and collected the next morning. In field, each model was analyzed for attack presence, number of attacks, part of the model that suffered the attack (head or other parts of the body) and type of attack.

Data analysis was performed in the program Past (Hammer et al. 2001) using Chi-square test ($\alpha = 0.05$) to compare proportion of attacks on triangular and round head snakes models and proportion of attacks in the head and body between the two kinds of snake models.

Results

From the 80 snake models, one of each treatment was excluded from analysis because they were damaged by human activities. A total of 38 (48.71%) models were attacked. A significant higher number of attacks was deferred on round head models (25 attacks) than on triangular head models (13 attacks) ($\chi^2 = 14.40$, df = 1, $p < 0.001$).

The number of attacks differed significantly between the head (12 attacks) and other parts of the body (31 attacks) ($\chi^2 = 89.82$, df = 1, $p \leq 0.001$). Five models were attacked both in the head and other parts of the body. The difference between the part of the model attacked in relation to the shape of the head was significant ($\chi^2 = 12.64$, df = 1, $p \leq 0.001$, Figure 2).

The types of attacks suffered by the artificial snakes were pecking and scratching (Figures 1c-e). Some of the models were broken and lacerated, including some missing tails. However, it was not possible to identify the predators through the attack imprints.

Discussion

Approximately half of artificial snakes were attacked, showing effectiveness of this technique to test the hypotheses of this study. Artificial snakes were successfully used in other studies, for example Wilgers & Horne (2007) investigated predation of artificial snakes in burned environments, Brodie & Janzen (1995) observed avoidance by avian predators of bicolor ringed pattern in snakes and Guimarães & Sawaya (2011) also tested the predation of triangular head shape snakes.

The hypothesis that lower predation rates occur on snakes with triangular heads was corroborated. A different result was found by Guimarães & Sawaya (2011), in whose study the head shape seemed not to confer advantage. These differences between studies may result from the different ecosystems where they were conducted. Head triangulation behavior, recurrently shown in the literature (Tozetti et al. 2009, Marques et al. 2001a), seems to be an effective strategy that results in a higher survival rate. Lower predations rates are also shown in other mimetic systems. For example, mimics of the coral snake *Micrurus nigrocinctus* are often less attacked than non-mimics (Brodie 1993).

Contrary to our prediction, the snake head was not an important target, presenting lower attack rates than other parts of the body in both types of models. Rodrigues (2005) reports predator preference for attacking the snake tails, however this was not evaluated in this study. Although attacks frequency was greater in other parts of the body than head, our experiment may have favored opportunistic animals, which may not tactically attack the head (Brodie 1993, Buasso et al. 2006). At our study site, there are records of several snakes' potential predators, including large and medium-size mammals, such as ocelots (*Leopardus pardalis*), wild cats (*Leopardus tigrinus*) and crab-eating foxes (*Cerdocyon thous*), small mammals (Marques et al. 2001b) and birds of prey (Fontana et al. 2008). Since it was not possible to identify the predators through the marks left, future work using camera traps would be useful to identify if predatory attack being directed to the snake's head is related to a specific type of predator.

Figure 1. Artificial snake models in field: a) round head, b) triangular head. Examples of attacks: c) scratches in the head, d) scratches in other part of the body, e) pecking in the head.

Figura 1. Modelos artificiais de serpente em campo: a) cabeça arredondada, b) cabeça triangular. Exemplos de ataques: c) arranhões na cabeça, d) arranhões no corpo, e) bicadas na cabeça.

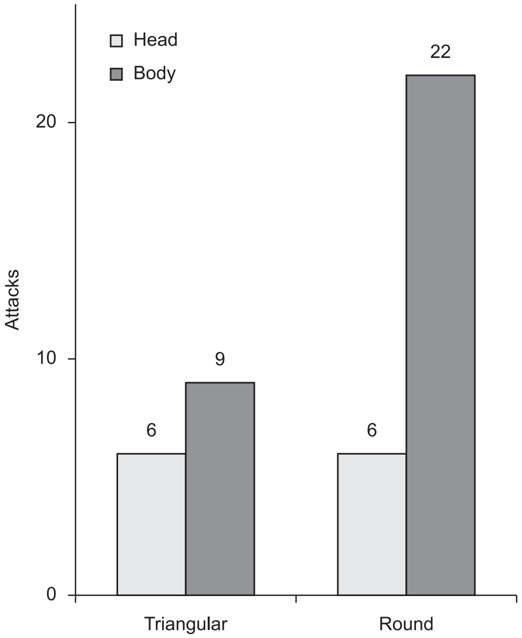

Figure 2. Number of artificial snake models attacked of triangular and round head divided in head and other parts of the body ($p \leq 0.001$).

Figura 2. Número de modelos artificiais de serpentes atacadas de cabeça triangular e arredondada divididos em cabeça e corpo ($p \leq 0.001$).

The use of plasticine models was in general effective to test our hypotheses, but results may be interpreted with caution to avoid eventual bias. First, the use of artificial snake models may have favored diurnal predators, which locate their prey visually, as opposed to nocturnal predators, which use their olfactory system to locate prey. Moreover, the fact that artificial models are static may contribute to high incidences of attacks since there was no defensive behavior to inhibit them. Also aerial predators identify their prey visually by motion, so stationary artificial snakes would decrease detection by these predators (Wilgers & Horne 2007), reducing the effect of such bias.

Despite of the importance of a set of defensive mechanisms or behaviors (Guimarães & Sawaya 2011), triangular shape of the head seems to be useful to prevent predation. Our data showed that snakes with triangular head are less frequent targets than the ones with round head. Then, such mimic behavior could avoid predator attacks. The results of this study using artificial snake models are expected to be used as basis for future studies about predator-prey interactions.

Acknowledgements

André Victor Lucci Freitas and Fernando Gertum Becker for early suggestions to the manuscript. Two anonymous reviewers made valuable suggestions on the manuscript. PPG-Ecologia UFRGS for funding the field work. CPCN Pró-Mata for providing permission to access the study site. This work was developed during the 2011 Ecology Field Course by PPG-Ecologia UFRGS.

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Received 30/11/2011
Revised 28/07/2012
Accepted 13/08/2012

Escarabeíneos (Coleoptera: Scarabaeidae: Scarabaeinae) de uma área de campo nativo no bioma Pampa, Rio Grande do Sul, Brasil

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SILVA, P.G., AUDINO, L.D., NOGUEIRA, J.M., MORAES, L.P. & VAZ-DE-MELLO, F.Z. **Dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) from native grassland in Pampa biome, Rio Grande do Sul, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn01612032012

Abstract: This work presents a survey of Scarabaeinae species from a natural grassland area in Bagé, state of Rio Grande do Sul, Brazil. Samplings were carried out with flight intercept traps and pitfall traps baited with human feces, rotten banana and rotten meat, from December 2005 to November 2006. A total of 4,573 individuals, belonging to 14 genera and 30 species were collected. *Onthophagus* aff. *hirculus* Mannerheim, 1829, *Canthon podagricus* Harold, 1868, *Ontherus sulcator* (Fabricius, 1775) and *Canthidium moestum* Harold, 1867 were the most abundant species. Most of the captured assemblage is composed by species coprophagous and generalists preferably necrophagous. Few species were strictly necrophagous and none was classified as saprophagous. The rollers and tunnelers were represented by similar numbers of species.
Keywords: *Scarabaeoidea, dung beetle, species survey, 'Campos Sulinos', southern Brazil.*

SILVA, P.G., AUDINO, L.D., NOGUEIRA, J.M., MORAES, L.P. & VAZ-DE-MELLO, F.Z. **Escarabeíneos (Coleoptera: Scarabaeidae: Scarabaeinae) de uma área de campo nativo no bioma Pampa, Rio Grande do Sul, Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn01612032012

Resumo: Este trabalho apresenta um levantamento das espécies de Scarabaeinae de uma área de campo nativo no município de Bagé, estado do Rio Grande do Sul, Brasil. As coletas foram realizadas com armadilhas de interceptação de voo e armadilhas de queda iscadas com fezes humanas, banana em decomposição e carne apodrecida, entre os meses de dezembro de 2005 e novembro de 2006. Foram capturados 4.573 indivíduos pertencentes a 14 gêneros e 30 espécies. *Onthophagus* aff. *hirculus* Mannerheim, 1829, *Canthon podagricus* Harold, 1868, *Ontherus sulcator* (Fabricius, 1775) e *Canthidium moestum* Harold, 1867 foram as espécies mais abundantes. A maior parte da assembleia capturada é constituída por espécies coprófagas e generalistas preferencialmente necrófagas. Poucas espécies foram estritamente necrófagas e nenhuma foi classificada como saprófaga. As roladoras e as escavadoras foram representadas por números similares de espécies.
Palavras-chave: *Scarabaeoidea, rola-bosta, levantamento de espécies, Campos Sulinos, sul do Brasil.*

Introdução

Os ecossistemas campestres do extremo sul do Brasil que pertencem ao bioma Pampa estão ali presentes há mais de 12 mil anos (Behling et al. 2004, 2005), cobrindo atualmente cerca de 2% do território nacional e 63% do Rio Grande do Sul, único estado brasileiro onde esse tipo de formação vegetal ocorre (Instituto... 2009). Possui uma riqueza única, apresentando altos índices de diversidade e endemismo (Brasil 2002, Behling et al. 2009, Bencke 2009). Contudo, apenas pequena parte de sua diversidade biológica é conhecida cientificamente (Nabinger et al. 2006), e esta se encontra ameaçada devido às intensas transformações deste bioma (Pillar et al. 2006, Roesch et al. 2009), que são geradas principalmente por atividades econômicas agropecuárias e silviculturais, as quais têm crescido e se expandido em área sobre os campos nativos a ritmos cada vez maiores (Pillar et al. 2006, Behling et al. 2009). As gramíneas e espécies vegetais herbáceas que constituem este bioma apresentam grande valor forrageiro, e por este motivo, a pecuária tem sido a principal atividade econômica da região (Boldrini 1997, 2002, Gonçalves 1999, Bilenca & Miñarro 2004, Carvalho et al. 2006, Overbeck et al. 2009).

Sendo assim, a conservação do Pampa é uma necessidade, já que as formas vegetais, animais e os processos biológicos desse sistema devem ser mantidos para as gerações futuras e para o funcionamento dos processos ecossistêmicos deste bioma (Pillar et al. 2006, Nabinger et al. 2009). O conhecimento de sua biodiversidade é, portanto, fundamental para o estabelecimento de políticas conservacionistas e estratégias de manejo sustentável, além de contribuir com novas informações acerca da diversidade de organismos ali existente (Pillar et al. 2006, Bencke 2009, Boldrini 2009).

Os representantes de Scarabaeinae (Coleoptera: Scarabaeidae) são popularmente conhecidos no Brasil como 'rola-bostas'. Cerca de 7.000 espécies deste grupo já foram descritas em todo o mundo (Schoolmeesters et al. 2010) com maior concentração de diversidade em florestas e savanas tropicais. No Brasil ocorrem mais de 700 espécies, sendo que quase um terço parece ser endêmica (Vaz-de-Mello 2000). No entanto, muitos estados brasileiros, incluindo o Rio Grande do Sul, não possuem sua fauna de 'rola-bostas' totalmente conhecida, e a realização de novos estudos pode incrementar o número de espécies, além de contribuir com o conhecimento da real distribuição destas ao longo do território nacional.

Os besouros deste grupo são detritívoros e se alimentam principalmente de fezes, carcaças e frutos podres, auxiliando na remoção desses materiais da superfície do solo e reingresso no ciclo de nutrientes (Halffter & Matthews 1966, Hanski & Cambefort 1991). Estes insetos exibem distintos comportamentos alimentares e nidificantes, possuem alta diversidade na região Neotropical, desempenham inúmeras funções benéficas ao ecossistema e são sensíveis às mudanças ambientais (Halffter & Favila 1993, McGeoch et al. 2002, Nichols et al. 2007, 2008, Gardner et al. 2008). Assim, cada vez mais têm sido utilizados tanto como indicadores ambientais quanto no controle biológico de parasitos coprobiontes através da desestruturação e enterro de massas fecais de grandes herbívoros em agroecossistemas pecuários (Waterhouse 1974, Flechtmann & Rodrigues 1995, Koller et al. 2007).

O objetivo deste estudo foi realizar um inventário da fauna de Scarabaeinae em uma área de campo nativo característico do bioma Pampa na porção sul do Rio Grande do Sul, e verificar a preferência alimentar das espécies, visando contribuir com o conhecimento deste grupo nesta região do estado.

Material e Métodos

O estudo foi desenvolvido na Empresa Brasileira de Pesquisa Agropecuária (Embrapa), unidade Embrapa Pecuária Sul, localizada no município de Bagé, sul do Rio Grande do Sul, entre dezembro de 2005 e novembro de 2006.

A metade sul do estado se caracteriza por apresentar extensas áreas de campos naturais com leves ondulações de terreno (entre 60 e 350 m de altitude) utilizados principalmente para a prática agropecuária (Bilenca & Miñarro 2004, Carvalho et al. 2006). Bagé apresenta clima subtropical semiúmido, temperatura média anual em torno de 18 °C, sendo a média do mês mais quente de 24 °C e a do mês mais frio de 12 °C (Instituto... 2008), com frequentes formações de geadas no inverno. A umidade relativa do ar média anual é de 80%, os índices pluviométricos médios são de 1.200 mm anuais, com variações ao longo dos anos (Pimentel 1940, Bilenca & Miñarro 2004, Carvalho et al. 2006).

Uma área de campo (31° 21' 10" S e 54° 00' 49" W) com aproximadamente 30 ha foi escolhida para a instalação das armadilhas e coleta dos insetos. A área é constituída de vegetação campestre nativa, onde as gramíneas (Poaceae) são as mais abundantes e o entorno formado por plantios de espécies forrageiras (*Bromus auleticus* Trinius e *Lolium multiflorum* Linnaeus), áreas de vegetação mais densa (*Eupatorium* sp., *Eryngium* spp. e *Saccharum* sp.), plantio de *Eucalyptus* sp. (cerca de um hectare), além de algumas pequenas áreas de capim-annoni (*Eragrostis plana* Ness), uma espécie exótica invasora.

Na área foram instaladas armadilhas de queda (*pitfall*) e de interceptação de voo para a coleta dos besouros. As armadilhas de queda foram montadas com a utilização de potes plásticos de 500 mL (12 cm de altura por 10 cm de diâmetro) enterrados de modo que sua borda ficasse ao nível do solo. Sobre os potes maiores foram acomodados potes plásticos de dimensões menores (6 cm de altura por 5 cm de diâmetro) para colocação das iscas, transpassados na borda superior por arame fino, que foi dobrado nas pontas e enterrado no solo de modo que deixasse o pote menor ao longo do diâmetro do pote maior. Azulejos de cerâmica (20 × 20 cm) amparados por pequenas estacas de madeira foram utilizados para a proteção das armadilhas.

Foram utilizadas 17 armadilhas de queda iscadas com fezes humanas (10 armadilhas), banana fermentada (quatro armadilhas) e fígado de frango apodrecido (três armadilhas), distribuídas para os lados de um transecto, de modo que as armadilhas iscadas com fígado ficassem no início e fim, as com fezes humanas na porção central e as com banana apodrecida na parte intermediária entre as com fezes e fígado. O maior número de armadilhas com fezes se deve ao hábito alimentar preferencial das espécies de Scarabaeinae pela coprofagia, principalmente em áreas campestres, além de ser a principal isca para esta fauna (Halffter & Matthews 1966).

As armadilhas de interceptação de voo foram montadas esticando-se um tecido resistente de malha fina (1,2 m de altura por 2 m de comprimento) em estacas de madeira com 1,7 m de altura presas por cordas em pequenas estacas enterradas no solo. O tecido foi amarrado nas estacas de modo que deixasse uma altura de 10 cm entre a parte inferior deste e o solo, onde foram acomodadas bandejas brancas para a coleta dos insetos que colidissem com o tecido. Foram utilizadas duas armadilhas de interceptação de voo, instaladas 100 m distantes da área com as armadilhas de queda e entre si.

Foi utilizada uma solução conservante (água, detergente, formalina a 10% e sal) para a coleta e preservação dos besouros, sendo depositado cerca de 300 mL em cada *pitfall* e seis litros em cada bandeja. As coletas foram realizadas quinzenalmente e a solução e iscas renovadas semanalmente. Os besouros foram triados, pré-processados e pré-identificados (em nível de gênero) no Laboratório de Entomologia da Embrapa Pecuária Sul, com a utilização de chave para gêneros de Scarabaeinae (Vaz-de-Mello et al. 2011). A identificação definitiva foi realizada no Laboratório de Ecologia de Invertebrados do Setor de Ecologia da Universidade Federal de Lavras, e o material coletado encontra-se depositado nas coleções dessa instituição e da Universidade Federal de Mato Grosso.

O hábito alimentar das espécies de Scarabaeinae foi estabelecido de acordo com a incidência de queda de no mínimo 80% nas armadilhas iscadas com diferentes recursos (Almeida & Louzada 2009), e comparados com dados da literatura (Martínez 1959, Halffter & Matthews 1966). Dessa forma, foi possível determinar a guilda trófica das espécies, classificando-as em: coprófagas (maior ocorrência na armadilha iscada com fezes humanas), necrófagas (maior ocorrência na armadilha iscada com fígado de frango apodrecido), saprófagas (maior ocorrência na armadilha iscada com banana fermentada) e generalistas (abundância de indivíduos semelhante em mais de um tipo de armadilha iscada) (Halffter & Favila 1993, Halffter & Arellano 2002). Devido ao número desigual de armadilhas de cada uma das iscas utilizadas, a caracterização da guilda trófica foi realizada com dados obtidos por apenas três armadilhas de cada uma das iscas selecionadas aleatoriamente. Foram excluídos desta análise os *singletons* e *doubletons*, pois não tiveram número suficiente de indivíduos para a inferência alimentar.

As espécies foram também classificadas de acordo com o modo que utilizam o recurso alimentar para a nidificação (guilda funcional): endocoprídeas (residentes - alimentam-se e nidificam no interior do recurso), paracoprídeas (escavadoras - escavam galerias no solo ao lado ou logo abaixo do recurso) e telecoprídeas (roladoras - retiram pequenas porções do recurso que são transformadas em esferas e roladas por diferentes distâncias até serem enterrados no solo) (Halffter & Matthews 1966, Hanski & Cambefort 1991).

Como forma de aferir estimativas do número de espécies esperado para a área de estudo, foram calculados os valores de cinco estimadores de riqueza não-paramétricos (Jackknife 1, Jackknife 2, Chao 1, Chao 2 e Bootstrap). Para avaliar o esforço amostral e comparar a riqueza de espécies obtida entre os diferentes métodos de coleta, foi construída uma curva de acumulação de espécies, com intervalo de confiança de ±95%, onde se relacionou o número de coletas realizadas com a riqueza observada média (Sobs – Mao Tau), obtida por meio de 500 randomizações. Estas análises foram realizadas com a utilização do software EstimateS 7.5.2 (Colwell 2005).

Resultados

Foram coletados 4.573 indivíduos de Scarabaeinae pertencentes a 14 gêneros e 30 espécies (Tabela 1). As tribos que estiveram representadas foram: Deltochilini (15 espécies – 50%), Coprini (sete espécies – 23,3%), Phanaeini (três espécies – 10%), Ateuchini (duas espécies – 6,7%), Onthophagini (duas espécies – 6,7%) e Oniticellini (uma espécie – 3,3%).

As espécies mais abundantes foram *Onthophagus* aff. *hirculus* Mannerheim, 1829 (62%), *Canthon podagricus* Harold, 1868 (10,4%), *Ontherus sulcator* (Fabricius, 1775) (8,8%) e *Canthidium moestum* Harold, 1867 (4%), que juntas representaram mais de 85% dos indivíduos coletados, sendo espécies comumente encontradas na região.

De acordo com os estimadores de riqueza calculados, a riqueza observada está próxima das estimadas, mas mesmo assim sugere que com a continuidade do estudo, provavelmente novos registros ainda seriam encontrados. O mínimo estimado foi de aproximadamente 31 (Chao 1) e o máximo em torno de 35 espécies (Jackknife 2), sendo registrado entre 86 e 97% da riqueza de Scarabaeinae esperada para a área estudada (Tabela 2).

Embora nenhuma das curvas tenha atingido a assíntota, é possível observar através do gráfico de acumulação de espécies, que o esforço amostral foi satisfatório em todas as metodologias de coleta utilizadas, já que as curvas se aproximaram da estabilização (Figura 1). A maior riqueza foi obtida através das armadilhas de queda iscadas com fezes humanas e de interceptação de voo, que não apresentaram diferenças significativas em relação ao número de espécies capturadas, de acordo com o intervalo de confiança. Estes dois métodos de coleta, contudo, diferiram das armadilhas de queda iscadas com carne apodrecida e banana, que foram responsáveis pela captura de um menor número de espécies (Figura 1).

Nove espécies (30%) foram classificadas como coprófagas. Apenas duas foram consideradas necrófagas e nenhuma como saprófaga (Tabela 1). As demais espécies (10), excetuando-se *singletons* e *doubletons*, e também *Uroxys dilaticollis* (Blanchard, 1845), que teve apenas um indivíduo coletado nas armadilhas de queda, foram caracterizadas como generalistas, mas tiveram seus hábitos preferenciais destacados. Oito espécies não puderam ser enquadradas em nenhuma das categorias alimentares, seguindo o critério deste estudo, pela baixa amostragem de indivíduos, sendo três delas *singletons* e cinco *doubletons*. Uma espécie ocorreu somente na armadilha de interceptação de voo (Tabela 1).

Foram capturadas 15 espécies telecoprídeas (também chamadas de roladoras), 14 paracoprídeas (escavadoras) e somente uma espécie endocoprídea (residente). As espécies roladoras, unicamente de Deltochilini, representaram 50% das espécies capturadas; a espécie residente foi representada por Oniticellini (3,33%) e as escavadoras (46,7%) pelas demais tribos registradas neste estudo (Tabela 1).

Onthophagus aff. *hirculus* foi a mais abundante nas armadilhas de interceptação de voo, assim como nas armadilhas de queda iscadas com fezes humanas. *Ontherus sulcator* também apresentou elevada abundância nestes dois tipos de armadilhas. As espécies que foram capturadas em maior número na armadilha de interceptação de voo do que nas armadilhas de queda iscadas foram *A. robustus* (79,1%), *Canthon bispinus* (Germar, 1824) (50,6%) e *U. dilaticollis* (75%) (Tabela 1).

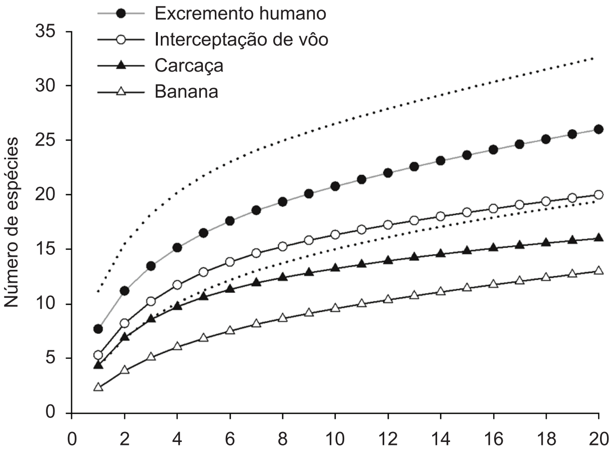

Figura 1. Curva de acumulação de espécies de Scarabaeinae (linhas pontilhadas: IC ± 95%) capturadas através de armadilhas de queda iscadas e armadilhas de interceptação de voo em campo nativo de Bagé, Rio Grande do Sul, Brasil, entre dezembro de 2005 e novembro de 2006.

Figure 1. Species accumulation curves of Scarabaeinae (dotted lines: CI ± 95%) captured by baited pitfall traps and flight interception traps in native grassland in Bagé, Rio Grande do Sul, Brazil, between December, 2005 and November, 2006.

Tabela 1. Espécies de Scarabaeinae coletadas com armadilhas de queda e de interceptação de voo em campo natural em Bagé, Rio Grande do Sul, Brasil, entre dezembro de 2005 e novembro de 2006.

Table 1. Species of Scarabaeinae collected through pitfall traps and flight interception traps in natural grassland in Bagé, Rio Grande do Sul, Brazil, between December, 2005 and November, 2006.

Tribo/espécies	**Armadilhas**				**Total**	**Guilda funcional**	**Guilda trófica**
	EX	**CA**	**BA**	**IV**			
ATEUCHINI							
Ateuchus robustus (Harold, 1868)	4	0	1	19	24	P	C
Uroxys dilaticollis (Blanchard, 1845)	1	0	0	3	4	P	NI
COPRINI							
Canthidium breve (Germar, 1824)	12	0	0	3	15	P	C
C. moestum (Harold, 1867)	119	30	26	11	186	P	G (C*, N, S)
Canthidium sp. 1	14	0	0	3	17	P	C
Canthidium sp. 2	1	3	0	1	5	P	G (C, N*)
Canthidium sp. 3	1	0	0	1	2	P	NI
Dichotomius nisus (Olivier, 1789)	2	0	0	0	2	P	NI
Ontherus sulcator (Fabricius, 1775)	375	0	3	25	403	P	C
DELTOCHILINI							
Canthon bispinus (Germar, 1824)	12	19	7	39	77	T	G (C, N*, S)
C. chalybaeus (Blanchard, 1845)	22	23	7	15	67	T	G (C, N*, S)
C. coeruleicollis (Blanchard, 1845)	1	0	0	1	2	T	NI
C. curvipes (Harold, 1868)	0	0	0	1	1	T	NI
C. aff. *heyrovskyi* (Balthasar, 1939)	2	0	0	0	2	T	NI
C. lividus (Blanchard, 1845)	47	35	15	8	105	T	G (C*, N, S)
C. mutabilis (Lucas, 1857)	1	10	2	10	23	T	G (C, N*, S)
C. ornatus bipunctatus (Burmeister, 1873)	137	2	0	10	149	T	C
C. podagricus (Harold, 1868)	68	172	93	144	477	T	G (C, N*, S)
C. rutilans (Castelnau, 1840)	0	2	2	0	4	T	G
C. seminitens (Harold, 1868)	0	4	0	0	4	T	N
Deltochilum elevatum (Castelnau, 1840)	2	3	1	0	6	T	G (C, N*, S)
D. sculpturatum (Felsche, 1907)	15	33	5	17	70	T	G (C, N*, S)
Malagoniella magnifica (Balthasar, 1939)	1	0	0	0	1	T	NI
Vulcanocanthon seminulus (Harold, 1867)	4	0	0	1	5	T	C
ONITICELLINI							
Eurysternus aeneus (Génier, 2009)	12	1	0	0	13	E	C
ONTHOPHAGINI							
Onthophagus aff. *hirculus* (Mannerheim, 1829)	2528	13	2	293	2836	P	C
O. aff. *tristis* (Harold, 1873)	2	0	0	0	2	P	NI
PHANAEINI							
Coprophanaeus milon (Blanchard, 1845)	0	17	0	2	19	P	N
Gromphas lacordairei (Brullé, 1834)	1	0	0	0	1	P	NI
Sulcophanaeus menelas (Castelnau, 1840)	49	1	1	0	51	P	C
Total de indivíduos	3433	368	165	607	4573		
Total de espécies	26	16	13	20	30		

EX: excremento humano; CA: carne apodrecida; BA: banana fermentada; IV: interceptação de voo; E: endocoprídea; P: paracoprídea; T: telecoprídea; C: coprófaga; N: necrófaga; S: saprófaga; G: generalista; NI: número insuficiente; (*) indica preferência alimentar da espécie com guilda trófica generalista (C* = preferencialmente coprófago; N* = preferencialmente necrófago; S* = preferencialmente saprófago). (EX: human excrement. CA: rotten meat; BA: rotten banana; IV flight interception trap; E: dweller; P: tunneler; T: roller; C: coprophagous; N: necrophagous; S: saprophagous; G: generalist; NI: insufficient number of individuals; (*) indicate the trophic preference of species with generalist trophic guild (C* = preferably coprophagous; N* = preferably necrophagous; S* = preferably saprophagous)).

Discussão

Conforme os estimadores de riqueza, a riqueza observada e estimada é semelhante, demonstrando que o esforço amostral foi satisfatório para a captura da assembleia de Scarabaeinae da área de campo nativo estudado. Contudo, devido à escassez de conhecimento para a maioria dos grupos de animais no Pampa (Bencke 2009), ressalta-se a necessidade de mais inventários de Scarabaeinae focados em outras localidades deste bioma e em seus ecossistemas associados por causa da rápida conversão de seus habitats nativos e modificação de sua biodiversidade, uma vez que os dados aqui apresentados restringem-se a somente uma área. Possivelmente, a realização de novos estudos poderá contribuir com novos registros e com o conhecimento da distribuição destas espécies no território brasileiro e no estado.

Tabela 2. Estimadores de riqueza (e desvio-padrão) calculados para estimar o número de espécies de Scarabaeinae em campo nativo de Bagé, Rio Grande do Sul, Brasil, através de armadilhas de queda iscadas e de interceptação de voo entre dezembro de 2005 e novembro de 2006.

Table 2. Richness estimators (and standard deviation) calculated to estimate the number of species of Scarabaeinae in native grassland in Bagé, Rio Grande do Sul, Brazil, using baited pitfall traps and flight interception traps between December, 2005 and November, 2006.

Estimadores	Número de espécies ± desvio padrão
Bootstrap	32,48 ± 2,38
Chao 1	30,9 ± 5,95
Chao 2	32,5 ± 6,53
Jackknife 1	34,75 ± 2,4
Jackknife 2	34,99 ± 3,78

Apesar de a maior abundância ter sido observada nas armadilhas iscadas com excremento humano, as armadilhas de interceptação de voo e de excremento não diferiram em relação ao número de espécies coletadas, e apresentaram uma riqueza maior quando comparadas às armadilhas iscadas com carne apodrecida e banana fermentada. Contudo, o número de indivíduos obtidos através das armadilhas de interceptação de voo foi baixo, semelhante a estas duas últimas armadilhas. Armadilhas de interceptação de voo têm sido empregadas para a captura de espécies de Scarabaeinae não atraídas às iscas utilizadas, sendo uma importante ferramenta para a mais completa amostragem da fauna de escarabeíneos presente no ecossistema (Davis 2000, Larsen & Forsyth 2005, Costa et al. 2009). Além de excrementos de mamíferos, outros tipos de recursos (como carne e fruta apodrecidas) são também utilizados para o conhecimento dos hábitos alimentares das espécies de Scarabaeinae, uma vez que muitas espécies podem ser atraídas por um grande número de recursos (Halffter & Matthews 1966, Larsen & Forsyth 2005). Contudo, a maior riqueza observada em armadilhas de queda iscadas com fezes humanas se deve ao fato de que Scarabaeinae, devido a processos evolutivos, possui maior número de espécies coprófagas que utilizam excrementos de mamíferos como alimento de adultos e larvas (Halffter & Matthews 1966, Hanski & Cambefort 1991). Na região Neotropical, excremento humano é um dos mais importantes atrativos para a efetiva captura das espécies de Scarabaeinae, tanto em florestas quanto em pastagens (Halffter & Matthews 1966, Falqueto et al. 2005, Larsen et al. 2006, Filgueiras et al. 2009).

O número de espécies especialistas coprófagas e necrófagas (11) é superior ao das generalistas (10). Estes resultados diferem da hipótese de que as assembleias neotropicais de Scarabaeinae possuem proporção maior de espécies generalistas em relação às especialistas (Halffter & Matthews 1966, Halffter 1991), e são semelhantes aos encontrados por Almeida & Louzada (2009) para a fauna de Scarabaeinae de diferentes fitofisionomias em Carrancas, Minas Gerais. No local amostrado houve uma distribuição similar entre o número de espécies especialistas e generalistas conforme as análises utilizadas.

Embora similar, o número de espécies telecoprídeas (também chamadas de roladoras), foi superior ao das paracoprídeas (ou escavadoras). Estes resultados diferem do padrão apresentado pela fauna de Scarabaeinae coletada em áreas abertas em distintas localidades do Brasil (por exemplo, Flechtmann et al. 1995, Aidar et al. 2000, Koller et al. 1999, 2007, Marchiori 2000, 2003, Marchiori et al. 2003), onde frequentemente há um número maior de espécies paracoprídeas em relação às demais guildas, como encontrado por Halffter et al. (1992) e Louzada & Lopes (1996) para áreas de floresta Neotropical. Este fato possivelmente se deve ao maior número de espécies pertencentes à Deltochilini que ocupam áreas abertas nesta região, onde as espécies escavadoras parecem mais restritas a habitats florestais.

Ao serem comparados os dados aqui obtidos sobre a preferência trófica das espécies com aqueles da literatura, *Ateuchus robustus* (Harold, 1868), *Canthidium breve* (Germar, 1824) e *Canthon ornatus bipunctatus* (Burmeister, 1873) possuem hábito alimentar estritamente coprófago, sendo também encontradas em excrementos de grandes mamíferos, onde a segunda é mais frequente nas primeiras horas da manhã e a terceira pode ser atraída por cadáveres de animais, especialmente durante os primeiros estágios de decomposição (Martínez 1959). *Canthidium* sp. 1 possui hábito alimentar coprófago, ocorrendo somente em armadilhas com fezes humanas e nas de interceptação de voo. *Eurysternus aeneus* (Génier, 2009) apresenta ampla distribuição em áreas florestadas no sul do Brasil, sul do Paraguai e nordeste da Argentina (Génier 2009), e frequentemente é registrada em maior número em armadilhas iscadas com fezes. *Onthophagus* aff. *hirculus* possui preferência pela coprofagia, mas foi também atraída por carne apodrecida e banana, embora em números muito reduzidos. *Vulcanocanthon seminulus* (Harold, 1867) é coletada na região principalmente atraída por excremento humano e de bovinos. *Ontherus sulcator* é uma espécie comum de ampla distribuição pela região Neotropical (Martínez 1959, Génier 1996) e *Sulcophanaeus menelas* (Castelnau, 1840) é frequente no centro-sul do Brasil (Edmonds 2000); ambas são atraídas por excrementos de mamíferos (Martínez 1959). *Canthon seminitens* (Harold, 1868) e *Coprophanaeus milon* (Blanchard, 1845) são frequentemente encontradas em cadáveres de pequenos animais (Martínez 1959), corroborando suas preferências alimentares à necrofagia.

Embora não classificadas quanto à preferência alimentar devido ao número insuficiente de indivíduos, *Gromphas lacordairei* (Brullé, 1834) e *Dichotomius nisus* (Olivier, 1789) possuem hábito alimentar coprófago, podendo, esta última, ser atraída por luz artificial (Martínez 1959). Ambas são espécies comuns em pastagens (Louzada et al. 1996, Morelli et al. 2002). *Malagoniella magnifica* (Balthasar, 1939) parece ser uma espécie coprófaga, assim como *Canthon* aff. *heyrovskyi* (Balthasar, 1939) e *Onthophagus* aff. *tristis* (Harold, 1873), que foram capturadas em armadilhas de queda iscadas com excremento humano. Contudo, estas últimas ainda necessitam de estudos complementares para a determinação de sua preferência alimentar. *Canthidium* sp. 3 e *Canthon coeruleicollis* (Blanchard, 1845) foram coletadas em número igual em *pitfall* com isca de fezes humanas e em redes de interceptação de voo, sendo a segunda também encontrada em carcaça de peixe (Martínez 1959). Destaca-se que esta última espécie foi citada para o Brasil por Martínez (1959), mas sem especificação da região, e por Biezanko et al. (1949) para o município de Pelotas, no sul do Rio Grande do Sul. Todos os demais registros mencionaram a espécie apenas para florestas de galeria na Argentina e Uruguai (Martínez et al. 1964, Halffter & Matthews 1966). Portanto, *C. coeruleicollis* foi registrada novamente para o Rio Grande do Sul após mais de 60 anos em área de campo. *Canthon curvipes* (Harold, 1868) foi capturada somente na armadilha de interceptação de voo, embora seja encontrada em excrementos de grandes herbívoros e fezes humanas, bem como em cadáveres de peixes e de outros pequenos animais (Luederwaldt 1911, Martínez 1959, Halffter & Matthews 1966). Silva et al. (2008) coletaram maior número desta espécie, atraída por carne apodrecida, em área de mata nativa no mesmo município, demonstrando que esta é possivelmente mais associada a estes tipos de ambientes.

Canthidium moestum e *Canthon lividus* (Blanchard, 1845), tiveram maior ocorrência em armadilhas iscadas com fezes humanas, mas possuem hábito alimentar generalista (Martínez 1959, Halffter & Matthews 1966); foram aqui classificadas como generalistas preferencialmente coprófagas. *Canthidium* sp. 2, *Canthon bispinus* (Germar, 1824), *C. chalybaeus* Blanchard, 1845, *C. mutabilis* (Lucas, 1857), *C. podagricus*, *Deltochilum elevatum* (Castelnau, 1840) e *D. sculpturatum* (Felsche, 1907), ocorreram em maior número nas armadilhas iscadas com carne apodrecida, sendo classificadas como generalistas preferencialmente necrófagas. *Canthon bispinus* já foi encontrada utilizando tanto excrementos quanto carcaças para produção de suas bolas-ninho (Halffter & Matthews 1966). *Canthon chalybaeus*, além de carcaças e excrementos frescos, também foi observada consumindo frutos de palmeiras (butiá) (Luederwaldt 1911; Martínez 1959, Halffter & Matthews 1966). *Canthon podagricus* e *C. mutabilis* são frequentemente registradas em carcaças de animais mortos (Luederwaldt 1911, Martínez 1959, Halffter & Matthews 1966), mas aqui também foram capturadas em armadilhas iscadas com banana fermentada e fezes humanas. *Deltochilum elevatum* e *D. sculpturatum* são espécies de hábito alimentar preferencialmente necrófago (Martínez 1959, Silva et al. 2008, Almeida & Louzada 2009), pois também podem utilizar excrementos (Sáenz & Morelli 1983) e, aparentemente, frutos apodrecidos. *Canthon rutilans* (Castelnau, 1840) é encontrada tanto em excrementos quanto em carcaças (Martínez 1959). Contudo, neste estudo obteve abundância igual em armadilhas iscadas com carne apodrecida e banana, e não ocorreu nas iscadas com excrementos, sendo enquadrada apenas como generalista. Possivelmente o tipo de ambiente pode ter influenciado nestes resultados, pois Silva et al. (2008) coletaram maior número de indivíduos em armadilhas iscadas com carne apodrecida do que em fezes bovinas e com preferência por habitat florestal.

Ateuchus robustus teve baixa ocorrência às iscas utilizadas possivelmente por possuir hábito alimentar específico de excrementos de herbívoros (Martínez 1959). *Canthon bispinus* teve maior abundância em armadilha de interceptação de voo, mas Martínez (1959) afirma que esta espécie possui hábito alimentar necrófago, podendo ser observada nos primeiros estágios de decomposição de carcaças de diferentes animais. Neste estudo, em relação às armadilhas de queda iscadas, esta espécie teve maior ocorrência nas iscadas com fígado apodrecido, mas foi caracterizada como generalista preferencialmente necrófaga; é provável que o tipo de isca não seja o preferencial da espécie. *Uroxys dilaticollis* apresenta um dos nichos menos evidentes dos Scarabaeinae, pois é reportada de ninhos de formigas *Acromyrmex lundi* (Guérin, 1838), caso de mirmecofilia (Martínez 1959, Vaz-de-Mello et al. 1998), e é também frequentemente encontrada associada a excrementos bovinos e equinos.

Onthophagus aff. *hirculus* e *O. sulcator* apresentaram elevada abundância nas armadilhas de fezes e de interceptação de voo, sendo as coprófagas mais abundantes neste estudo. Estas duas espécies, por serem paracoprídeas (escavadoras) e muito comuns na região, devem receber atenção especial devido à importante função que desempenham na remoção de massas fecais da superfície de pastagens e na utilização no controle biológico de dípteros e helmintos parasitos de importância veterinária. De acordo com Doube (1990), os besouros 'rola-bostas' escavadores processam maior quantidade de esterco em comparação com os roladores (telecoprídeos) de mesmo tamanho.

Além do maior número de armadilhas de queda iscadas com fezes humanas utilizado neste estudo, a maior concentração de espécies coprófagas, em relação às necrófagas e saprófagas, é provavelmente fruto das condições encontradas em um ambiente de campo característico do Pampa em relação aos recursos alimentares disponíveis para os escarabeíneos. Neste ambiente, onde a prática pecuária é comum (semelhante à área estudada), existe grande quantidade de esterco de ruminantes (e.g. bovinos, equinos e ovinos), sendo este o recurso alimentar encontrado em maior abundância e com maior frequência, levando à dominância da coprofagia em ambientes campestres (Halffter & Matthews 1966). Carcaças de animais podem estar disponíveis no ambiente de campo, mas não com a mesma disponibilidade do esterco, não possibilitando, desta forma, uma elevada riqueza e abundância de espécies com guilda alimentar do tipo necrófaga.

Nenhuma espécie foi classificada como saprófaga. Isto sugere que frutos em decomposição não são frequentes no ambiente campestre estudado, ao contrário do que acontece em ecossistemas florestais nativos, onde este tipo de recurso pode ser mais abundante. As espécies que foram atraídas por iscas de banana em decomposição, são, em sua maioria, espécies generalistas, que podem utilizar os frutos como um recurso alternativo ao seu alimento preferencial. Isto pode diminuir a competição em alimentos escassos e efêmeros como excrementos e carcaças de pequenos animais e elevar a diversidade do grupo (Halffter & Halffter 2009).

Apesar de ser um importante grupo de insetos responsáveis por várias funções benéficas aos ecossistemas, a fauna de Scarabaeinae ainda é muito pouco estudada no Rio Grande do Sul, e especialmente no bioma Pampa. Estudos futuros direcionados ao conhecimento desta fauna poderão subsidiar dados sobre a biologia e a distribuição das espécies de Scarabaeinae pelo estado e no território brasileiro. Tais informações, como as adquiridas com a realização deste estudo, são fundamentais para embasar qualquer iniciativa de manejo e conservação da biodiversidade e de ecossistemas.

Agradecimentos

Ao pesquisador Marcos Flávio Silva Borba, associado a Embrapa Pecuária Sul, pelo incentivo, apoio e disponibilização de recursos para a realização da pesquisa. Aos professores Júlio Louzada (UFLA) e Rocco Di Mare (UFSM) pela disponibilização de espaço para a execução de parte deste trabalho. Aos revisores pelas valiosas contribuições. Este trabalho contou com auxílios parciais da FAPEMAT (570847/2008 e 447441/2009) e CNPq (151603/2007-3 e 304925/2010-1).

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Recebido em 20/06/2011
Versão reformulada recebida em 25/05/2012
Publicado em 07/08/2012

Transferability and characterization of microsatellite markers in five Bromeliaceae species belonging to the subfamilies Pitcairnoideae and Bromelioideae

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MIRANDA, F.D., GONTIJO, A.B.P.L., SANTILIANO, F.C., FAVORETO, F.C. & SOARES, T.C.B. **Transferability and Characterization of Microsatellite Markers in five Bromeliaceae species belonging to the subfamilies Pitcairnioideae and Bromelioideae**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?short-communication+bn02812032012

Abstract: Microsatellite markers previously developed for *Pitcairnia albiflos* Herb. and *Pitcairnia geysksii* L.B.Sm. were used in cross-amplification tests of five other Bromeliaceae species. Ten (76.9%) out of the 13 evaluated pair of primers had positive results for some of the species tested. The number of polymorphic alleles ranged between two and four in most species. H_o values ranged between zero, in *Pitcairnia flammea* Lindl. (PaA05), *Aechmea ramosa* Mart ex Schult *&* Schult and *Billbergia horrida* Regel (PaC05), and one in *Billbergia euphemiae* E. Morren (PaA05, PaA10, PaC05 and PaD07). This study showed that microsatellite markers developed for *P. albiflos* and *P. geysksii* effectively amplified the DNA samples of *Pitcairnia flammea*, *Aechmea nudicaulis*(L.) Griseb., *Aechmea ramosa*, *Billbergia horrida* and *Billbergia euphemiae*, validating the transferability of these markers to species of the *Pitcairnioideae* and *Bromelioideae* subfamilies.

Keywords: *cross-amplification, SSR, genetic diversity, bromeliads, conservation.*

MIRANDA, F.D., GONTIJO, A.B.P.L., SANTILIANO, F.C., FAVORETO, F.C. & SOARES, T.C.B. **Transferibilidade e caracterização de marcadores microssatélites em cinco espécies de Bromeliaceae pertencentes às subfamílias Pitcairnioideae e Bromelioideae**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?short-communication+bn02812032012

Resumo: Marcadores microssatélites originalmente desenvolvidos para *Pitcairnia albiflos* Herb. e *Pitcairnia geysksii* L.B.Sm. foram testados para amplificação heteróloga do genoma de cinco outras espécies de Bromeliacea. Dos treze pares de *primers* avaliados, dez (76,9%) geraram resultados positivos para algumas das espécies em estudo. O número de alelos polimórficos por loco variou entre dois e quatro para a maioria das espécies. Os valores de H_O variaram entre zero em *Pitcairnia flammea* Lindl. (PaA05), *Aechmea ramosa* Mart ex Schult *&* Schult e *Billbergia horrida* Regel (PaC05) e um para *Billbergia euphemiae* E. Morren (PaA05, PaA10, PaC05 e PaD07). Este estudo demonstrou que marcadores microssatélites desenvolvidos para *P. albiflos* e *P. geysksii* mostraram-se eficientes para amplificação heteróloga de amostras de DNA de *Pitcairnia flammea, Aechmea nudicaulis*(L.)Griseb.*, Aechmea ramosa, Billbergia horrida e Billbergia euphemiae*, validando a transferibilidade destes marcadores para espécies das subfamílias Pitcairnioideae e Bromelioideae.

Palavras-chave: *amplificação heteróloga, SSR, diversidade genética, bromélias, conservação.*

Introduction

The family Bromeliaceae plays an important role in the conservation of neotropical plant diversity. These epiphytic plants of the Atlantic Forest are among the most visited by birds, also serving as shelter and food for other species (Pizo 1994, Siqueira Filho & Leme 2000). The family Bromeliaceae is organized into three subfamilies: Pitcairnioideae, Tillandsioideae and Bromelioideae (Cronquist 1988), including 3172 species grouped into 58 genera (Luther 2008).

Many members of this family have economic value, e.g. the pineapple plant (*Ananas comosus* (L.) Murril), the 'caroa' (*Neoglaziovia variegata* (Arruda) Mez), which produces fibers and the ornamental plants, especially those of the *Aechmea*, *Billbergia, Canistrum* and *Cryptanthus* genera (Benzig 2000).

Despite their ecological and economic importance, little is known about genetic structure and diversity in natural populations of Bromeliads. According to Cavallari et al. (2006), preservation of the genetic diversity has become the main focus of most conservation programs and knowing the distribution of this diversity within and between natural populations is the first step. Understanding genetic variation within the populations of a given species is an essential prerequisite for conservation action (Barbará et al. 2007), which is essential for the establishment of sustainable forms of economic exploitation.

Therefore, the use of molecular genetic markers to assess genetic diversity of populations plant species occurring in Atlantic Forest has been reported in several studies (Chen et al. 2002, Boneth et al. 2003, Cavallari et al. 2006). Because of their greater convenience, the molecular markers most commonly used in analysis of genetic diversity in plants are polymerase chain reaction-based assays (PCR), particularly microsatellite or Simple Sequence Repeats (SSR) (Litt & Luty 1989), for they are a group of markers highly informative due to their multiallelic and codominant nature, reproducibility, heritability, relative abundance and extensive genome coverage (Powell et al. 1996, Yamamoto et al. 2002).

However, the main limitation on the use of these markers for analysis of genetic diversity in different species is the high cost for developing specific primers. An alternative approach would be the cross amplification of primers. SSR markers can be transferred between related species and genera, which considerably reduces their costs (Ferreira & Grattaplaglia 1998). SSR transferability has been reported to many families of plants, including Fabaceaea (Peakall et al. 1998, Kölliker et al. 2001) Cucurbitaceae (Katzir et al. 1996), Poaceae (Saghai Maroof et al. 1994, Röder et al. 1995, Thiel et al. 2003), Solanaceae (Provan et al. 1996, Smulders et al. 1997, Nagy et al. 2007, Moon et al. 2008); Euphorbiaceae (Yu et al. 2011) and Bromeliaceae (Sarthou et al. 2003, Barbará et al. 2007, Paggi et al. 2008). Thus, in this paper eight microsatellite markers previously developed for *Pitcairnia albiflos* and five markers developed for *Pitcairnia geysksii* were used in cross-amplification tests of five other neotropical Bromeliaceae species (*Pitcairnia flammea*, *Aechmea nudicaulis*, *Aechmea ramosa*, *Billbergia horrida* and *Billbergia euphemiae*).

Materials and Methods

Five markers of microsatellite loci previously developed for *Pitcairnia geysksii* (Sarthou et al. 2003) and eight to *Pitcairnia albiflos* (Paggi et al. 2008) (Table 1) were used in cross- amplification tests of five other Bromeliaceae species belonging to the Pitcairnioideae (*Pitcairnia flammea*) and Bromelioideae (*Aechmea nudicaulis*, *Aechmea ramosa*, *Billbergia horrida* and *Billbergia euphemiae*) subfamilies. A total of 12 *P. flammea* individuals (20° 40' 52.39" S and 41° 20' 43.38" W), eight *A. nudicaulis* (20° 40' 30.83" S and 41° 20' 57.01" W), 12 of *A. ramosa* (20° 40' 30.83" S and 41° 20' 57.01" W), 10 of *B. horrida* (20° 40' 20.1" S and 41° 22' 35.8" W) and four *B. euphemiae* (20° 40' 24,4" S and 41° 20' 55.2" W) were used in the analysis. One voucher for each species (accession nº 5569, nº 55681, nº55657, nº 55664 and nº 55660 respectively) was deposited in the CESJ Herbarium at Universidade Federal de Juiz de Fora (UFJF).

Leaf samples were collected from individuals of these species in natural populations occurring in fragments of the Atlantic Forests, in Burarama, Cachoeiro de Itapemirim, ES. DNA of plant samples were extracted and purified using the cetyltrimethylammonium bromide (CTAB) extraction method, as described by Doyle & Doyle (1990).

In order to improve the PCR result, the optimal annealing temperatures of each pair of primers to be tested were determined (between 48 and 56 °C). In all cases, microsatellite loci were amplified in a 15 µL volume containing 0.4 µM of each primer, 1 U Taq DNA polymerase, 0.1 mM of each dNTP, 1 × $MgCl_2$ – free reaction buffer (10 mM Tris-HCl pH 8.3 and 50 mM KCl), 2 mM $MgCl_2$ and 30 ng of template DNA.

Amplifications were performed using a Techne TC-412 thermal cycler under the following conditions: 5 minutes denaturation at 94 °C followed by 30 cycles of 1 minute of initial denaturation at 94 °C, 1 minute of annealing temperature at 54 °C and 1 minute of extension at 72 °C, and elongation at 72 °C for 7 minutes.

Amplified fragments were separated by electrophoresis on 2.5% agarose gel containing 0.02 ug/mL ethidium bromide, 1x TBE buffer (0.89 M Tris-HCl pH 8.3, 0.89 M boric acid and 0.02 M EDTA), at 110 volts for approximately three hours. Afterwards, the gels were photographed under UV light, using the gel documentation system Biolocus L PIX (Loccus Biotecnologia®). Gel electrophoresis was used to assess the number and size of amplified fragments, as well as polymorphism detection.

Analyses of genetic variability at the microsatellite *loci* were done using the genotypes obtained for all five species of bromeliads evaluated in this study. The number of alleles per locus and the observed and expected heterozygosities under Hardy-Weinberg equilibrium were estimated. These analyses and the test for deviation from Hardy-Weinberg expectations were performed with Genes program (Cruz 2008).

Results and Discussion

Ten of the 13 microsatellite loci evaluated generated amplification products. In PaA10, PaB12, PaC05, PaD07, PaZ01 and Pit5 loci cross-amplification was successful for the five study species, for the annealing temperature of these primers was identical (54 °C). The other markers had positive results for some of these species (Table 2). In *P. flammea,* there was positive amplification to 10 (76.92%) microsatellites loci, of which only three were monomorphic, in *A. Nudicaulis,* six (46.15%) markers generated amplification products, since in five of them polymorphism was detected, to *A. ramosa* and *B. horrida,* eight (61.53%) markers were successfully amplified, with only one monomorphic locus and, in *B. euphemiae,* nine (69.23%) markers generated positive results, as in seven polymorphism was detected.

Paggi et al. (2008) used the same markers previously developed for *P. albiflos* (subfamily Pitcairnioideae) to test cross amplification in 16 other bromeliad species, six of which belong to subfamily Pitcairnioideae, eight to family Bromelioideae and two to family Tillandsioideae. In this paper, PaB12, PaC05 and PaD07 markers showed positive results of amplification in all species belonging to subfamily Pitcairnioideae. PaA05, PaA09 and PaB11 markers exhibited exclusive transference only to this subfamily. On the other hand, PaA10, PaC05, PaD07 and PaZ01 markers were successfully transferred to species distributed in the three subfamilies.

Table 1. Characteristics of microsatellite loci used on heterologous amplification tests, including the name of the species for which the marker was previously developed, locus name, primer sequences, microsatellite sequence, size of fragments detected in the original citation and GenBank accession number.

Tabela 1. Características dos loci microssatélites usados nos testes de amplificação heteróloga, incluindo o nome da espécie para a qual o marcador foi originalmente desenvolvido, o nome do *locus*, a seqüência do *primer*, a seqüência do microssatélite, o tamanho do fragmento detectado na citação original e o número de acesso no GeneBank.

Species name	Locus	Primer sequences (5'-3')	SSR motif	Size range (bp)	Accession number
Pitcairnia albiflos	PaA05[a]	F: ACCGGGTTCAGGGAAAATAC R: TTGAGGCTAAGAGCGAGGAG	$(TTC)_{10}NN(CT)_{17}$	228-258	EU293085
Pitcairnia albiflos	PaA09[a]	F: AGAAGAGAACCCACCCCAAG R: GTGTTCCGCGACACTACAAA	$(CT)_{25}$	191-213	EU293086
Pitcairnia albiflos	PaA10[a]	F: AACCATTGACATCCGCTGTT R: CTTCGGAAGCTCCTCTGGAT	$(ATG)_{10}$	146-149	EU293087
Pitcairnia albiflos	PaB11[a]	F: AGAGGCTGAGAGAGGTAAACCA R: CGAGCCCTCTTTCTGAACC	$(AG)_{9}$	159-171	EU293088
Pitcairnia albiflos	PaB12[a]	F: CCCGAGGGACATTCTCTCTT R: CATGGCGCAGTAGTGTTTTC	$(CT)_{19}NN(CT)_{4}NN(CT)_{4}NN(TG)_{7}(TC)_{5}$	219-259	EU293089
Pitcairnia albiflos	PaC05[a]	F: TCGATGTCGACGGTAGTGAG R: TCCTCTCGCTTTGATTCACC	$(AG)_{18}NN(GA)_{7}$	149-153	EU293090
Pitcairnia albiflos	PaD07[a]	F: TCCATGTGCCTCATCATAGC R: TGCCCACAAAGCATATCAGT	$(TG)_{10}$	233-239	EU293091
Pitcairnia albiflos	PaZ01[a]	F: TGACCAGATAGCACCATCCA R: TTGAGTGTTGGAGCCCACTT	$(AG)_{20}$	185-199	EU293092
Pitcairnia geyskesii	Pit2[b]	L: TTAGCGGCAGTTAGAAACAGG R: GATCTCCGATGTCTTGTTAGG	$(CT)_{13}$	191-219	AY188957
Pitcairnia geyskesii	Pit4[b]	L: CCGACTCTATCGTCAAAGG R: TTATCACCTCCCATGTCTCC	$(CT)_{16}$	214-230	AY188958
Pitcairnia geyskesii	Pit5[b]	L: TTGAGCCATGAACAATAGGG R: AGAATTCTAGTGGCAGTCCTC	$(GA)_{20}$	310-343	AY188959
Pitcairnia geyskesii	Pit6[b]	L: AAAGCTACATCGTCGAAAACAAC R: CAATCAAGTTTCGGGTCACTAC	$(CT)_{11}$	108-120	AY188960
Pitcairnia geyskesii	Pit9[b]	L: AACCATTACATGCACCCTCAC R: TCACTGGGGAAGCCATAGAG	$(TC)_{13}(AT)_{9}$	113-129	AY188962

[a]markers described by Paggi et al. (2008) and [b]markers described by Sarthou et al. (2003).

In the present study, microsatellite markers, which until then had been described only to species of the genus *Pitcairnia*, such as PaA05, PaA09 and PaB11, were found to effectively generate cross amplification in species of *Aechmea* and *Billbergia* (Table 2), validating the transferability of these markers in these genus. Similar results were found by Palma-Silva et al. (2007) who successfully performed the transposition of SSR markers developed from species of subfamily Tillandsioideae (*Vrissea gigantea* and *Alcantarea imperialis*) to Bromelioideae and Pitcairnioideae species.

Another important aspect of our findings was the polymorphic markers identified for each one of the assessed species. Considering only the polymorphic loci, the number of alleles per locus ranged between two and four for most of the species (Table 2). These findings differ from those obtained by Sarthou et al. (2003) and Paggi et al. (2008), regarding the number of alleles detected and the size of fragments generated. According to Wang et al. (2009), this may have occurred because of the different methodologies used, namely capillary electrophoresis in the genotyping studies where these markers were originally described and agarose gel electrophoresis, in the present study. Another possible explanation is that these differences are the result of variations in the number of tandem repeat polymorphisms on the tested loci. In their evaluation of the percentage of transferability of SSR markers developed from *Nicotiana tabacum* to other species of the same genus, Moon et al. (2008) also found differences in reproducibility of amplifications, with variable fragment sizes, compared to the expected. Bravo et al. (2006) argue that there may be considerably variation both in the number of repetitions as well in levels of polymorphism between the species for which SSR markers were previously developed and the species that showed a cross reaction.

Regarding genotype distribution and values of the expected (H_E) and observed (H_O) heterozygosity (Table 2), in *P. flammea*, these ranged between 0.19 (PaA05) and 0.62 (PaZ01), and from zero (PaA05) to 0.64 (PaC05) respectively. In *A. Nudicaulis*, H_E ranged from 0.33 (PaA10) to 0.64 (PaZ01) and H_O between 0.25 (Pit5) and 0.63 (PaZ01) (Table 2). In *A. ramosa* and *B. horrida*, H_E ranged from 0.37 (PaA10, Pit5) to 0.63 (PaB12, PaZ01) and the values of H_O were detected ranging between zero (PaC05) and 0.77 (PaA05, PaB12) and from 0.25 (Pit5) to 0.77 (PaB12), respectively. To *B. euphemiae*, H_E ranged from 0.22 (PaA09) to 0.59 (PaZ01) and H_O ranged between zero (Pit5) and one (PaA05, PaA10, PaC05 and PaD07). Moreover, significant deviations from Hardy-Weinberg equilibrium were observed in some loci in population samples of the five bromeliad species. Similar results were reported by many authors in cross amplification studies using SSR markers for different species (Sarthou et al. 2003, Gimenes et al. 2007, Paggi et al. 2008, Nazareno et al. 2009). In most cases, this can be attributed to the existence of null alleles (alleles not amplified in some genotypes) or to sampling errors, causing the Wahlund effect. Still according to Wright (1965), the level of heterozygosity found in a population is highly dependent on the mating system and on the evolutionary history of the species, as well as on a number of other factors.

Therefore, given the high success rate in the cross amplification test and the level of polymorphism detected, the microsatellite

Table 2. Results of heterologous amplifications of microsatellite loci in DNA samples of individuals of *Pitcairnia flammea*, *Aechmea nudicaulis*, *Aechmea ramosa*, *Billbergia horrida* and *Billbergia euphemiae* species.

Tabela 2. Resultados das amplificações heterólogas de loci microssatélites em amostras de DNA de indivíduos das espécies *Pitcairnia flammea, Aechmea nudicaulis, Aechmea ramosa, Billbergia horrida e Billbergia euphemiae*.

Specie	Loci	PaA05	PaA09	PaA10	PaB11	PaB12	PaC05	PaD07	PaZ01	Pit5	Pit9	Média
P. flammea (n = 12)	Size range (bp)	185-210	215-270	60	90	240-290	65-85	60-100	250-280	320	70-90	
	Number of alleles	2	3	1	1	3	3	2	3	1	2	
	H_O	0	0.36	-	-	0.4	0.64	0.09	0.2	-	0.54	0.31
	H_E	0.19**	0.43*			0.46	0.53	0.23*	0.62**		0.5	0.42
A. nudicaulis (n = 8)	Size range (bp)	-	-	140-160	-	190	165-195	250-280	160-200	360-400	-	
	Number of alleles	-	-	2	-	1	2	2	4	3	-	
	H_O	-	-	0.43	-	-	0.6	0.5	0.63	0.25	-	0.48
	H_E			0.33*			0.62	0.37*	0.64	0.55**		0.50
A. ramosa (n = 12)	Size range (bp)	380-460	-	130-160	60-110	80-120	85-95	230-260	160-190	380	-	
	Number of alleles	2	-	2	2	4	2	2	3	1	-	
	H_O	0.77	-	0.16	0.57	0.77	0	0.75	0.25	-	-	0.47
	H_E	0.47*		0.37	0.41*	0.63**	0.42**	0.46*	0.63*			0.48
B. horrida (n = 10)	Size range (bp)	280	-	130-160	140-160	240-255	250-270	190-210	170-200	345-365	-	
	Number of alleles	1	-	2	2	2	2	2	3	2	-	
	H_O	-	-	0.55	0.57	0.77	0.44	0.63	0.66	0.25	-	0.55
	H_E			0.5*	0.48	0.5*	0.34**	0.43**	0.62*	0.37*		0.46
B. euphemiae (n = 4)	Size range (bp)	390-420	140-160	180-210	-	180	190-210	230-260	175-195	320-340	380	
	Number of alleles	2	2	2	-	1	2	2	3	2	1	
	H_O	1	0.25	1	-	-	1	1	0.5	0	-	0.67
	H_E	0.5*	0.22	0.5*			0.5*	0.5*	0.59	0.5*		0.47

The annealing temperature was the same for all the markers - 54 °C; statistically significant deviation from Hardy-Weinberg equilibrium (*$P < 0.005$; **$P < 0.001$).

markers used here can make a significant contribution to research on genetic structure of natural populations of Bromeliads. As described by Barbará et al. (2007), the findings of the present study provide subsidies to the establishment of effective strategies for conservation of forest genetic resources. Another important aspect is highlighted by Noor & Feder (2006). According to these authors, the possibility of cross amplification of genetic markers allow comparative studies among closely related taxa, as well as understanding of the genetic mechanisms of speciation and population divergence.

Acknowledgements

Authors thank biologist Dayvid Rodrigues Couto for his assistance with collection of plant material and Fundação de Amparo à Pesquisa do Espírito Santo (FAPES), for financial support.

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Received 26/03/2012
Revised 28/08/2012
Accepted 29/08/2012

First records of the Crested Black-Tyrant (*Knipolegus lophotes*, Tyrannidae) in the State of Mato Grosso do Sul, Brazil

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GODOI, M.N., COSTACURTA, M.B., NUNES, A.P., PATRIAL, E.W. & MORANTE FILHO, J.C. **First records of the Crested Black-Tyrant (*Knipolegus lophotes*, Tyrannidae) in the State of Mato Grosso do Sul, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?short-communication+bn01012032012

Abstract: The Crested Black-Tyrant (*Knipolegus lophotes*) is a member of the Tyrannidae family that occurs throughout open areas in central, southeastern and southern Brazil. Although this species occurs in regions that surround the state of Mato Grosso do Sul, there had never been a recorded sighting in the state. Thus, information on its distribution across Brazil's midwestern region is scarce. In this study, we report the first sightings of *K. lophotes* in Mato Grosso do Sul. These records extend the known distribution range of the species in midwestern Brazil and contribute to expanding knowledge of bird species composition in this region. We believe that the absence of *K. lophotes* from the lists of bird species recorded in different localities in Mato Grosso do Sul may be a reflection of its local rarity and the lack of bird inventory efforts in this region, which underscores the need for further research into bird communities in this poorly known region of Brazil.
Keywords: *birds, Tyrannidae, range extension, Cerrado, mid-western Brazil.*

GODOI, M.N., COSTACURTA, M.B., NUNES, A.P., PATRIAL, E.W. & MORANTE FILHO, J.C. **Primeiros registros da maria-preta-de-penacho (*Knipolegus lophotes*, Tyrannidae) no estado de Mato Grosso do Sul, Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?short-communication+bn01012032012

Resumo: A Maria-Preta-de-Penacho (*Knipolegus lophotes*) é um membro da família Tyrannidae que no Brasil ocorre em áreas abertas das regiões sudeste, central e sul. Apesar de ocorrer em regiões próximas ao estado de Mato Grosso do Sul, a espécie nunca foi registrada neste estado, e assim informações sobre sua distribuição no centro-oeste do país são escassas. Neste artigo reportamos os primeiros registros da ocorrência de *K. lophotes* no Mato Grosso do Sul. Estes registros ampliam a área de distribuição conhecida dessa espécie na região centro-oeste do Brasil e contribuem para o conhecimento da avifauna desta região. Acredita-se que o registro recente de *K. lophotes* no Mato Grosso do Sul se deva tanto a sua raridade local quanto a falta de estudos ornitológicos mais amplos no estado, apontando a necessidade da realização de mais estudos nesta região pouco conhecida do país em relação a sua avifauna.
Palavras-chave: *aves, Tyrannidae, extensão de distribuição geográfica, Cerrado, centro-oeste do Brasil.*

Introduction

The Crested Black-Tyrant (*Knipolegus lophotes*, Boie 1828) is a small member of the Tyrannidae family. It measures 20.5 – 21 cm, being that the female specimen is larger than the male (Sick 1997). This species occurs in shrubby and semi arboreal fields (known locally as *campos sujos* and *campos cerrados*, respectively), dry forests, shrubby riparian formations and rocky fields in mountains (Sick 1997, Sigrist 2009, Grantsau 2010).

Its distribution in South America covers a large portion of Uruguay, northeastern Paraguay and Brazil (Birdlife International 2009), where it occurs in the country's midwestern (State of Mato Grosso), southeastern (Minas Gerais, São Paulo, Espírito Santo and Rio de Janeiro), central (Goiás and Tocantins) and southern regions (Paraná to Rio Grande do Sul) (Ridgely & Tudor 1994, Sick 1997, Grantsau 2010).

The Crested Black-Tyrant (*K. lophotes*) occurs over a wide geographic range in central Brazil and has been recorded in regions near the state of Mato Grosso do Sul, such as Emas National Park in the state of Goiás (Hass 2003) and Chapada dos Guimarães in the state of Mato Grosso (Lopes et al. 2009). Although some bird inventories have been conducted in Mato Grosso do Sul, specifically in the Pantanal wetlands (Tubelis & Tomas 2003), Serra da Bodoquena (Pivatto et al. 2006), Cerrado (Silva et al. 2006), Chaco (Straube et al. 2006) and the Paraná River basin (Gimenes et al. 2007), there has never been any confirmed evidence of the occurrence of *K. lophotes* in the state. Thus, there is a great knowledge gap concerning the geographic distribution of *K. lophotes* across the midwestern region of Brazil, which underscores the need for more detailed information on its occurrence in this region. In this study, we present the first records of *K. lophotes* in the state of Mato Grosso do Sul, expanding knowledge on its geographic distribution in Brazil and contributing to the knowledge of bird composition in a poorly studied region of Brazil.

Materials and Methods

The data presented here were obtained by means of bird inventories conducted by the authors between 2009 and 2011. The inventories took place near the stream of São Domingos in the town of Caarapó (22° 43' S and 54° 39' W), Correntes River in the town of Sonora (17° 32' S and 54° 26' W), and in plateaus in the town of Rio Negro (19° 28' S and 54° 49' W). The method used to conduct the surveys was bird census based on direct observation (Rodrigues et al. 2005), which consists of sampling as many habitats as possible through visualization techniques and bird vocalizations during periods of high bird activity, between 06:00 – 10:00 and 15:00 – 18:00 hours. *K. lophotes* individuals were sighted and identified via binoculars and bird identification guides (Ridgely & Tudor 1994, Sigrist 2009). Whenever possible, individuals were photographed as a means to record their sighting and photos were then uploaded to Wiki Aves (online Encyclopedia of Brazilian Birds). Additional information on each recorded sighting, such as geographic coordinates and type of habitat, were also recorded to better characterize the species' occurrence and distribution in the state of Mato Grosso do Sul.

Results and Discussion

In this study, we present the first records of *K. lophotes* in the state of Mato Grosso do Sul and expand its known geographic distribution in Brazil. The records were collected from three different localities in the state (Figure 1). On June 18, 2009, one individual was sighted and photographed by Marco Costacurta in the town of Caarapó, located in the southeast region of the state. The specimen, identified as an adult male, was perched on a wire fence in a pasture near the stream of São Domingos (22° 43' S and 54° 39' W). The second recorded sighting took place in a sugar-cane plantation near the same stream, on the morning of June 19, 2009. On both occasions, Marco Costacurta observed the bird's black plumage and crests and used these features for species identification. The landscape of São Domingos stream is dominated by cultivated pastures, with small fragments of riparian forests and extensive sugar-cane cultivation. Another area of species occurrence in Mato Grosso do Sul is the region of Correntes River, in areas adjacent to the Small Hydro Power Plant Santa Gabriela in the municipality of Sonora (17° 32' S and 54° 26' W). In this area, Mauricio Godoi sighted *K. lophotes* individuals in February, May and November 2010 (Godoi 2011), and José Carlos Morante Filho sighted individuals in February 2011 (Morante Filho 2011) (Figures 1 and 2). On these occasions, pairs of *K. lophotes* were observed foraging in grasslands and shrubby fields in the margins of Correntes River. This region's landscape is dominated by patches of cerrado *stricto sensu,* riparian forests and cultivated pastures. Finally, during a brief bird inventory undertaken at Serra de Maracaju in March 2011, Eduardo Patrial sighted and photographed a *K. lophotes* individual in a shrubby field located in a plateau in the town of Rio Negro (19° 28' S and 54° 49' W) (Figure 1). In this region, the landscape is predominantly dominated by plateaus with cultivated pastures and Cerrado vegetation.

The Crested Black-Tyrant (*K. lophotes*) is not present in the lists of worldwide endangered species (Birdlife International 2009) or Brazilian endangered species (Silveira & Straube 2008). This species has a wide geographic distribution in central and southern Brazil, is predominantly insectivore and is mainly found in grasslands and shrubby fields (Willis 1976, Ribeiro et al. 2002), which could favored the expansion in its distribution by consequence of deforestation and the expansion of cultivated pastures in the state of Mato Grosso do Sul. Despite its wide geographic range and preference for open areas, which would make it an easily sighted bird, *K. lophotes* has not been previously sighted in the state of Mato Grosso do Sul.

With regard to the occurrence of congeneric species in Mato Grosso do Sul, at this time the only sight records are for *K. striaticeps* in the town of Corumbá (Naumburg 1930) and *K. aterrinus* in Bodoquena National Park (Bornschein et al. 2003). Although the distribution maps of *K. lophotes* in Brazil (Dunning 1987, Ridgely & Tudor 1994, Sigrist 2009, Gwynne et al. 2010) include a small and isolated area in the state of Mato Grosso do Sul (Pantanal and the southmost region of the state), there are no published records of the species' occurrence in these regions (Straube et al. 1996, Tubelis & Tomas 2003). Revisions of bird species lists from the town of Coxim (Pinto 1940), high Paraná River wetlands (Gimenes et al. 2007), Serra da Bodoquena (Pivatto et al. 2006) and the state's eastern Cerrado region (Pinto 1932, Silva et al. 2006), indicate no records of *K. lophotes* either.

Published records of *K. lophotes* sightings in midwestern Brazil come mainly from the Distrito Federal region (Braz & Cavalcanti 2001). However, confirmed sightings of the species in Cerrado regions near Mato Grosso do Sul, such as Emas National Park (Hass 2003) and Chapada dos Guimarães National Park (Lopes et al. 2009), suggest it does occur in the state. Therefore, we believe that the absence of the species from the bird lists of different localities in the state of Mato Grosso do Sul may reflect its local rarity and the lack of bird inventory efforts in this region. This is further reinforced by the fact that recent surveys found other bird species for the first time in the state (Zucca et al. 2007, Faxina et al. 2010, Godoi et al. 2011).

Thus, there is a clear need for more bird inventories in the state of Mato Grosso do Sul that would sample different state regions

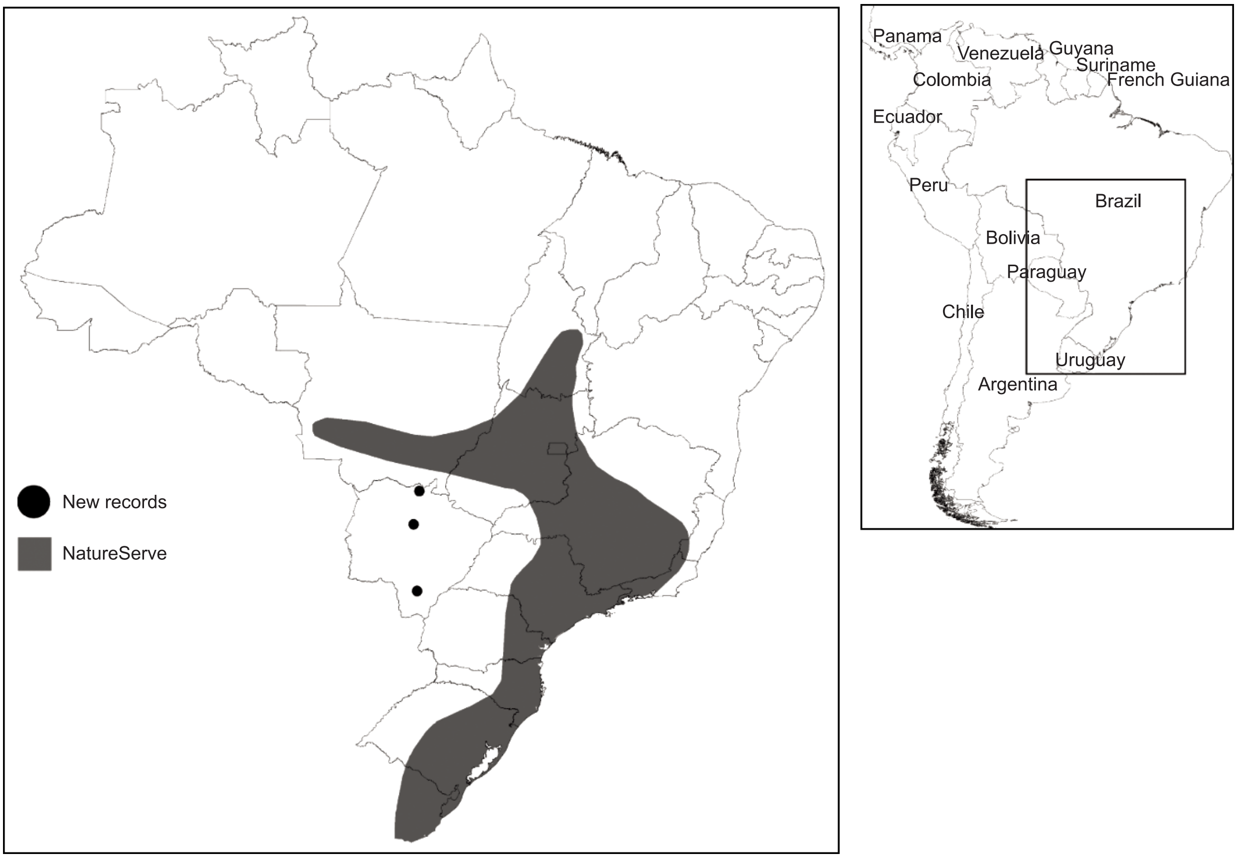

Figure 1. Geographic distribution of the Crested Black-Tyrant (*Knipolegus lophotes*) in Brazil (according Ridgely & Tudor 1994) and the records obtained in the state of Mato Grosso do Sul. Image: Roberto Gamarra.

Figura 1. Distribuição geográfica da maria-preta-de-penacho (*Knipolegus lophotes*) no Brasil (segundo Ridgely & Tudor 1994) e os registros obtidos no estado de Mato Grosso do Sul. Imagem: Roberto Gamarra.

Figure 2. Adult male of the Crested Black-Tyrant (*Knipolegus lophotes*) photographed in the margins of Correntes river, Sonora county, state of Mato Grosso do Sul. Photo: José Carlos Morante Filho.

Figura 2. Macho adulto da maria-preta-de-penacho (*Knipolegus lophotes*) fotografado nas margens do rio Correntes, município de Sonora, Mato Grosso do Sul. Foto: José Carlos Morante Filho.

in order to better understand bird composition in the midwestern regions of Brazil, as well as provide more detailed information on the occurrence of different bird species whose distribution is poorly known in this region of the country.

Acknowledgements

We would like to thank Roberto Gamarra for creating the distribution map and all anonymous reviewers who contributed to the final version of this manuscript. M. N. Godoi and A. P. Nunes also thank the Post-Graduate Program in Ecology and Conservation at Universidade Federal de Mato Grosso do Sul (Federal University of Mato Grosso do Sul) and CAPES (Coordination for the Improvement of Higher Level Personnel) for its postgraduate scholarship awards. Finally, we are very grateful to Rodrigo Neves Godoi, Janaína Ribeiro and Débora Cristina P. S. de Aquino for the final revision of the English version of this manuscript.

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Received 29/03/2012
Revised 08/06/2012
Accepted 25/07/2012

Tree and shrub species of the Atlantic Forest on the slopes of Marambaia Island, Rio de Janeiro, Brazil

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Abstract: This study describes the tree and shrub component of the Atlantic Forest on the slopes of Marambaia Island, RJ. It further evaluates which species are found at threatened species lists and the similarity that the studied forest component has with other nearby locations with similar vegetation. Data gathering relied on the joint effort of arbitrary walks and sampling units known as Transect. The same sampling criterion was applied at both approaches (DBH greater than or equal to 5 cm). A similarity analysis, followed by a Cluster analysis, was used to compare the studied vegetation component. Similarity calculations were based in the Bray-Curtis coefficient. We detected a total of 235 species. These are divided in 134 genera and 52 families. The richest families are Myrtaceae (38 spp.), Fabaceae (20 spp.) and Rubiaceae (20 spp.). The richest genera are *Eugenia* (16 spp.), *Myrcia* (8 spp.) and *Ocotea* (6 spp.). Nineteen of the detected species are currently listed as threatened and the studied forest component is mostly resembled to the vegetation at Rio Bonito (RJ). Our evidence shows that the evaluated tree and shrub layer seems to be well preserved and represents an important area for conservational efforts. The results additionally indicate that this vegetation seems to have a greater floristic resemblance to drier and further locations, rather than to more humid and close ones.
Keywords: *dense ombrophilous forest, floristic, species richness, similarity, phytogeography.*

NETTESHEIM, F.C., MENEZES, L.F.T., CARVALHO, D.C., CONDE, M.M.S., SOMNER, G.V., RODRIGUES, G.A. & ARAUJO, D.S.D. **Espécies arbóreas e arbustivas da Floresta Atlântica sobre as encostas da Ilha da Marambaia, Rio de Janeiro, Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn01112032012

Resumo: Este estudo descreve a florística do componente arbóreo e arbustivo da Floresta Atlântica sobre as encostas da Ilha da Marambaia, RJ. Também são avaliadas quais das espécies encontradas constam em listas de espécies ameaçadas e qual a semelhança deste componente da vegetação com locais próximos cobertos pelo mesmo tipo de vegetação. A coleta de dados se valeu do esforço conjunto de caminhadas arbitrárias e de unidades amostrais conhecidas como "Transect". O critério de inclusão na amostragem foi o mesmo para ambos os métodos (DAP igual ou maior a 5 cm). O componente estudado foi comparado a outras áreas através de uma análise de similaridade, seguida de um dendrograma. Os cálculos de similaridade foram baseados no coeficiente de Bray-Curtis. Detectamos, ao todo, 235 espécies, distribuídas em 134 gêneros e 52 famílias. As famílias mais ricas são Myrtaceae (38 spp.), Fabaceae (20 spp.) e Rubiaceae (20 spp.), enquanto os gêneros mais ricos são *Eugenia* (16 spp.), *Myrcia* (8 spp.) e *Ocotea* (6 spp.). Dezenove das espécies detectadas constam em listas de espécies ameaçadas de extinção e o componente estudado tem maior similaridade com a floresta em Rio Bonito (RJ). As evidências mostram que a vegetação estudada parece estar bem preservada e representa uma área importante para esforços conservacionistas. Os resultados indicam ainda que o remanescente florestal em questão aparenta ser mais semelhante a locais mais secos e distantes do que próximos e úmidos.

***Palavras-chave:** floresta ombrófila densa, florística, riqueza de espécies, similaridade, fitogeografia.*

Introduction

The Atlantic Forest is one of the world's most threatened tropical biomes (Conservation... 2011). Such status comes as a result from the continuous exploitation during various agricultural cycles and expansion of croplands (Dean 1996, Câmara & Coimbra-Filho 2000, Tonhasca Junior 2005). As an outcome of ongoing human activities and deforestation, an increasing number of isolated forest fragments are created. This process compromises the forest´s natural dynamic, avoids the survival of many species and contributes to the segregation of many animal and plant populations. Consequently, genetic flow between individuals is hampered and biological diversity reduced both locally and regionally (Primack & Rodrigues 2001, Rocha et al. 2006). Floristic studies of these forest fragments are a way of providing important information regarding the vegetation's current conservation status and ecological role. These studies have enabled the detection of interesting phytogeography patterns, priority species for conservation, relevant restoration actions and other significant trends regarding Atlantic Forest remnants (Oliveira-Filho & Fontes 2000, Fundação... & Instituto... 2002, Rambaldi et al. 2003, Nettesheim et al. 2010).

Two defining characteristics of the Atlantic Forest are its high plant species diversity and endemism levels (Murray-Smith et al. 2009, Conservation... 2011). Though not conclusive, many recent studies linked this floristic variation to the broad latitudinal and altitudinal range that this forest covers (Oliveira-Filho & Fontes 2000, Scudeller et al. 2001, Oliveira-Filho et al. 2005, Caiafa & Martins 2010, Nettesheim et al. 2010). Such reasoning is coherent with the existence of different forest types and associated ecosystems identified among the environmentally heterogeneous landscape within the Atlantic Forest (Veloso et al. 1991, Scarano 2002, Tonhasca Junior 2005).

Most of the Atlantic Forest plant species diversity and endemism known is found in fairly large and contiguous preserved areas of Dense Ombrophilous Forest (Veloso et al. 1991, Murray-Smith et al. 2009). In Rio de Janeiro state, the most important Atlantic Forest remnants cover the Serra do Mar mountain range and the better preserved vegetation is mainly present at its southern extension (Fundação... & Instituto… 2002, Rambaldi et al. 2003). Apparently, the tree and shrub flora variation from Rio de Janeiro southern region to its center becomes greater once Serra do Mar starts to get further from the ocean (Nettesheim et al. 2010). This topographic differentiation seems to determine a clear floristic distinction among remnants over Serra do Mar mountain range and over the plain landscape in front of it, known as the Guanabara Graben (grabens are linear terrain depressions at regions that endure tensional tectonic forces – Guerra & Guerra 1997). This topographic and floristic pattern can be found at Mangaratiba Environmental Protection Area, a protected area that covers close to 22618 ha. This conservation unit withholds contiguous continental forest areas as well as several islands at Sepetiba Bay (Rambaldi et al. 2003). Marambaia Island is one of these islands. It is composed by a low mountain area and a sandy stretch with 47 km of length. While the mountain area marks the entrance of Sepetiba Bay and is covered by Submontane Dense Ombrophilous Forest (*sensu* Veloso et al. 1991), the plain area reaches the continent and is covered by well-preserved coastal dune vegetation (Menezes et al. 2005).

A recent study showed, through a Cluster analysis, that Marambaia Island Submontane Dense Ombrophilous Forest (here treated as slope forest) seems to be more similar and grouped together to other areas on the slopes of Serra do Mar (Nettesheim et al. 2010). However, the same effort calls attention to the fact that such pattern was not so clear when the data was evaluated with a different analysis. According to the Canonical Correspondence Analysis, Marambaia Island slope forest seems to be more similar to hotter, lower and drier areas at Rio de Janeiro's Guanabara Graben (Nettesheim et al. 2010). These authors suggest that further evaluations taking into account abundance data about areas withholding the same forest type as Marambaia Island could help to clear up such discrepancies.

The floristic composition of Marambaia Island forest has already been studied (Conde et al. 2005). However, this assessment didn´t focus neither on describing a specific community layer nor on elucidating any phytogeography patterns. Therefore, the present survey aims at further describing the Marambaia Island slope forest tree and shrub layer composition and determining to which slope forest locations within Serra do Mar and Guanabara Graben (Almeida & Carneiro 1998) in Rio de Janeiro and Northern São Paulo it mostly resembles. In order to do that the present effort is guided by the following questions: (1) How many families, genera and species of trees and shrubs can there be detected in this slope forest? (2) What are the richest families and are they consistent with other nearby Atlantic Forest locations? (3) Are there threatened species? (4) When compared (based on species abundance data) to nearby slope forest studies, Marambaia Island slope forest is more resembled to areas at Serra do Mar mountain range or at the Guanabara Graben?

Methods

Study area – The study site is located in Sepetiba Bay, Mangaratiba municipality, in Southern Rio de Janeiro state (23° 04' S and 43° 53' W – Figure 1). The mountainous area soil lies over a gneiss crystalline basement terrain (Souza et al. 2005). According to the Brazilian Soil Classification System (Embrapa 2006) the soil is an association of Ultissol, Inceptsol and Entissol. The highest point at the area reaches an altitude of 641 m (Góes et al. 2005). The climate at Marambaia Island is rainy tropical. Mean monthly temperatures are over 20 °C and the annual mean is 23.7 °C . Mean annual precipitation is 1239.7 mm, 37% restricted to the summer months (rainiest season) and 15% to the winter months (driest season – Mattos 2005). Although nowadays the vegetation of Marambaia represents an important Atlantic Forest remnant, it sustained past anthropic interventions. The presence of the Brazilian Navy in the area as of the 1970's, together with its geographic isolation, guaranteed the conservation of the site during this period (Pereira et al. 1990, Conde et al. 2005, D.F. Silva, unpublished data).

Data sampling – This activity took place from January 2004 to January 2010 and relied on both a quantitative (transect method – Gentry 1982) and a qualitative approach (arbitrary walks through the area). Floristic composition presented here is the sum of the information provided by these methods. The same sampling criterion was adopted for both approaches, including trees and shrubs with diameter at breast height (dbh) equal to or greater than 5 cm.

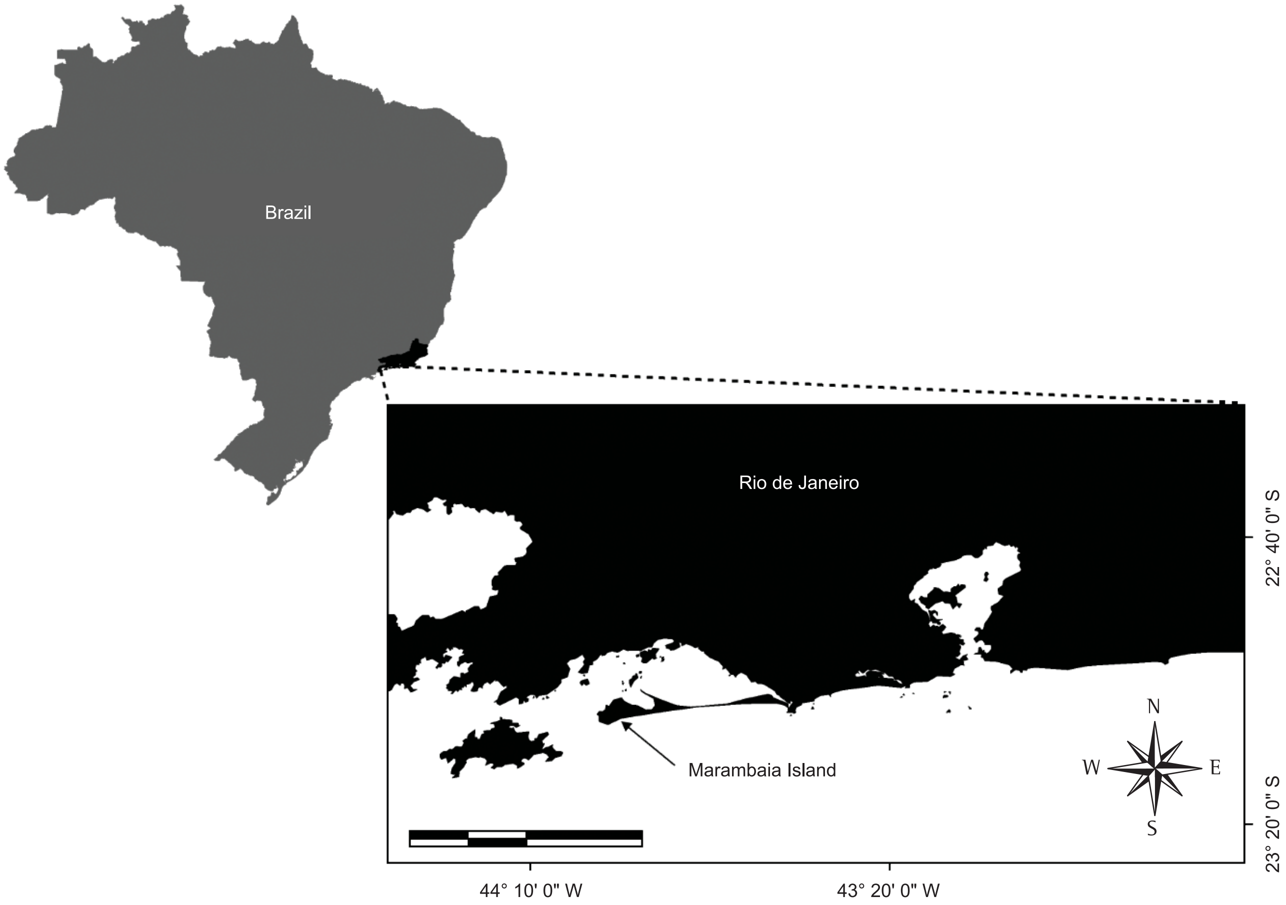

Figure 1. Location of Marambaia Island at southern Rio de Janeiro state, Brazil.

Besides the dbh restriction, only fertile individuals were included in the qualitative approach. Quantitative data was gathered at 40 sampling units, each unit with 2 × 50 m (100 m^2). The sampling units were established arbitrarily in altitudes varying from 50 to 500 m, covering a total area of 4000 m^2 (0.4 ha). Specimens of each species were collected to confirm their identity and deposited in Rio de Janeiro Federal Rural University Botany Department's Herbarium (RBR). The present effort species nomenclature follows APG III (Angiosperm… 2009). Species names and authors were checked at the Brazilian Flora Species List (*in* http://floradobrasil.jbrj.gov.br/2011) and at the International Plant Name Index site (*in* http://www.ipni.org/ipni/plantnamesearchpage.do).

Data evaluation and analysis – To determine if the richest families found at this effort are consistent with other nearby areas, we compared it with 20 Atlantic Forest studies (Table 1) at Rio de Janeiro and São Paulo states. For this comparison we emphasized forest areas at Serra do Mar mountain range and at the Guanabara Graben (Almeida & Carneiro 1998, Nettesheim et al. 2010).

To assess if any of the detected species is considered threatened we relied on two widely adopted endangered species lists. One was the Brazilian Environmental Ministry (MMA) list and the other was the Union for the Conservation of Nature (IUCN) Red List. Given that the criteria adopted to determine species conservation status varies according to the organization that develops the list, the same species may be considered endangered in one but not the other.

Six of the 20 Atlantic Forest studies initially gathered were chosen to be included in the similarity analysis. Only these studies met the criteria of providing species abundance data regarding a forest type equal and close to the one found at Marambaia Island. Five were developed in Rio de Janeiro state and one in São Paulo (Table 2). However, it´s important to note that one of the five studies from Rio de Janeiro state (at Tinguá Biological Reserve – REBIO Tinguá) seems to have been carried out at about 650 to 900 m of altitude, which would classify this forest as Montane Ombrophilous Forest (Rodrigues 1996). Still, we decided on keeping it in the analysis due to the following reasons: the work doesn't give a clear description of where samples were taken from (no coordinates); the altitude of 600 m that should define the distinction between Submontane and Montane Atlantic Forest is, though generally accepted by scientists, rather arbitrary; a good deal of REBIO Tinguá is a preserved Submontane Ombrophilous Forest; and excluding this information from the analysis would decrease even more the number of available efforts that supply quality species abundance data from near Marambaia Island. We also recognize that the compared studies relied in different sampling strategies. Nevertheless, although results must be interpreted with caution, we believe evaluating questions with abundance data may help to detect patterns that could go by unnoticed with presence/absence data.

With the information present in these six studies and the present effort, we assembled a Q matrix based on the abundance of each species within each location. Species not identified to specific level and synonyms were excluded of the data. We decided on keeping in the analysis species that occurred only once at any of the seven areas and that were represented by less than five individuals. This was made because we also ran the cluster analysis subtracting these "unwanted" species and the pattern found was the same as if they were kept in the

Table 1. Atlantic Forest study sites used to compare the richest families with the present effort.

Study area	Reference	Forest type
Campos dos Goytacazes – RJ	Carvalho et al. (2006a)	Low land Semideciduous Seasonal Forest
Mata do Carvão – RJ	Silva & Nascimento (2001)	Low land Semideciduous Seasonal Forest
Serra da Capoeira Grande – RJ	Peixoto et al. (2004)	Low land Dense Ombrophilous Forest
Poço das Antas baixada – RJ	Guedes-Bruni et al. (2006a)	Low land Dense Ombrophilous Forest
Região do Imbé – RJ	Moreno et al. (2003)	Submontane Dense Ombrophilous Forest
Praia do Sul, Ilha Grande – RJ	Oliveira (2002)	Submontane Dense Ombrophilous Forest
Imbaú – RJ	Carvalho et al. (2006b)	Submontane Dense Ombrophilous Forest
Represa de Ribeirão das Lages – RJ	Peixoto et al. (1995)	Submontane Dense Ombrophilous Forest
Poço das Antas morrote – RJ	Guedes-Bruni et al. (2006b)	Submontane Dense Ombrophilous Forest
Cachoeiras de Macacu – RJ	Kurtz & Araujo (2000)	Submontane Dense Ombrophilous Forest
Maciço da Tijuca – RJ	Oliveira et al. (1995)	Submontane Dense Ombrophilous Forest
Rio Bonito – RJ	Carvalho et al. (2007)	Submontane Dense Ombrophilous Forest
Juréia – Itatins – SP	Mamede et al. (2004)	Submontane Dense Ombrophilous Forest
Peruíbe – SP	Oliveira et al. (2001)	Submontane Dense Ombrophilous Forest
Picinguaba – SP	Sanchez et al. (1999)	Submontane Dense Ombrophilous Forest
Ubatuba – SP	Silva & Leitão Filho (1982)	Submontane Dense Ombrophilous Forest
Pindamonhangaba – SP	Gomes et al. (2005)	Montane Dense Ombrophilous Forest
Macaé de Cima secundária – RJ	Pessoa et al. (1997)	Montane Dense Ombrophilous Forest
Macaé de Cima preservada – RJ	Guedes-Bruni et al. (1997)	Montane Dense Ombrophilous Forest
Reserva Biológica Tinguá – RJ	Rodrigues (1996)	Montane Dense Ombrophilous Forest

Table 2. Methodological and environmental characteristics of the Submontane Dense Ombrophilous Forests areas evaluated in the similarity analysis. Alt. – predominant sampling altitude (m.); Precip. – mean annual precipitation (mm); Temp. – mean annual temperature (°C); Met. – study methodology (P = plot, T = transect, PQ = quadrant point); Crit. – sampling inclusion criterion (DBH in cm); Bs. Ar. – total sampled basal area ($m^2.ha^{-1}$); Area – total sampled area (m^2 – plots and transects methods) or number of points (quadrant point method); Abd. – total sampled abundance; S – total number of sampled species.

Code	Study area	Alt.	Precip.	Temp.	Met.	Crit.	Bs. Ar.	Area	Abd.	S
UBA, SP	Ubatuba[1]	120	2448	22.6	PQ	≥ 10	----	160	640	123
IGR, RJ	Praia do Sul, Ilha Grande[2]	165	1975	22.5	P	≥ 2.5	57.90	7800	2332	236
PAM, RJ	Poço das Antas morrote[3]	115	2118	24.5	P	≥ 5	25.59	10000	580	174
PAR, RJ	Cachoeiras de Macacu[4]	200	2558	23.0	PQ	≥ 5	57.30	150	592	138
RBT, RJ	Rio Bonito[5]	100	1750	26.0	P	≥ 5	29.00	4000	776	106
TIN, RJ	Reserva Biológica Tinguá[6]	650	2099	21.6	PQ	≥ 2.5	----	200	800	189
IMA, RJ	Ilha da Marambaia[7]	130	1239	23.7	T	≥ 5	55.68	4000	941	169

[1] Silva & Leitão Filho (1982); [2] Oliveira (2002); [3] Guedes-Bruni et al. (2006b); [4] Kurtz & Araujo (2000); [5] Carvalho et al. (2007); [6] Rodrigues (1996); [7] this study.

analysis (with a slight increase of the similarity values). Besides, we understand that rare species are common in the Atlantic Forest and may provide important clues about floristic differentiation patterns. Therefore, the final matrix listed the abundance of 528 species distributed at seven different slope forest locations. This matrix was standardized dividing the species abundance value recorded in each location by the total abundance recorded in that location. Following matrix standardization we calculated a similarity matrix between each pair of evaluated areas based on the Bray-Curtis coefficient distance measure. Once Bray-Curtis is a dissimilarity measure, we subtracted the resulting dissimilarity values from 1 in order to determine the areas similarities. Then we used these Bray-Curtis similarity values to build a similarity dendrogram synthesizing the relationship among the compared locations. The dendrogram was elaborated using the Unweighted Pair Group with Arithmetic Mean – UPGMA – clustering method (McCune & Grace 2002, Gotelli & Ellison 2004).

Results

A total of 235 species were detected. These are distributed in 134 genera and 52 families (Table 3). Eighteen families (34.6%) and 113 genera (84.3%) are represented by only one species. The richest families are Myrtaceae (38 spp.), Fabaceae (20 spp.), Rubiaceae (20 spp.), Lauraceae (14 spp.), Sapotaceae (12 spp.) and Euphorbiaceae (11 spp.). The most expressive genera are *Eugenia* (16 spp.), *Myrcia* (8 spp.), *Ocotea* (6 spp.), *Ficus* (6 spp.), *Inga* and *Psychotria* (5 spp.).

Nineteen of the 235 detected species (about 8%) are included on threatened species lists (Table 3). Sixteen of them appear at the IUCN Red List (International... 2010) and the other three at the Brazilian Environmental Ministry list (Brasil 2008). Sapotaceae is the family with the greatest number of species (5) at the threatened species lists considered.

The plant community at this study has greater floristic similarity (20.2%) with the slope forest in Rio Bonito (RJ – Table 4). This resemblance is the second highest found by the analysis, after Rio Bonito and Poço das Antas (RJ), with 21.6%. On the other hand, Marambaia slope forest is least resembled to Ubatuba (SP – 8,3%). The lowest value of similarity was found between Rio Bonito and Ilha Grande (3.4%). When the similarity information regarding the areas was summarized by the Cluster, it was possible to distinguish three groups (Figure 2): the first one formed by Ubatuba and Ilha

Table 3. Tree and shrub species from Marambaia slope forest. Voucher – specimen collector and researcher sample number. Species sampled qualitatively are preceded by an asterisk. Threatened species are identified by its conservation status in superscript and bold: LR1 – low risk, least concern; LR2 – low risk, conservation dependent; V – vulnerable; E – endangered (according to IUCN Red List status) or DD – deficient data; TE – threatened with extinction (according to Brazilian Environmental Ministry status).

Family/species	Voucher
ANACARDIACEAE	
Astronium graveolens Jacq.	M.S. Conde 646
Tapirira guianensis Aubl.	D. Araujo 10542
ANNONACEAE	
*_Anaxagorea dolichocarpa_ Sandwith & Sandwith	F.C. Nettesheim 18
Guateria candolleana Schltdl.	F.C. Nettesheim 177
Guateria cf. *villosissima* A.St.-Hil.	F.C. Nettesheim 127
*_Xylopia brasiliensis_ Spreng.	H.P. Lima 347
Xylopia langsdorffiana A.St.-Hil. & Tul.	F.C. Nettesheim 225
Xylopia sericea A.St.-Hil.	M.S. Conde 476
APOCYNACEAE	
Aspidosperma pyricollum Müll. Arg.	H.F. Baylão 87
Malouetia cestroides (Nees *ex* Mart.) Müll.Arg.	F.C. Nettesheim 140
Tabernaemontana laeta Mart.	G.M. Siqueira 25
AQUIFOLIACEAE	
Ilex integerrima (Vell.) Reissek	L.F. Menezes 757
ARALIACEAE	
Schefflera angustissima (Marchal) Frodin	F.C. Nettesheim 216
ARECACEAE	
Astrocaryum aculeatissimum (Schott) Burret $^{\mathbf{LR1}}$	L.F. Menezes 417
*_Syagrus romanzoffiana_ (Cham.) Glassman	F.C. Nettesheim 294
ASTERACEAE	
Vernonanthura discolor (Spreng.) Less.	F.C. Nettesheim 169
BIGNONIACEAE	
Cybistax antisyphilitica (Mart.) Mart.	F.C. Nettesheim 31
Handroanthus heptaphyllus Mattos	F.C. Nettesheim 223
*_Jacaranda puberula_ Cham.	R.S. Nunes 1
Sparattosperma leucanthum (Vell.) K.Schum.	L.F. Menezes 1065
*_Tabebuia cassinoides_ (Lam.) DC. $^{\mathbf{DD}}$	F.C. Nettesheim 295
BORAGINACEAE	
*_Cordia sellowiana_ Cham.	D.C. Carvalho 29
Cordia trichoclada DC.	L.F. Menezes 592
*_Cordia trichotoma_ (Vell.) Arráb. _ex_ Steud.	F.C. Nettesheim 203
BURSERACEAE	
Protium brasiliense (Spreng.) Engl.	M.S. Conde 648
Protium heptaphyllum (Aubl.) Marchand	G.A. Rodrigues sem nº
Tetragastris breviacuminata Swart	F.C. Nettesheim 81
CANNABACEAE	
Celtis iguanaea (Jacq.) Sarg.	F.C. Nettesheim 228
*_Trema micrantha_ (L.) Blume	M.C. Souza 13
CHRYSOBALANACEAE	
Hirtella hebeclada Moric. *ex* DC.	F.C. Nettesheim 141
Licania kunthiana Hook.f.	F.C. Nettesheim 221
Licania riedeli Prance	F.C. Nettesheim 37
Parinari excelsa Sabine	M.S. Conde 634
CLETHRACEAE	
Clethra scabra Pers.	F.C. Nettesheim 52
CLUSIACEAE	
*_Garcinia brasiliensis_ Mart.	F.C. Nettesheim 246
Garcinia gardneriana (Planch. & Triana.) Zappi	F.C. Nettesheim 1
*_Kielmeyera_lathrophyton__Saddi	D.C. Carvalho 56
COMBRETACEAE	

Table 3. Continued...

Family/species	Voucher
Terminalia januariensis DC. $^{\mathrm{VU}}$	F.C. Nettesheim 234
CUNNONIACEAE	
Lamanonia ternata Vell.	F.C. Nettesheim 22
ELAEOCARPACEAE	
Sloanea guianensis (Aubl.) Benth.	F.C. Nettesheim 76
ERYTHROXYLACEAE	
**Erythroxylum passerinum* Mart.	F.C. Nettesheim 112
Erythroxylum pulchrum A.St.-Hil.	A. Melo 13
Erythroxylum subsessile (Mart.) O.E.Schulz.	D.C. Carvalho 02
EUPHORBIACEAE	
Actinostemon concolor (Spreng.) Müll.Arg.	D.C. Carvalho 58
Actinostemon communis (Müll.Arg.) Pax.	L.F. Menezes 718
Alchornea triplinervia (Spreng.) Müll.Arg.	L.F. Menezes 244
Algernonia brasiliensis Baill.	F.C. Nettesheim 84
Aparisthmium cordatum (A.Juss.) Baill.	M.C. Souza 11
**Croton compressus* Lam.	A. Melo 12
Croton floribundus Lund. *ex* Didr.	F.C. Nettesheim 60
Croton sphaerogynus Baill	L.F. Menezes 783
**Joannesia princeps* Vell.	D.C. Carvalho 72
**Sebastiania gaudichaudii* (Müll. Arg.) Müll. Arg.	G.M. Siqueira 15
Senefeldera verticillata (Vell.) Croizat	F.C. Nettesheim 147
FABACEAE	
**Albizia polycephala* (Benth.) Killip *ex* Record	R. Facre 08
**Andira anthelmia* (Vell.) Benth.	R.S. Nunes 2
**Andira fraxinifolia* Benth.	L.F. Menezes 1110
Copaifera lucens Dwyer	F.C. Nettesheim 35
**Dalbergia frutescens* (Vell.) Britton	R. Facre 13
Inga capitata Desv.	F.C. Nettesheim 105
**Inga edulis* Mart.	F.C. Nettesheim 299
Inga lanceifolia Benth. $^{\mathrm{EN}}$	F.C. Nettesheim 104
**Inga laurina* (Sw.) Willd.	M.S. Conde 650
Inga subnuda Salzm. *ex* Benth.	M.S. Conde 486
Myrocarpus frondosus Allemão $^{\mathrm{DD}}$	F.C. Nettesheim 103
Ormosia arborea (Vell.) Harms	D. Araujo 10549
Piptadenia gonoacantha (Mart.) J.F.Macbr.	D.C. Carvalho 57
Pseudopiptadenia contorta (DC.) G.P.Lewis & M.P.Lima	H.P. Lima 343
Pseudopiptadenia leptostachya (Benth.) Rauschert	F.C. Nettesheim 106
**Schizolobium parahyba* (Vell.) Blake	A.S. Medeiros 120
**Tachigali pilgeriana* (Harms) Oliveira-Filho $^{\mathrm{EN}}$	F.C. Nettesheim 116
**Senna silvestris* (Vell.) H.S.Irwin & Barneby	M.C. Souza 108
**Swartzia langsdorffii* Raddi	F.C. Nettesheim 164
**Zolernia ilicifolia* (Brongn.) Vogel	R.S. Nunes 4
LAURACEAE	
Aniba firmula (Nees & Mart.) Mez	L.F. Menezes 658
Beilschmiedia rigida (Mez) Kosterm. $^{\mathrm{TE}}$	F.C. Nettesheim 194
Endlicheria glomerata Mez	F.C. Nettesheim 193
**Endlicheria paniculata* (Spreng.) J.F.Macbr.	G.A. Rodrigues 3
Licaria armeniaca (Nees) Kosterm.	L.F. Menezes 822
**Nectandra membranacea* (Sw.) Griseb.	L.F. Menezes 1064
Nectandra oppositifolia Nees	M.S. Conde 484
**Nectandra puberula* (Schott) Ness	G.A. Rodrigues 4
**Ocotea aciphylla* (Ness & Mart.) Mez $^{\mathrm{LR1}}$	G.A. Rodrigues 5
**Ocotea divaricata* (Ness) Mez	D.C. Carvalho 130
Ocotea elegans Mez	F.C. Nettesheim 130
Ocotea lancifolia (Schott) Mez	R.S. Nunes 5

Table 3. Continued...

Family/species	Voucher
Ocotea notata (Nees & Mart.) Mez	D. Araújo 9762
Ocotea teleiandra (Meisn.) Mez	F.C. Nettesheim 04
LECYTHIDACEAE	
**Cariniana estrellensis* (Raddi) Kuntze	F.C. Nettesheim 296
Cariniana legalis (Mart.) Kuntze ^{VU}	M.S. Conde 463
MALVACEAE	
Ceiba speciosa (A.St.-Hil) Ravenna	F.C. Nettesheim 224
Erioteca penthaphylla (Vell. & K.Schum.) A.Robyns	F.C. Nettesheim 25
Luehea divaricata Mart. & Zucc.	F.C. Nettesheim 28
Pseudobombax grandiflorum (Cav.) A.Robyns	L.F. Menezes 533
Quararibea turbinata (Sw.) Poir.	F.C. Nettesheim 200
MALPIGHIACEAE	
**Byrsonima crispa* A.Juss.	G.A. Rodrigues 11
Byrsonima laxiflora Griseb.	F.C. Nettesheim 62
**Byrsonima sericea* DC.	J.P. Junior 46
MELASTOMATACEAE	
**Huberia ovalifolia* DC.	M.S. Conde 470
**Miconia calvescens* DC.	H.P. Lima 340
**Miconia chartacea* Triana	G.A. Rodrigues 6
Miconia cinnamomifolia (DC.) Naudin	M.S. Conde 478
**Miconia dodecandra* Cogn.	K.C. Silva 14
Miconia prasina (Sw.) DC.	H.P. Lima 348
**Tibouchina estrellensis* (Raddi) Cogn.	F.C. Nettesheim 190
**Tibouchina granulosa* (Desr.) Cogn.	R.S. Nunes 6
**Tibouchina trichopoda* (DC.) Baill	K.C. Silva 25
MELIACEAE	
**Guarea guidonia* (L.) Sleumer	F.C. Nettesheim 179
Guarea macrophylla Vahl	F.C. Nettesheim 16
**Trichilia casarettoi* C.DC. ^{VU}	F.C. Nettesheim 188
Trichilia elegans A.Juss.	L.F. Menezes 586
Trichilia lepidota Mart.	D.C. Carvalho 54
MONIMIACEAE	
Mollinedia oligantha Perkins	M.S. Conde 474
MORACEAE	
Brosimum guianense (Aubl.) Huber	M.C. Souza 92
Ficus adhatodifolia Schott *ex* Spreng.	L.F. Menezes 594
Ficus arpazusa Casar.	F.C. Nettesheim 138
**Ficus clusiifolia* Schott.	F.C. Nettesheim 183
**Ficus cyclophylla* (Miq.) Miq.^{EN}	A.C.C. Moreira 11
Ficus gomelleira Kunth	L.F. Menezes 1001
Ficus luschnathiana (Miq.) Miq.	M.C. Souza 10
Sorocea guilleminiana Gaudich.^{VU}	G.A. Rodrigues 10
**Sorocea hilarii* Gaudich.	L.F. Menezes 229
MYRISTICACEAE	
Virola gardneri (A.DC.) Warb.	F.C. Nettesheim 149
MYRSINACEAE	
**Myrsine coriacea* (Sw.) R.Br. *ex* Roem & Schult.	L.F. Menezes 596
Myrsine venosa A.DC.	L.F. Menezes 583
MYRTACEAE	
Calyptranthes lanceolata O.Berg	L.F. Menezes 1093
Calyptranthes lucida Mart. *ex* DC.	F.C. Nettesheim 111
Campomanesia guazumifolia (Cambess.) O.Berg	F.C. Nettesheim 14
**Campomanesia guaviroba* (DC.) Kiaersk.	L.F. Menezes 999
Eugenia bahiensis DC.	F.C. Nettesheim 198

Table 3. Continued...

Family/species	Voucher
**Eugenia brasiliensis* Lam.	L.F. Menezes 632
Eugenia excelsa O.Berg	F.C. Nettesheim 101
**Eugenia florida* DC.	G.A. Rodrigues 7
Eugenia microcarpa O.Berg	F.C. Nettesheim 218
**Eugenia neolanceolata* Sobral	R.S. Nunes 11
**Eugenia neonitida* Sobral	M.C. Souza 134
**Eugenia neosilvestris* Sobral	F.C. Nettesheim 108
Eugenia oblongata Mattos & D.Legrand	F.C. Nettesheim 197
Eugenia prasina O.Berg ^{VU}	F.C. Nettesheim 220
Eugenia punicifolia (Kunth) DC.	F.C. Nettesheim 80
Eugenia riedeliana O.Berg	F.C. Nettesheim 15
Eugenia rostrata O. Berg	F.C. Nettesheim 47
**Eugenia sulcata* Spring *ex* Mart.	L.F. Menezes 627
Eugenia tinguyensis Cambess.	F.C. Nettesheim 79
**Eugenia uniflora* L.	R.S. Nunes 12
Marlierea excoriata Mart.	F.C. Nettesheim 6
Marlierea obscura O.Berg	F.C. Nettesheim 110
Marlierea suaveolens Cambess.	F.C. Nettesheim 24
Marlierea tomentosa Cambess.	F.C. Nettesheim 100
Myrceugenia myrcioides (Cambess.) O. Berg	F.C. Nettesheim 61
Myrcia acuminatissima O.Berg	F.C. Nettesheim 134
Myrcia laxiflora Cambess.	F.C. Nettesheim 40
Myrcia multiflora (Lam.) DC.	L.F. Menezes 672
Myrcia pubipetala Miq.	L.F. Menezes 521
**Myrcia selloi* (Spreng.) N.Silveira	L.F. Menezes 992
Myrcia spectabilis DC.	M.S. Conde 468
Myrcia splendens (Sw.) DC.	F.C. Nettesheim 30
**Myrcia tijucensis* Kiaersk.	H.P. Lima 355
**Myrciaria floribunda* (H.West *ex* Willd.) O.Berg.	R.S. Nunes 13
**Myrciaria tenella* (DC.) O.Berg	A. Melo 25
Neomitranthes aff. *glomerata* (D.Legrand) D.Legrand	F.C. Nettesheim 41
Plinia rivularis (Cambess.) Rotman	F.C. Nettesheim 245
Psidium cattleianum Sabine	F.C. Nettesheim 44
NYCTAGINACEAE	
Guapira opposita (Vell.) Reitz	H.P. Lima 322
OCHNACEAE	
**Ouratea cuspidata* (A.St.-Hil.) Engl.	R.S. Nunes 14
Ouratea miersii (Planch.) Engl.	M.S. Conde 674
**Ouratea oliviformis* (A.St.-Hil.) Engl.	D.C. Carvalho 70
**Ouratea parviflora* (A.DC.) Baill.	F.C. Nettesheim 226
OPILIACEAE	
Agonandra excelsa Griseb.	F.C. Nettesheim 85
PERACEAE	
Pera glabrata (Schott) Poepp. *ex* Baill.	D. Araujo 9886
PHYTOLACACEAE	
**Gallesia integrifolia* (Spreng.) Harms	F.C. Nettesheim 292
PIPERACEAE	
**Piper arboreum* Aubl.	G.M. Siqueira 78
**Piper mollicomum* Kunth	R.S. Nunes 15
Piper rivinoides Kunth	F.C. Nettesheim 195
PROTEACEAE	
Roupala aff. *meisneri* Sleumer	F.C. Nettesheim 26
QUIINACEAE	
**Quiina glazovii* Engl.	F.C. Nettesheim 143

Table 3. Continued...

Family/species	Voucher
RHAMNACEAE	
Colubrina glandulosa Perkins	F.C. Nettesheim 157
RUBIACEAE	
Amaioua intermedia Mart. *ex* Schul & Schult.f.	L.F. Menezes 585
Alseis floribunda Schott	F.C. Nettesheim 89
Bathysa stipulata (Vell.) C.Presl	F.C. Nettesheim 10
Coussarea accedens Müll.Arg.	F.C. Nettesheim 248
**Coussarea meridionalis* (Vell.) Müll.Arg.	D. Hottz 66
Coussarea nodosa (Benth.) Müll.Arg.	F.C. Nettesheim 97
Coutarea hexandra (Jacq.) K.Schum.	F.C. Nettesheim 50
**Faramea calyciflora* A.Rich. *ex* DC.	F.C. Nettesheim 236
Faramea occidentalis (L.) A.Rich.	F.C. Nettesheim 153
Guettarda viburnoides Cham. & Schltdl.	M.S. Conde 460
Ixora gardneriana Benth.	F.C. Nettesheim 159
Posoqueria latifolia (Rudge) Schult.	F.C. Nettesheim 51
Psychotria carthagenensis Jacq.	F.C. Nettesheim 91
Psychotria mapourioides DC.	F.C. Nettesheim 247
Psychotria pubigera Schltdl.	D. Hottz 25
Psychotria racemosa Rich.	D. Hottz 29
Psychotria stenocalyx Müll.Arg.	G.M. Siqueira 81
Randia armata (Sw.) DC.	D.C. Carvalho 62
**Rudgea nobilis* Müll.Arg. $^{\mathbf{DD}}$	D. Hottz 91
Simira pikia (K.Schum.) Steyerm.	F.C. Nettesheim 232
RUTACEAE	
Almeidea rubra A.St.-Hil.	F.C. Nettesheim 2
**Dictyoloma vandellianum* A.Juss	G.A. Rodrigues 2
**Esenbeckia grandiflora* Mart.	R.S. Nunes 7
Zanthoxylum rhoifolium Lam.	M.C. Souza 12
SALICACEAE	
Casearia arborea (Rich.) Urb.	A. Melo 08
**Casearia commersoniana* Cambess.	L.F. Menezes 209
**Casearia decandra* Jacq.	R.S. Nunes 10
Casearia sylvestris Sw.	F.C. Nettesheim 17
Xylosma prockia (Turcz.) Turcz.	F.C. Nettesheim 82
SAPINDACEAE	
**Allophylus heterophyllus* (Cambess.) Radlk.	R.S. Nunes 8
Allophylus petiolulatus Radlk.	F.C. Nettesheim 117
Cupania concolor Radlk.	M.S. Conde 477
**Cupania emarginata* Cambess.	H.P. Lima 321
Cupania oblongifolia Mart.	D. Araujo 1607
**Cupania racemosa* (Vell.) Radlk.	L.F. Menezes 526
Matayba guianensis Aubl.	F.C. Nettesheim 219
**Sapindus saponaria* L.	L.F. Menezes 1042
SAPOTACEAE	
Chrysophyllum flexuosum Mart. $^{\mathbf{LR2}}$	F.C. Nettesheim 173
Chrysophyllum aff. *lucentifolium* Cronquist.	F.C. Nettesheim 230
Chrysophyllum paranaense T.D.Penn. $^{\mathbf{VU}}$	F.C. Nettesheim 146
Ecclinusa ramiflora Mart. $^{\mathbf{LR2}}$	L.F. Menezes 517
**Manilkara subsericea* (Mart.) Dubard	R.S. Nunes 9
Micropholis cf. *cuneata* Pierre *ex* Glaz.	F.C. Nettesheim 67
**Micropholis crassipedicellata* (Mart. & Eichler) Pierrie $^{\mathbf{LR2}}$	G.A. Rodrigues 12
Pouteria bangii (Rusby) T.D.Penn.	F.C. Nettesheim 36
Pouteria caimito (Ruiz & Pav.) Radlk.	L.F. Menezes 1505
**Pouteria* cf. *durlandii* (Standl.) Baehni	F.C. Nettesheim 229

Table 3. Continued...

Family/species	Voucher
**Pouteria* cf. *torta* (Mart.) Radlk.	F.C. Nettesheim 131
Pradosia kuhlmannii Toledo^{EN}	L.F. Menezes 1090
SIPARUNACEAE	
Siparuna guianensis Aubl.	R. Facre 10
SOLANACEAE	
Solanum argenteum Dunal	L.F. Menezes 597
TERNSTROEMIACEAE	
**Ternstroemia brasiliensis* Cambess.	G.A. Rodrigues 9
URTICACEAE	
Cecropia pachystachya Trécul	F.C. Nettesheim 291
VERBENACEAE	
**Cytharexyllum myrianthum* Cham.	M.C. Souza 79
VIOLACEAE	
Rinorea guianensis Aubl.	F.C. Nettesheim 148
Rinorea laevigata (Sol. *ex* Ging.) Hekking	F.C. Nettesheim 231
VOCHYSIACEAE	
Vochysia oppugnata (Vell.) Warm.	M.S. Conde 469
**Qualea gestasiana* A.St.-Hil.	G.A. Rodrigues 13

Table 4. Bray-Curtis distance values among sites listed at Table 2 and included in the similarity analysis.

	PAM, RJ	PAR, RJ	TIN, RJ	IMA, RJ	RBT, RJ	UBA, SP	IGR, RJ
PAM, RJ	–						
PAR, RJ	11.8	–					
TIN, RJ	19.5	19.6	–				
IMA, RJ	18.4	15.0	16.9	–			
RBT, RJ	**21.6**	5.7	9.6	**20.2**	–		
UBA, SP	8.8	9.3	10.7	8.3	12.9	–	
IGR, RJ	7.7	10.7	10.5	8.7	3.4	18.7	–

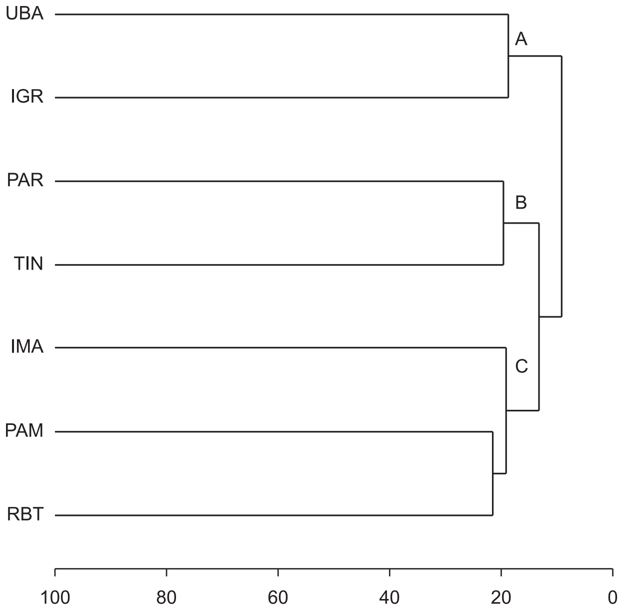

Figure 2. Similarity Cluster based on Bray-Curtis distance measure and UPGMA method. The areas considered in this Cluster are listed at Table 2 and the three similarity groups are designated by the letters A, B and C.

Grande (A), the second one composed of Cachoeiras de Macacu and Tinguá (B) and the third one formed by Marambaia, Poço das Antas and Rio Bonito (C).

Discussion

Relative to the previous study of Conde et al. (2005), the present effort represents a detection increase of 104.3% species, 44.1% genera and 26.8% families. The number of new occurrences to the area helps to ensure a more accurate description of the Marambaia slope forest flora community.

A high number of families and genera are represented by only one species. This trend has also been observed in studies at Rio de Janeiro state and other forest fragments along the Atlantic Forest extension (Silva & Nascimento 2001, Moreno et al. 2003, Peixoto et al. 2004). Some studies have pointed out that this fact is probably related to the Atlantic Forest´s diverse flora and high number of endemic species. This diversity would favor high species turnover rates, consequently diminishing the number of families and genera with more than one species (Oliveira-Filho & Fontes 2000, Scudeller et al. 2001, Oliveira-Filho et al. 2005, Nettesheim et al. 2010, Caiafa & Martins 2010).

On the other hand, the six richest families represent 48.9% of all recorded species at the area. When compared to the other 20 Atlantic Forest studies shown at Table 1, it is evident that these six families are usually the richest at Rio de Janeiro and northern São Paulo states.

Particularly prominent among these studies are Myrtaceae, Fabaceae, Lauraceae and Rubiaceae. The first two appear in 19 of the 21 areas, occupying the first or second richest status in 13 of them, while the latter two appear among the richest families respectively at 18 and 14 locations. Therefore, the high species richness found in these families at Marambaia slope forest is consistent with other nearby Atlantic Forest locations (Kurtz & Araujo 2000, Oliveira 2002, Guedes-Bruni et al. 2006a, b, Carvalho et al. 2007, 2009). These results are corroborated by a meta-analysis of 125 Atlantic Forest remnants in the Brazilian Southeastern Ombrophilous and Seasonal Forests (Oliveira-Filho & Fontes 2000). This study emphasizes Myrtaceae, Rubiaceae, Euphorbiaceae and Melastomataceae as usual detainers of the highest numbers of species at the vegetation in this region.

This same study also shows *Eugenia*, *Myrcia*, *Ocotea* and *Miconia* as the richest genera in these forests (Oliveira Filho & Fontes 2000). Therefore, given our results, the richness patterns of the genera at Marambaia slope forest seems to be consistent with the local and regional patterns detected for the Atlantic Forest at Southeastern Brazil (Peixoto & Gentry 1990, Moreno et al. 2003, Carvalho et al. 2006b, Nettesheim et al. 2010). It is thus reasonable to assume that, despite man's interference in the past, with all these richest families and genera, the Submontane Dense Ombrophilous Forest on Marambaia Island is an important remnant and its preservation must be guaranteed. A comparison of the basal area at this study (55.68 m^2) with the value at the well preserved Cachoeiras de Macacu slope forest (57.30 m^2) (Kurtz & Araujo 2000), gives support to this reasoning. This seems especially true if we consider that when four sites with different disturbance histories were evaluated at Ilha Grande (RJ), the "climax" area presented a basal area of 57.90 m^2 (Table 2). Though these last two comparisons must be seen with caution due to the different sampling methods (Table 2), the lack of studies with standardized methods led us to use the available data.

The number of species found at threatened species lists is another evidence that the Marambaia slope forest is an important Atlantic Forest remnant despite past interference. It does not have as many threatened species as the nearby Serra do Mar State Park. Gomes et al. (2011) found 35 threatened species (14% of the 251 species detected) at this location. Nevertheless, Marambaia slope forest still detains a high percentage of threatened species, especially if considering that it is not a protected area. This remnant's importance increases when taken into account the relevance of this site to the conservation of Sapotaceae. Other species that shows why this is an interesting area for conservation efforts and tree population studies are *Beilschmiedia rigida* (Mez) Koslerm., *Inga lanceifolia* Benth., *Tachigali pilgenianum* Harms, *Ficus cyclophylla* (Miq.) Miq. and *Pradosia kuhlmannii* Toledo (Table 3). According to the IUCN and MMA criteria, they are threatened of extinction and have a high risk of disappearing in the wild in the near future (Brasil 2008, International... 2010).

When compared to other studies that evaluated the floristic similarity in Atlantic Forest areas (Peixoto et al. 2004, Rolim et al. 2006, Carvalho et al. 2006b, Nettesheim et al. 2010), the similarity among the seven areas analyzed can be considered low (Table 4). This calls attention to the high tree and shrub floristic variation particularly within Submontane Dense Ombrophilous Forests. The floristic differentiation that this type of forest presents may play an important role at increasing Atlantic Forest overall vegetation diversity. These similarity results are consistent with the elevated heterogeneity highlighted in other Atlantic Forest comparison studies (Oliveira-Filho & Fontes 2000, Peixoto et al. 2004, Oliveira-Filho et al. 2005, Carvalho et al. 2006b, Rolim et al. 2006, Nettesheim et al. 2010).

Our Cluster analysis based in these similarities yielded some interesting results. Though grouped with Poço das Antas and Rio Bonito (both about 150 km distant from Marambaia Island), Marambaia slope forest is closer to Ilha Grande (~20 km) and Ubatuba (~100 km) and was initially expected to be more similar to them. According to the environmental data of the seven compared areas, Marambaia and the other locations in group C have the highest mean annual temperatures, lowest sampled altitudes and seem to present a trend toward lower rain incidence (Table 2). It appears logical to assume these characteristics also suggest that the areas in group C are drier than the other evaluated locations. Thus, it seems that the floristic resemblance of the areas in this group is most likely a consequence of environmental resemblance than geographical proximity. Such hypothesis should be further tested by future efforts, but group B represents an additional evidence to support it. At this group, Cachoeiras de Macacu appears together with Tinguá even though they are 80 km apart, and Rio Bonito is actually only 30 km away from Cachoeiras de Macacu. Of the seven evaluated locations, both Cachoeiras de Macacu and Tinguá exhibit the highest sampled altitudes and an elevated rain level. Although recent studies have highlighted that the environment is important to understand Atlantic Forest floristic patterns in Southeastern Brazil, the extent to which random processes are relevant to structure this forest is still an unanswered question (Oliveira-Filho & Fontes 2000, Oliveira-Filho et al. 2005, Nettesheim et al. 2010).

Such results suggest that, considering floristic composition, the Marambaia Island slope forest tree and shrub community is closer to slope forests at the Guanabara Graben than to the Serra do Mar Mountain range, like first suggested by the Cluster provided by Nettesheim et al. (2010). However, this difference may be a consequence of the Cluster analysis itself. As Nettesheim et al. (2010) took into consideration 32 areas, the different grouping of Marambaia slope forest at their work may be due to more available data regarding its floristic similarity with other places (including areas with different forest types). Consistently with this reasoning, when we ran the Cluster analysis with presence/absence regarding the same seven areas evaluated here, the groups formed didn't change. Thus the difference among our results and the ones at Nettesheim et al. (2010) is not necessarily a consequence of using abundance data. To ideally tackle the discrepancy between our results and those found by Nettesheim et al. (2010) it would be preferable to have quality abundance data regarding at least the 32 areas considered in their analysis.

Despite these inconsistencies, the greater resemblance of Marambaia Island slope forest and the apparently drier areas at Guanabara Graben is reasonable given our field observations. The studied vegetation seems rather dry and doesn't exhibit the conspicuous epiphytic stratum nor the dense pteridophyte community typically found at wetter forests. Given its low mean annual precipitation (Table 2), this may be a consequence of the local topography, which is not a prominent barrier to rain coming from the ocean. This same situation may be true at the other slope forests present at the Guanabara Graben and could explain why these areas, though far from each other, have a similar flora.

The present effort represents a significant update of the Marambaia slope forest tree and shrub community description. It adds a substantial amount of new species, genera and families occurrences at the area. Also, the comparison of its richest families and genera with other Atlantic Forest studies, together with the recorded basal area, seem like a robust evidence that this remnant is, despite of past interference, presently well preserved. This conclusion is further supported by the 19 endangered species detected at the area. Their detection is reasonable evidence that there can be viable and restricted populations of these species at Marambaia Island slope forest, strongly requiring the conservation of this vegetation. Our results also show that the Marambaia Island slope forest seems to be more related to Submontane Dense Ombrophilous Forests at the Guanabara Graben. Nevertheless, though similarity patterns among Atlantic Forest areas are important evidence of trends like this vegetation's high heterogeneity, there are still unanswered questions that need to be properly addressed. To efficiently give light into this discussion it would be interesting that future contributions sample standardized abundance biological and environmental data across a wide number of Atlantic Forest remnants.

Acknowledgements

To the UFRRJ Biology Institute for supporting this and other studies conducted in Marambaia; to the Marambaia Island Training Centre – CADIM, for the area access permissions and logistic backup during field activities; to the taxonomists Ariane L. Peixoto, Haroldo C. de Lima, Maria de Fátima Freitas, Alexandre Quinet, Carine Quinet, Marcelo C. Souza, Genise V. Somner, Lucy S. Vale, Elsie F. Guimarães, Fernando Regis Di Maio, Ronaldo Marquete and Inês Cordeiro for the kindness in identifying botanic materials; to the colleagues who helped in the field and in the lab; to the anonymous referees who provided valuable insights and critics that greatly improved this manuscript quality.

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Received 14/11/2011
Revised 24/07/2012
Accepted 31/07/2012

Diversidade de mamíferos de médio e grande porte da região do rio Urucu, Amazonas, Brasil

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SANTOS, F.S. & MENDES-OLIVEIRA, A.C. **Diversity of medium and large sized mammals in the Urucu basin, Amazonas, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn02712032012

Abstract: Between April 2008 and May 2009, studies on the species richness, composition and relative abundance of the medium and large sized mammals were carried out in the Urucu basin (Brazilian Amazon). The survey was conducted using line transect sampling method, active search for signs and camera-traps. A total of 41 species of 17 families and eight orders were recorded. Primates was the group with the highest species richness in sympatry (13 species), followed by carnivores (11 species). Primates, Perissodactyla, Artiodactyla and Rodentia were the most abundant groups. The high diversity of medium and large sized mammals presented here indicates the importance of the region for mammals conservation in Amazonia.
Keywords: *line transect census, active search for signs, camera-trap, species richness, composition, relative abundance.*

SANTOS, F.S. & MENDES-OLIVEIRA, A.C. **Diversidade de mamíferos de médio e grande porte da região do rio Urucu, Amazonas, Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn02712032012

Resumo: Entre abril de 2008 e maio de 2009 foram realizadas expedições para o estudo sobre a riqueza, a composição e a abundância relativa dos mamíferos de médio e grande porte na região do rio Urucu (Amazonas, Brasil). Foram empregados três métodos de amostragem: censo por transecção linear, busca ativa por vestígios e armadilhas fotográficas. No total foram registradas 41 espécies de mamíferos pertencentes a 17 famílias e oito ordens. As ordens com maior riqueza foram Primates, com 13 espécies registradas, e Carnivora, com 11 espécies registradas. Entre os grupos mais abundantes se destacaram as ordens Primates, Perissodactyla, Artiodactyla e Rodentia. A alta diversidade de espécies de mamíferos de médio e grande porte encontrada em Urucu reforça a importância desta região para a conservação da mastofauna amazônica.
Palavras-chave: *censo por transecção linear, busca ativa por vestígios, armadilhas fotográficas, riqueza, composição, abundância relativa.*

Introdução

As florestas neotropicais são conhecidas por abrigar uma alta diversidade de espécies de mamíferos (Eisenberg & Thorington 1973, Emmons 1984, Janson & Emmons 1990, Malcolm 1990, Wilson 1990, Emmons & Feer 1997, Peres 1999, Patterson et al. 2003). Somente na Amazônia brasileira são reconhecidas 399 espécies de mamíferos, sendo este o bioma com maior riqueza e endemismo do país, pois quase 58% destas espécies são exclusivas desta região (Paglia et al. 2012).

A diversidade de mamíferos não está homogeneamente distribuída ao longo de todo o bioma amazônico (Ayres & Clutton-Brock 1992, Silva et al. 2005). Silva et al. (2005) sugeriu a divisão da Amazônia em oito áreas de endemismo, tendo os principais rios como barreiras biogeográficas. No caso dos mamíferos de médio e grande porte, as maiores diferenças biogeográficas são em relação ao grupo de primatas (Ayres & Clutton-Brock 1992), enquanto que grande parte dos outros táxons possui uma distribuição ampla ao longo do bioma (Emmons & Feer 1997, Eisenberg & Redford 1999). Entretanto, nos últimos 20 anos, os padrões ecológicos da mastofauna de médio e grande porte têm sofrido variações não só em função de fatores abióticos (Ron 2000), mas também em função da intensidade da pressão antrópica (Lopes & Ferrari 2000, Ferrari et al. 2003, Michalski & Peres 2007).

A Amazônia é um dos biomas mais bem preservados do mundo, porém sua cobertura vegetal vem sendo constantemente reduzida (Fearnside 2005, Instituto... 2012). Apesar das taxas de desmatamento na região sofrerem um decréscimo nos últimos anos, mais de 6.000 km² de florestas foram desmatadas somente em 2011 (Instituto... 2012). A extração de madeira, a exploração de produtos minerais, a atividade pecuária e o cultivo de produtos agrícolas, que constituem a base das atividades econômicas na região, são responsáveis por grande parte da degradação das florestas e diminuição da biodiversidade (Barreto et al. 2005, Fearnside 2005, Nepstad et al. 2006, Davidson et al. 2012). Adicionalmente, a atividade tradicional de caça também tem tido impacto considerável sobre as populações de grandes vertebrados amazônicos, principalmente sobre os mamíferos de médio e grande porte (Bodmer et al. 1997, Peres 2000, Siren et al. 2004, Peres & Palacios 2007). Os impactos destas atividades se refletem na lista de espécies ameaçadas de extinção, a qual inclui 9% dos mamíferos com ocorrência registrada para este bioma (Machado et al. 2008).

Estudos demonstram que algumas espécies de mamíferos podem se beneficiar das alterações causadas pelas atividades antrópicas, enquanto outras podem ter sua população reduzida ou mesmo extinta localmente (Lopes & Ferrari 2000, Ferrari et al. 2003, Michalski & Peres 2007, Sampaio et al. 2010). Ahumada et al. (2011) observou que florestas fragmentadas apresentam uma redução na riqueza de espécies, redução na diversidade funcional e uma maior dominância de espécies do que áreas de florestas contínuas.

Apesar da reconhecida riqueza, os estudos sobre mamíferos amazônicos ainda são incipientes e as comunidades são fracamente amostradas, não contemplando toda a gama de espécies existentes neste bioma (Emmons & Feer 1997, Silva et al. 2001, Costa et al. 2005, Peres 2005). Além da extensão territorial e questões logísticas inerentes à Amazônia, as dificuldades metodológicas para realização de estudos com estes animais também devem ser consideradas. A diversidade de hábitos, dieta, comportamento, uso de habitats e atividades circadianas implicam em uma grande complexidade metodológica na amostragem dos mamíferos, sendo necessária a aplicação de diferentes métodos complementares na tentativa de se alcançar o máximo da comunidade de uma determinada área (Voss & Emmons 1996, Pardini et al. 2003).

Em função de sua importância biogeográfica, a região da bacia do Rio Urucu tem sido considerada como uma das áreas prioritárias para realização de inventários na Amazônia, pois apresenta uma elevada biodiversidade e alto grau de conservação de sua paisagem, tendo grande importância para a fauna ameaçada, endêmica e rara (Peres 1999, Capobianco et al. 2001). Esse conhecimento é fundamental para a compreensão dos processos ecológicos e definição de estratégias para conservação das espécies (Primack & Rodrigues 2001, Silva et al. 2001, Santos 2003). Este trabalho teve como objetivo contribuir para o conhecimento da riqueza, composição e abundância relativa das espécies de mamíferos de médio e grande porte na região do Rio Urucu.

Material e Métodos

1. *Área de estudo*

Este estudo foi realizado na área florestal da Base Operacional Geólogo Pedro de Moura (BOGPM) pertencente à empresa PETROBRAS S/A. Desde a instalação desta base, em 1986, vem sendo desenvolvidas na área atividades de exploração e produção de petróleo e gás natural. Entre os procedimentos para a extração destes recursos está a abertura de clareiras em meio à floresta, as quais são acessadas por uma estrada principal que possui cerca de 50 km de extensão e várias vicinais.

A BOGPM se localiza na Bacia do Rio Urucu, no município de Coari, Estado do Amazonas (4° 53’ 7” S e 65° 20’ 59” W) e abrange uma área de cerca de 514.000 ha (Figura 1a). Por ser uma área de acesso difícil e restrito, não existe pressão de caça ou comunidades rurais residentes nas proximidades.

A vegetação da região é composta por floresta ombrófila densa de terra firme (80 a 85% da área) e floresta ombrófila densa de várzea, apresentando dossel uniforme, árvores altas (23-32 m de altura), copas grandes e sub-bosque pouco denso (Amaral 1996, Lima Filho et al. 2001, Lima et al. 2008). O clima é tipo Afi (classificação de Köppen) com temperaturas médias anuais variando entre 25,2 °C e 26,2 °C e a precipitação anual média de 2.349 mm (Lima et al. 2008).

2. *Coleta de dados*

A coleta de dados foi realizada em cinco expedições distribuídas nos períodos seco e chuvoso entre abril de 2008 a maio de 2009. As amostragens sistemáticas da comunidade de mamíferos de médio e grande porte foram realizadas utilizando os métodos de censo por transecção linear (Emmons 1984, Buckland et al. 2001, Peres & Cunha 2011), busca ativa por vestígios (Voss & Emmons 1996) e armadilhamento fotográfico (Tomas & Miranda 2003).

Os métodos de censo por transecção linear e busca ativa por vestígios foram realizados concomitantemente. Para isso, foram estabelecidas quatro transecções de três quilômetros de extensão cada uma, distantes entre si por no mínimo três quilômetros (Figura 1b). As transecções foram percorridas sempre nos mesmos horários, no período matutino (6h 30 às 9h 30) e vespertino (14h00 às 17h00h). Os vestígios incluíram pegadas, fezes, vocalizações e carcaças de animais encontrados nas transecções (Voss & Emmons 1996). O esforço amostral empregado totalizou 378,5 km percorridos durante 45 dias de campo.

Para a amostragem com armadilhas fotográficas foram selecionados 20 pontos de amostragem ao longo da área de estudo (Figura 1b). Em cada ponto de amostragem foram colocadas duas armadilhas com distância mínima de 500 m entre elas, totalizando 40 armadilhas fotográficas (Tigrinus Modelo 6.0C, Versão 1.0). Os equipamentos foram fixados em árvores a uma altura de 40 cm do solo e foram programados para funcionar ininterruptamente durante

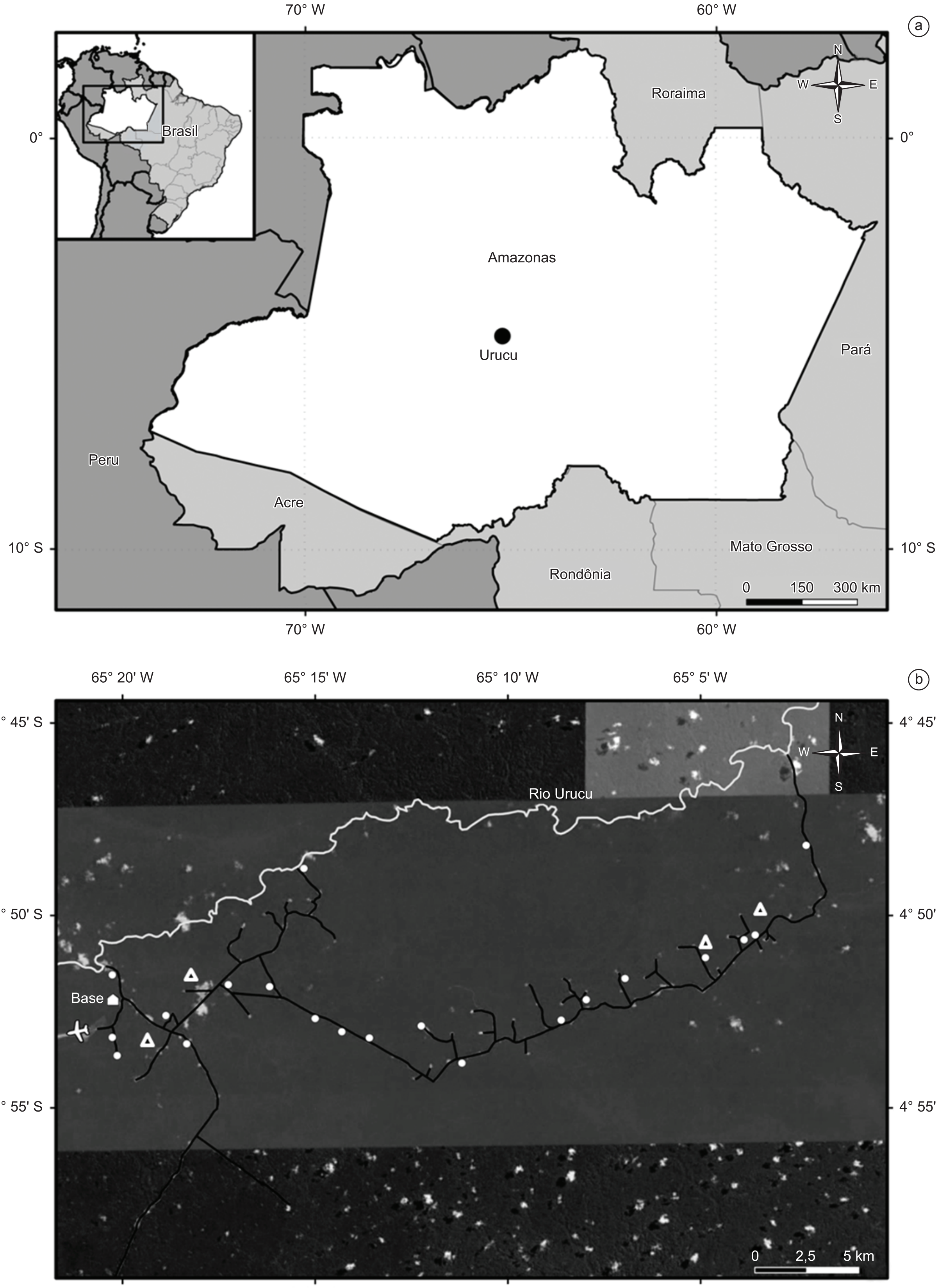

Figura 1. (a) Mapa de localização da área de estudo, Base Operacional Geólogo Pedro de Moura (BOGPM), na Bacia do Rio Urucu, Estado do Amazonas, Brasil. (b) Localização dos 20 pontos amostrados através do método de armadilhas fotográficas (círculos brancos) e das quatro transecções utilizadas para os métodos de censo por transecção linear e busca ativa por vestígios (triângulos vazados).

Figure 1. (a) Study region in Base Operacional Geólogo Pedro de Moura (BOGPM), Urucu River Basin, State of Amazonas, Brazil. (b) The 20 camera trap points (white circles) and the four transects used for mammal censuses and active search of signs (open triangles).

todo período de amostragem. As câmeras ficaram expostas durante 24 dias, totalizando um esforço amostral de 768 câmeras/dia.

Registros ocasionais como espécimes atropelados, animais atravessando as estradas ou pegadas de mamíferos nas estradas de acesso também foram incorporados à lista de composição de espécies da área.

3. *Análise de dados*

A riqueza foi dada pelo somatório de espécies amostradas através de todos os métodos aplicados, incluindo os encontros ocasionais. Para as estimativas de riqueza e cálculos de abundância relativa somente os registros obtidos nos três métodos sistemáticos foram utilizados.

Foram construídas curvas de acumulação de espécies para avaliar a relação entre o esforço amostral (em dias) e o número de espécies registradas em cada um dos três métodos empregados (Espartosa 2011). Para obter estimativas de riqueza de espécies para cada método utilizou-se o estimador não-paramétrico Jackknife de primeira ordem, realizando-se 1.000 aleatorizações na ordem das amostras. Este método estima a riqueza total somando a riqueza observada a um parâmetro calculado a partir do número de espécies raras e do número de amostras (Santos 2003). Tanto para a curva de acumulação de espécies quanto para a estimativa de riqueza foi utilizado o programa EstimateS 8.0 (Colwell 2006).

Para os métodos de censo por transecção linear e busca ativa por vestígios a abundância relativa foi baseada na taxa de avistamento para cada espécie, considerando-se o número de avistamentos/vestígios a cada 10 km percorridos (Pardini et al. 2003, Chiarello 1999). O registro de grupos sociais durante o censo por transecção linear foi contabilizado apenas como um avistamento. No caso da busca por vestígios, devido à dificuldade em diferenciar rastros de espécies semelhantes ou que apresentaram grande sobreposição de pegadas no substrato, a abundância relativa foi calculada para dois grupos: 1) *Mazama* sp. (incluindo os registros de *M. americana* e *M. nemorivaga*) e 2) Tayassuidae (incluindo os registros de *Pecari tajacu* e *Tayassu pecari*). Já para as armadilhas fotográficas, a abundância relativa foi calculada através da relação entre o número de registros de cada espécie e o esforço amostral (Silveira et al. 2003).

As espécies foram classificadas quanto ao risco de extinção utilizando-se o Livro Vermelho da Fauna Brasileira Ameaçada de Extinção (Machado et al. 2008), a Lista Vermelha das Espécies Ameaçadas (International… 2012) e a Avaliação do Estado de Conservação dos Ungulados (Instituto... 2012a).

Resultados

A riqueza total na área de estudo foi de 41 espécies de mamíferos de médio e grande porte, distribuídas em 17 famílias e oito ordens (Tabela 1). Somente a ordem dos primatas contribuiu com 31,7% da riqueza total registrada (13 espécies). O método de censo por transecção linear foi o responsável pelo registro do maior número de espécies (26), seguido pela busca ativa por vestígios (18) e pelas armadilhas fotográficas (17). Os registros ocasionais acrescentaram cinco espécies de mamíferos de médio e grande porte à riqueza total, sendo que as espécies *Tamandua tetradactyla*, *Ateles chamek* e *Aotus nigriceps* foram registradas através de observação direta e *Puma yagouaroundi* e *Speothos venaticus* através de pegadas nas estradas de acesso. Apenas três espécies foram comuns aos três métodos de amostragem (*Tapirus terrestris*, *Puma concolor* e *Dasyprocta fuliginosa*).

As curvas de acumulação de espécies obtidas para cada um dos métodos não atingiram uma assíntota com o esforço realizado (Figura 2a). O censo por transecção linear foi o método mais eficiente no registro da riqueza de espécies. A curva de acumulação de espécies mostrou que o censo por transecção linear ultrapassou o número de espécies registradas pela busca por vestígios e armadilhas fotográficas após 13 dias de amostragem. A partir do estimador não-paramétrico Jackknife 1 obteve-se uma estimativa de riqueza de 30 espécies para o método de transecção linear, 24 espécies para a busca por vestígios e 23 espécies para armadilha fotográfica (Figura 2b).

A abundância relativa total para o método de censo por transecção linear foi de 5,5 avistamentos/10 km. Somente a ordem Primates registrou 3,78 avistamentos/10 km, o que corresponde a cerca de 68% do total. As espécies com maior abundância relativa foram *Lagothrix cana* (1,03 avistamentos/10 km), *Saguinus pileatus* (0,98 avistamentos/10 km) e *Sapajus macrocephalus* (0,77 avistamentos/10 km). As ordens Perissodactyla e Pilosa foram menos abundantes (*T. terrestris* com 0,13 avistamentos/10 km e *Myrmecophaga tridactyla* com 0,05 avistamentos/10 km) (Tabela 1).

Já pelo método de busca de vestígios, as ordens Artiodactyla e Perissodactyla obtiveram os maiores valores de abundância relativa,

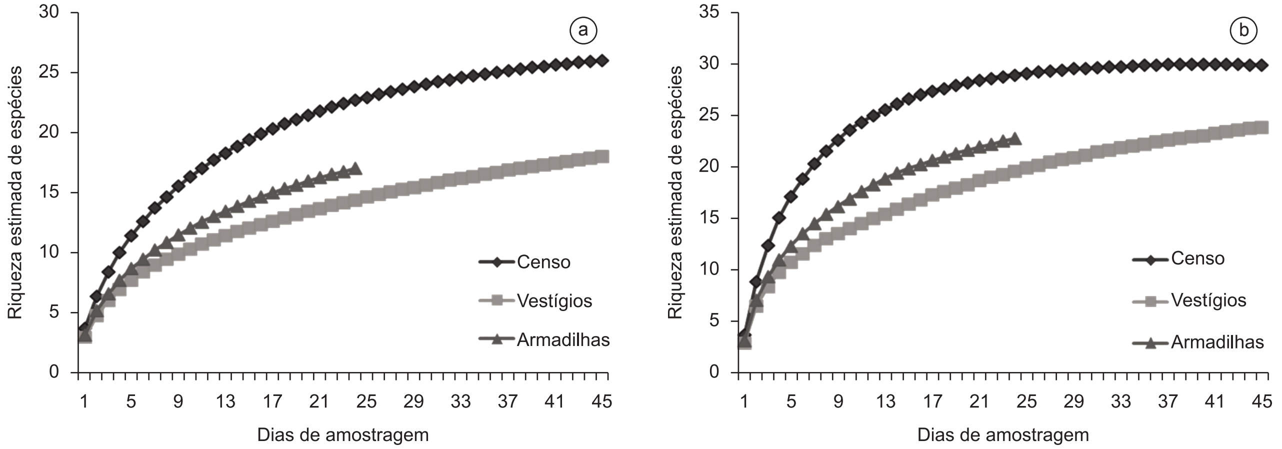

Figura 2. Curva de acumulação de espécies observadas (a) e obtidas através do estimador não-paramétrico Jackknife 1 (b) a partir do esforço amostral (em dias) de cada método empregado na obtenção dos registros de mamíferos de médio e grande porte para a região do Rio Urucu, Amazonas, Brasil.

Figure 2. Accumulation curve of species observed (a) and obtained by non-parametric Jackknife 1 estimator (b) from the sampling effort (in days) of medium and large sized mammals in the Urucu region, Amazonas, Brazil.

Tabela 1. Lista de espécies de mamíferos registradas na região do Rio Urucu (Amazonas, Brasil), abundância relativa por método e estado de conservação.

Table 1. Mammals species list, relative abundance for each method and conservation status in the Urucu region, Amazonas, Brazil.

Táxon	**Métodos de detecção**				**Status Br[1]/Int[2]**
	Abundância relativa			**Outro**	
	CTL	**BAV**	**AF**		
Artiodactyla					
Mazama americana (Erxleben, 1777)	0,13	0,87[4]	0,014	*c*	DD[3]/DD
Mazama nemorivaga Cuvier 1817	0,05		-	*c*	DD[3]/LC
Pecari tajacu (Linnaeus, 1758)	0,03	1,11[4]	0,003	*c*	LC[3]/LC
Tayassu pecari (Link, 1795)	0,11		0,003	*c*	LC[3]/NT
Carnivora					
Atelocynus microtis (Sclater, 1883)	-	-	0,001	*c*	DD/NT
Eira barbara (Linnaeus, 1758)	0,16	-	0,001	*c*	NA/LC
Galictis vittata (Schreber, 1776)	-	-	-	*c*	NA/LC
Leopardus pardalis (Linnaeus,1758)	-	0,08	0,007	*c*	NA/LC
Leopardus wiedii (Schinz, 1821)	-	0,05	-	*c*	VU/NT
Lontra longicaudis (Olfers, 1818)	-	-	-	*c*	NA/DD
Nasua nasua (Linnaeus, 1766)	0,05	-	-	*c*	NA/LC
Panthera onca (Linnaeus, 1758)	-	0,03	0,003	*c*	VU/NT
Potos flavus (Schreber, 1774)	-	-	-	*c*	NA/LC
Procyon cancrivorus (G.[Baron] Cuvier, 1798)	-	-	0,001	*c*	NA/LC
Pteronura brasiliensis (Gmelin, 1788)	0,03	-	-	*c*	VU/EN
Puma concolor (Linnaeus,1771)	0,03	0,03	0,004	*c*	NA/LC
Puma yagouaroundi (É. Geoffroy Saint-Hilaire,1803)	-	-	-	*b;c*	NA/LC
Speothos venaticus (Lund, 1842)	-	-	-	*b;c*	VU/NT
Cingulata					
Dasypus kappleri Krauss, 1862	-	-	-	*c*	NA/LC
Dasypus novemcinctus Linnaeus,1758	-	-	-	*c*	NA /LC
Dasypus sp. Linnaeus,1758	-	0,05	0,001		
Priodontes maximus (Kerr, 1792)	-	0,03	-	*c*	VU/VU
Didelphimorphia					
Didelphis marsupialis Linnaeus,1758	-	-	0,004	*c*	NA/LC
Perissodactyla					
Tapirus terrestris (Linnaeus, 1758)	0,13	1,88	0,053	*c*	LC[3]/VU
Pilosa					
Bradypus variegatus Schinz, 1825	-	-	-	*c*	NA /LC
Choloepus didactylus (Linnaeus, 1758)	-	0,03	-	*c*	NA /LC
Cyclopes didactylus (Linnaeus,1758)	-	-	-	*c*	NA /LC
*Myrmecophaga tridactyla (*Linnaeus, 1758)	0,05	-	0,005	*c*	VU/VU
Tamandua tetradactyla (Linnaeus, 1758)	-	-	-	*a; c*	NA /LC
Primates					
Alouatta seniculus (Linnaeus,1766)	0,08	0,03	-	*c*	DD/LC
Aotus nigriceps Dollman,1909	-	-	-	*a;c*	NA/LC
Ateles chamek (Humboldt, 1812)	-	-	-	*a; c*	NA/EN
Callicebus cupreus (Spix,1823)	0,16	-	-	*c*	NA/LC
Callicebus torquatus (Hoffmannsegg,1807)	0,18	-	-	*c*	NA/LC
Cebuella pygmaea (Spix, 1823)	0,03	-	-	*c*	NA/LC
Cebus albifrons (Humboldt, 1812)	0,08	-	0,001	*c*	NA/LC

Métodos: censo por transecção linear (CTL), busca ativa por vestígios (BAV), armadilha fotográfica (AF); Outros: presença confirmada por observação direta ocasional (*a*), presença confirmada por registro ocasional de pegadas (*b*), presença confirmada segundo Peres 1999 (*c*); Estado de conservação (Br[1] - lista brasileira de espécies ameaçadas segundo Machado et al 2008; Int[2] - lista internacional de espécies ameaças segundo IUCN 2012; [3]espécies de ungulados avaliadas segundo ICMBio 2012): não avaliado (NA), dados insuficientes (DD), pouco preocupante (LC), quase ameaçado (NT), vulnerável (VU), ameaçado (EN); [4]Abundância relativa calculada para *Mazama* sp. e Tayassuidae.

Methods: line transect census (CTL), active search for signs (BAV), camera trap (AF); Others: occasional observation (*a*), occasional tracks (*b*) and registered by Peres 1999 (*c*); Conservation status (Br[1] - following Machado et al 2008; Int[2] - following IUCN 2012; [3]following ICMBio 2012): not evaluated (NA), data deficient (DD), least concern (LC), near threatened (NT), vulnerable (VU), endangered (EN); [4]Relative abundance of *Mazama* sp. and Tayassuidae.

Tabela 1. Continuação...

Táxon	Métodos de detecção				Status Br[1]/Int[2]
	Abundância relativa			Outro	
	CTL	BAV	AF		
Lagothrix cana (E. Geoffroy, 1812)	1,03	0,26	-	*c*	NA/EN
Pithecia albicans Gray,1860	0,26	0,03	-	*c*	NA/VU
Saguinus fuscicollis avilapiresi (Hershkovitz, 1966)	0,05	-	-	*c*	NA/LC
Saguinus pileatus (I. Geoffroy & Deville, 1848)	0,98	0,24	-	*c*	NA/LC
Saimiri macrodon (Elliot, 1907)	0,16	0,08	-	*c*	NA/LC
Sapajus macrocephalus Spix, 1823	0,77	0,05	-	*c*	NA/LC
Rodentia					
Coendou prehensilis (Linnaeus, 1758)	-	-	-	*c*	NA/LC
Cuniculus paca (Linnaeus, 1766)	-	0,24	0,010	*c*	NA/LC
Dasyprocta fuliginosa Wagler, 1832	0,26	0,37	0,029	*c*	NA/LC
Guerlinguetus ignitus (Gray, 1867)	0,18	-	-	*c*	NA/DD
Microsciurus flaviventer (Gray, 1867)	0,05	-	-	*c*	NA/DD
Myoprocta pratti Pocock, 1913	0,11	-	-	*c*	NA/LC
Urosciurus spadiceus Olfers, 1818	0,34	-	0,003	*c*	NA/LC

Métodos: censo por transecção linear (CTL), busca ativa por vestígios (BAV), armadilha fotográfica (AF); Outros: presença confirmada por observação direta ocasional (*a*), presença confirmada por registro ocasional de pegadas (*b*), presença confirmada segundo Peres 1999 (*c*); Estado de conservação (Br[1] - lista brasileira de espécies ameaçadas segundo Machado et al 2008; Int[2] - lista internacional de espécies ameaças segundo IUCN 2012; [3]espécies de ungulados avaliadas segundo ICMBio 2012): não avaliado (NA), dados insuficientes (DD), pouco preocupante (LC), quase ameaçado (NT), vulnerável (VU), ameaçado (EN); [4]Abundância relativa calculada para *Mazama* sp. e Tayassuidae.

Methods: line transect census (CTL), active search for signs (BAV), camera trap (AF); Others: occasional observation (*a*), occasional tracks (*b*) and registered by Peres 1999 (*c*); Conservation status (Br[1] - following Machado et al 2008; Int[2] - following IUCN 2012; [3]following ICMBio 2012): not evaluated (NA), data deficient (DD), least concern (LC), near threatened (NT), vulnerable (VU), endangered (EN); [4]Relative abundance of *Mazama* sp. and Tayassuidae.

destacando-se *T. terrestris* (1,88 registros/10 km)*,* Tayassuidae (1,11 registros/10 km) e *Mazama* sp. (0,87 registros/10 km). Seis espécies de primatas foram registradas através de vocalizações, destacando-se *L. cana* (0,26 registros/10 km) (Tabela 1).

As espécies mais comumente amostradas pelo método de armadilhas fotográficas foram *T. terrestris* (0,053) e *D. fuliginosa* (0,029)*,* representando 57,3% da abundância relativa total. Cinco espécies foram fotografadas apenas uma vez (*Dasypus* sp., *Cebus albifrons*, *Atelocynus microtis*, *Eira barbara* e *Procyon cancrivorus*) obtendo uma abundância relativa de 0,001. Apesar da baixa abundância, uma maior riqueza de espécies de carnívoros foi registrada através das armadilhas fotográficas, totalizando seis espécies (Tabela 1; Figura 3).

Entre os mamíferos registrados, seis encontram-se na Lista Brasileira de Espécies Ameaçadas de Extinção do Ministério do Meio Ambiente (Machado et al. 2008) e sete espécies figuram na Lista Vermelha da IUCN (International… 2012) (Tabela 1).

Discussão

A riqueza observada em Urucu corresponde a 85,4% das espécies de mamíferos de médio e grande porte registradas em um estudo anterior realizado nos anos de 1988 e 1989 por Peres (1999). Ambos os estudos evidenciaram a alta diversidade da mastofauna nesta região de floresta contínua. Outros estudos realizados também na porção ocidental da Amazônia apresentaram variações na riqueza de espécies. Iwanaga (2004) amostrou 42 espécies para o Parque Nacional do Jaú (PNJ), enquanto que Haugaasen & Peres (2007) registraram 27 espécies no Lago Uauaçú, no rio Purus, e Patton et al. (2000) estudando diversas áreas ao longo do rio Juruá, encontrou 18 espécies na área a jusante do rio, 21 espécies na porção central, ambas localizadas no estado do Amazonas, e 28 espécies na cabeceira do rio, no estado do Acre.

A riqueza de espécies de primatas coexistindo na região do rio Urucu superou a riqueza encontrada em vários estudos, incluindo áreas com alto nível de preservação. Na Amazônia oriental, Lopes & Ferrari (2000) e Ferrari et al. (2003) registraram apenas sete e oito espécies na Reserva Biológica do Gurupi (Maranhão) e na região do rio Tapajós (Pará). Já na Amazônia ocidental, Röhe (2007) encontrou 10 espécies de primatas vivendo em simpatria na região do rio Madeira e Peres (1997) e Patton et al. (2000) observaram 12 espécies ao longo do rio Juruá.

Esta alta diversidade de primatas registrada em Urucu comparada a outros estudos corrobora a hipótese de que há um incremento na diversidade de mamíferos no sentido leste-oeste em função de um gradiente longitudinal na Amazônia (Voss & Emmons 1996, Peres & Janson 1999, Silva et al. 2001). Além disso, a variação no número de espécies simpátricas pode ser atribuída aos diferentes tipos florestais e a diversidade de habitat (Peres & Janson 1999). Em comunidades de primatas observa-se que áreas de terra firme podem apresentar riqueza e índices de diversidade significativamente maiores do que em florestas de várzea (Peres 1997).

Apesar da alta riqueza de espécies de primatas na região de Urucu, a abundância das espécies foi menor se comparada aos estudos desenvolvidos na região do rio Juruá (Peres 1997) ou do rio Purus (Haugaasen & Peres 2007). A abundância em Urucu apresentou valores mais próximos aos encontrados para o PNJ (Iwanaga 2004). Isto pode ser explicado pela disponibilidade de nutrientes no solo, os quais podem influenciar nos padrões de distribuição de primatas (Janzen 1974, Emmons 1984, Peres 1999). Florestas associadas aos rios de água branca, como os rios Juruá e Purus, recebem sazonalmente uma alta carga de nutrientes e sedimentos que tendem

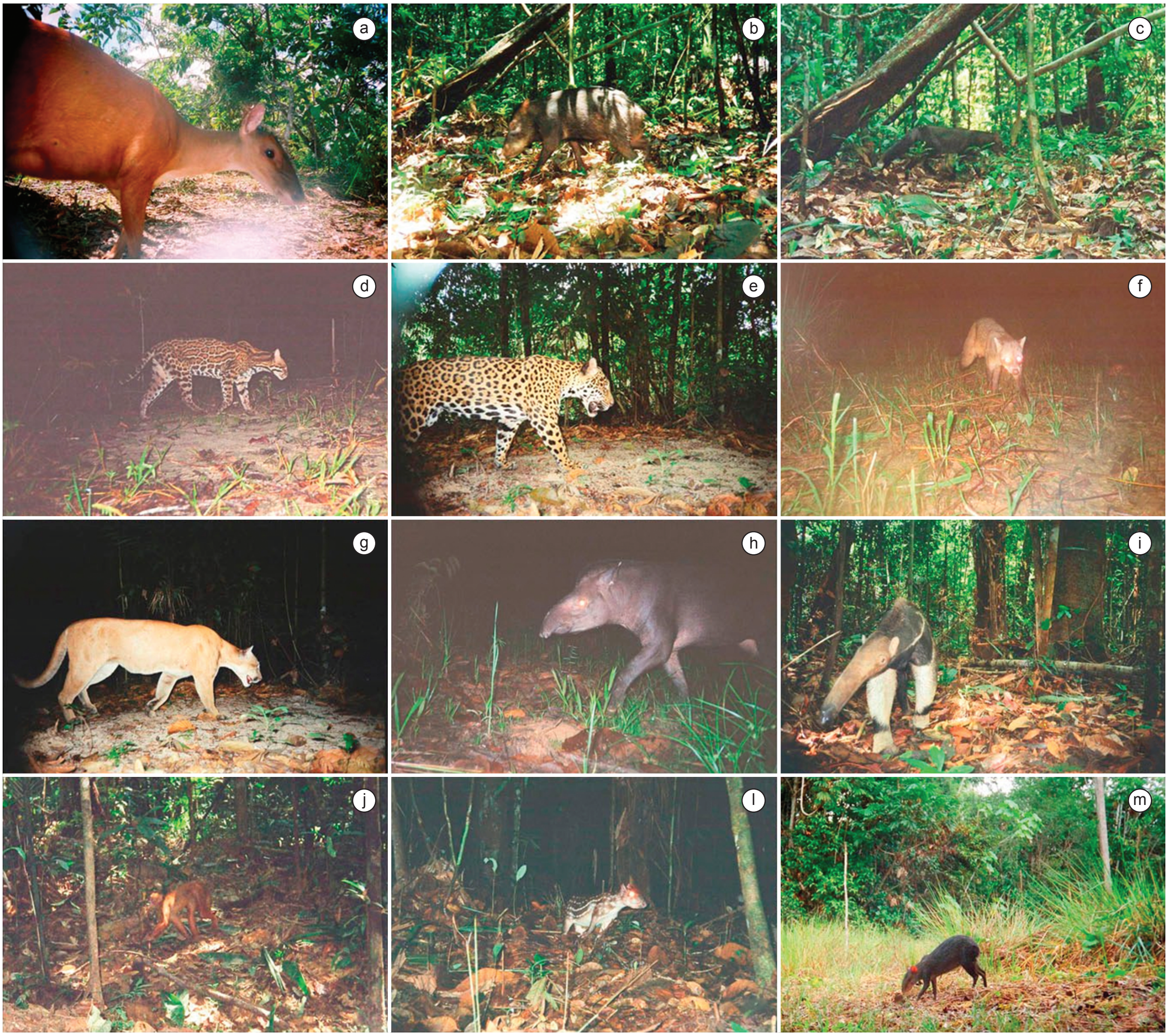

Figura 3. Espécies registradas através das armadilhas fotográficas: (a) *Mazama americana,* (b) *Tayassu pecari*, (c) *Atelocynus microtis*, (d) *Leopardus pardalis*, (e) *Panthera onca*, (f) *Procyon cancrivorus*, (g) *Puma concolor*, (h) *Tapirus terrestris*, (i) *Myrmecophaga tridactyla*, (j) *Cebus albifrons*, (l) *Cuniculus paca* e (m) *Dasyprocta fuliginosa*.

Figure 3. Species registered by camera trap: (a) *Mazama americana,* (b) *Tayassu pecari*, (c) *Atelocynus microtis*, (d) *Leopardus pardalis*, (e) *Panthera onca*, (f) *Procyon cancrivorus*, (g) *Puma concolor*, (h) *Tapirus terrestris*, (i) *Myrmecophaga tridactyla*, (j) *Cebus albifrons*, (l) *Cuniculus paca* e (m) *Dasyprocta fuliginosa*.

a aumentar a produtividade das plantas e, consequentemente, favorecerem os animais que possuem uma dieta baseada em folhas e frutos. Já as florestas associadas aos rios de água preta, como a região de Urucu e o Parque Nacional do Jaú, são caracterizadas tipicamente por apresentarem solos pobres em nutrientes, refletindo em uma menor abundância das espécies frugívoras e folívoras (Janzen 1974, Emmons 1984, Peres 1999).

Com relação à amostragem da mastofauna, a utilização de diferentes métodos foi fundamental para registrar a alta riqueza da comunidade de mamíferos na área de estudo. As curvas de acumulação de espécies não estabilizaram para nenhum dos métodos empregados e mesmo as estimativas de riqueza demonstraram que individualmente nenhum dos três métodos alcançaria todas as espécies esperadas para a área.

A seletividade dos métodos pode ser observada em estudos que utilizam transecção linear (Haugaasen & Peres 2007, Michalski & Peres 2007, Parry et al. 2007), os quais registram muito bem a fauna diurna, principalmente os primatas. Enquanto que estudos com armadilhas fotográficas raramente detectam os mamíferos arborícolas, mas são eficientes para animais noturnos e com hábitos discretos como, por exemplo, os carnívoros (Maffei et al. 2002, Silveira et al. 2003, Srbek-Araujo & Chiarello 2005, Kasper et al. 2007, Tobler et al. 2008). A busca ativa por vestígios foi bastante eficiente na amostragem de animais terrestres, complementando o método de armadilhamento fotográfico.

Estudos em áreas abertas ou fragmentos florestais demonstram que a eficiência do método está atrelada às características da fauna local, sendo que nestas áreas o uso de armadilhas fotográficas ou censo de rastros/parcelas de areia podem ser mais indicados para a amostragem de mamíferos de médio e grande porte (Silveira et al. 2003, Espartosa et al. 2011). No caso de florestas amazônicas aonde a diversidade de primatas é alta, o censo por transecção linear é um método indispensável para a avaliação da comunidade de mamíferos de uma área (Peres & Cunha 2011).

Como a abundância das espécies pode ser influenciada pela seletividade dos métodos adotados, optou-se neste trabalho por analisar cada método separadamente, considerando as limitações de cada um (Kasper et al. 2007). Os resultados demonstram que o censo por transecção linear revelou uma maior abundância relativa da mastofauna arborícola, subestimando a mastofauna terrestre. O contrário foi observado para os métodos de busca por vestígios e armadilhas fotográficas, nos quais a abundância relativa dos mamíferos terrestres foi maior.

A alta diversidade de espécies de mamíferos de médio e grande porte registrada neste estudo reforça a importância da região do rio Urucu para a conservação da mastofauna amazônica. Além do grande número de primatas, a riqueza de felinos e canídeos, representando animais de topo de cadeia, e a presença e abundância de grandes herbívoros, como veados, porcos-do-mato e antas, demonstram o alto nível de conservação desta região.

Apesar dos muitos anos de exploração mineral na região, a localização remota e o acesso restrito à área da BOGPM acabam permitindo que os mamíferos de médio e grande porte não sejam diretamente afetados por fatores como desflorestamento, perda de habitat e pressão de caça, os quais constituem as principais causas para o declínio populacional das espécies de grandes vertebrados na Amazônia (Machado et al. 2008, International… 2012).

A presença de espécies ameaçadas de extinção, principalmente daquelas que possuem uma área de ocorrência restrita, como *Pithecia albicans*, endêmica do Amazonas, e *Lagothrix cana* (Eisenberg & Redford 1999, International… 2012), ou que são consideradas espécies-chave nos ecossistemas, como *Panthera onca*, *Leopardus wieddi* e *Speothos venaticus*, fomenta a necessidade de estudos específicos sobre a biologia dessas espécies, bem como de um monitoramento em longo prazo da comunidade de mamíferos face às atividades de exploração na área. Estudos deste tipo podem fornecer dados importantes não só para a conservação de espécies ameaçadas, mas também para espécies pouco conhecidas pela ciência como, por exemplo, *Atelocynus microtis*.

Agradecimentos

Agradecemos ao Museu Paraense Emílio Goeldi, Universidade Federal do Pará, FINEP e PETROBRÁS pelo apoio na realização deste projeto; a Dra. Ana Lúcia da Costa Prudente, a Susanne L. de Maria e Renata C. Soares de Lima pelo apoio nas expedições de campo; à Marcelo J. Sturaro pela formatação do mapa da área; à Walfrido M. Tomas pela ajuda na identificação dos rastros; a Capes pela bolsa de Mestrado.

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Recebido em 28/02/2012
Versão reformulada recebida em 24/08/2012
Publicado em 27/08/2012

New records confirming the occurrence of the ghost shrimps *Biffarius biformis* (Biffar, 1970) and *B. fragilis* (Biffar, 1971) (Decapoda, Callianassidae) in Brazil and the southwestern Atlantic

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BOTTER-CARVALHO, M.L., CARVALHO, P.V.V.D.B.C. & SANTOS, P.J.P. **New records confirming the occurrence of the ghost shrimps *Biffarius biformis* (Biffar, 1970) and *B. fragilis* (Biffar, 1971) (Decapoda, Callianassidae) in Brazil and the southwestern Atlantic.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02012032012

Abstract: Previous records of the callianassid ghost shrimps *Biffarius biformis* (Biffar, 1971) and *Biffarius fragilis* (Biffar, 1970) from Pernambuco, northeastern Brazil, were considered as doubtful, because their original record (Carvalho et al. 1997) in a conference abstract cannot be considered as a valid publication. The original material examined by Carvalho et al. (1997) combined with the more recently collected material of *B. biformis* and *B. fragilis*, confirm the presence of these two species in Brazil and the southwestern Atlantic. Taxonomic and ecological remarks, as well as illustrations, are provided for both species.
Keywords: *Callianassidae, Biffarius, new records, Brazil, Atlantic Ocean.*

BOTTER-CARVALHO, M.L., CARVALHO, P.V.V.D.B.C. & SANTOS, P.J.P. **Novos registros confirmam a ocorrência dos camarões fantasma *Biffarius biformis* (Biffar, 1970) e *B. fragilis* (Biffar, 1971) (Decapoda, Callianassidae) no Brasil e sudoeste do Atlântico.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02012032012

Resumo: A ocorrência dos camarões fantasma *Biffarius biformis* (*Biffar* 1971) e *Biffarius fragilis* (Biffar 1970) no nordeste do Brasil têm sido considerada duvidosa, porque o registro original (Carvalho et al. 1997) realizado em resumo durante uma conferência regional não pode ser considerado válido. Neste trabalho, o estudo dos espécimens examinados por Carvalho et al. (1997), combinados com o material coletado mais recentemente, confirma a presença dessas duas espécies na costa brasileira e no sudoeste do Atlântico. São fornecidas novas informações taxonômicas, ecológicas e ilustrações.
Palavras-chave: *Callianassidae, Biffarius, novos registros, Brasil, Oceano Atlântico.*

Introduction

Ghost-shrimps of the family Callianassidae (Axiidea) are among the most common burrowing crustaceans in coastal soft-bottom environments, with about 54% of all known species found in very shallow waters (0-2 m) (Dworschak 2004). About 155 callianassid species are known worldwide, 39 of them in the western Atlantic (Dworschak 2000); the majority of species are distributed in the Indo-West Pacific (Sakai 1999b, Dworschak 2000).

Seventeen species of callianassids have been reported for Brazil (Rodrigues 1971, Coelho & Ramos-Porto 1986, Manning & Felder 1991, Rodrigues & Manning 1992a, b, Manning & Lemaitre 1993, Botter-Carvalho et al. 1995, Coelho 1997, Melo 1999, Coelho et al. 2007). However, the actual species richness of these cryptic bioturbators may be heavily underestimated, which is partly due to sampling difficulties (see Garcia et al. 2003).

The genus *Biffarius* Manning and Felder, 1991 includes 11 small-sized species worldwide (Sakai 1999b, Tudge et al. 2000, Guzmán & Thatje 2003, Poore 2008), three in the Atlantic Ocean and eight in the Pacific Ocean. At present, three species of this genus are known from Brazil: *Biffarius delicatulus* Rodrigues & Manning, 1992, originally described from the coasts of São Paulo, and *B. biformis* (Biffar, 1971b) and *B. fragilis* (Biffar, 1970), both briefly reported from Pernambuco (Carvalho et al. 1997). However, only the description of *B. delicatulus* may be accepted as a valid record of *Biffarius* in Brazil. The records of the two northeastern congeners appeared in abstracts of a local conference (Carvalho et al. 1997), which was later merely cited by Coelho (1997) in his revision of the "Thalassinidea" (now Axiidea + Gebiidea). Coelho (1997) clearly stated that did not examine any specimens of *B. biformis* and *B. fragilis*. Melo (1999), in his major treatment of Anomura and "Thalassinidea", also referred to Carvalho et al. (1997) as being the first record of these two species in Brazil. More recently, Coelho et al. (2007) included *B. biformis* and *B. fragilis* in their checklist of Brazilian decapod crustaceans, based on the same earlier listing in Coelho (1997). Applying Article 9 of the International Code of Zoological Nomenclature (1999) the original record of *B. biformis* and *B. fragilis* (Carvalho et al. 1997) is not a published study, making the Brazilian records of these two species doubtful.

The present study is the first formal confirmation of the presence of *B. biformis* and *B. fragilis* in Brazil and the southwestern Atlantic, based on the material originally examined by Carvalho et al. (1997), as well as more recently (2003) collected material. The Brazilian material is illustrated and some taxonomic and ecological notes are provided.

Materials and Methods

All specimens of *Biffarius biformis* and *B. fragilis* were collected in the intertidal habitats of Pernambuco, northeastern Brazil (Figure 1). The northern sampling site (Site 1 - 7° 48'44" S and 34° 48' 48" W) is located at Itamaracá Island next to the mouth of Santa Cruz Channel, which connects a large estuarine complex composed of several small rivers (Figure 1). At this site, the ghost shrimps were collected in the intertidal zone of a sandy beach (Praia do Forte Orange). The superficial layer of sediment consists of well-sorted coarse sand and the depth of the redox potential discontinuity layer is approximately 10 cm. The anoxic layer consists of fine sand and mud sediments with abundant biogenic detritus. Salinity range during low tide is 31.0-34.5‰. The southern sampling sites (Site 2 and 3) are located in a southern area of Praia da Casa Caiada (7° 59' 42" S, 34° 49' 48" W and 7° 58' 15" S and 34° 49' 49" W, respectively), an urban beach polluted by domestic sewage (Figure 1). The beach is semi-enclosed by a groyne and a series of seven seawalls, which favour the deposition of fine sediments and increased water temperature and salinity mainly during summer (Pereira et al. 1996). Site 2 is located approximately 100 m outward from the shoreline, and is characterized by a depositional environment formed by an inshore gravel bank adjacent to the seawall. Site 3 is located in the intertidal zone of Praia da Casa Caiada (Figure 1). The sediment (muddy sand) here is poorly oxygenated, superficially covered by conspicuous microphytobenthic patches, and has a dense population of the snail *Neritina virginea* (L.). Pereira et al. (1996) reported the range of salinity and water temperature of 36.3-30.0‰ and 31.3-28.0 °C during summer and winter, respectively. Site 2 is characterized by moderate to poorly sorted quartz sand and 95% biogenic debris (Pereira et al. 1996); the sub-surface layer is characterized by well-sorted fine sand.

Sampling took place during low tide, in the intertidal zone, using a bait suction ("yabby") pump, modified from that of Hailstone & Stephenson (1961). The pumped water (with sediments) was sieved through a 0.3 mm mesh to retain callianassids and other gallery-associated infauna. All samples were fixed in 4% buffered seawater-formaldehyde solution and 24 hours later transferred into 70% ethanol. Biometric measurements were made using a digital caliper (0.1 mm) or a micrometric eyepiece, following Biffar (1971a) for morphometric standards. Drawings were made with the aid of a stereomicroscope equipped with a camera lucida.

At site 1, the density of ghost shrimp burrows was estimated as the mean number of burrow openings per m^2 along five transects. At sites 2 and 3, this estimation was not possible due to co-occurrence of other infaunal, burrowing organisms, such as polychaetes and stomatopods.

The following abbreviations are used in the text: CL, carapace length (mm); TL, total length (mm); MZUSP, Museu de Zoologia da Universidade de São Paulo.

Taxonomic Section

Biffarius biformis (Biffar, 1971b)

Callianassa biformis Biffar 1971b: 225, Figure 1. – Rabalais et al. 1981: 101.

Biffarius biformis – Manning & Felder 1991: 769.

Material examined: Brazil, Pernambuco: Itamaracá Island, Praia do Forte Orange, Site 1, 1 ♂ (4.17 mm CL), 23.XI.1995 (MZUSP 19074); Itamaracá Island, Praia do Forte Orange, Site 1, 1 ovigerous ♀ (5.20 mm CL, 24.1 mm TL), 23.XI.1995 (MZUSP 19072); Olinda, Praia da Casa Caiada, Site 2, 1 ♀ (4.73 mm CL), 23.XII.2003 (MZUSP 19073).

Ecology: *Biffarius biformis* was collected in the lower intertidal only. Burrow openings were very sparse ($<0.1.m^{-2}$), small (1-2 mm diameter) and rather inconspicuous, without mound-like accumulation of sediments. No commensals were observed in sieved sediments. The lower intertidal was largely dominated by the callianassid *Neocallichirus maryae* Karasawa, 2004, with some specimens of *Callichirus major* (Say 1818), and, in muddy patches near the low-tide level, *Sergio guassutinga* (Rodrigues 1971). Galleries of these ghost shrimps were inhabited by the pinnotherid crabs *Austinixa aidae* (Righi 1967) and *Pinnixa* sp.; small reddish polyclads were found only in galleries of *S. guassutinga*.

Biffarius biformis was previously recorded from both intertidal and subtidal habitats, burrowing in fine sand or mud bottoms (Biffar 1971b, Dörges 1972, Holland & Polgar 1976, Rabalais et al. 1981, Prezant et al. 2002). Rabalais et al. (1981) stated that *B. biformis* is

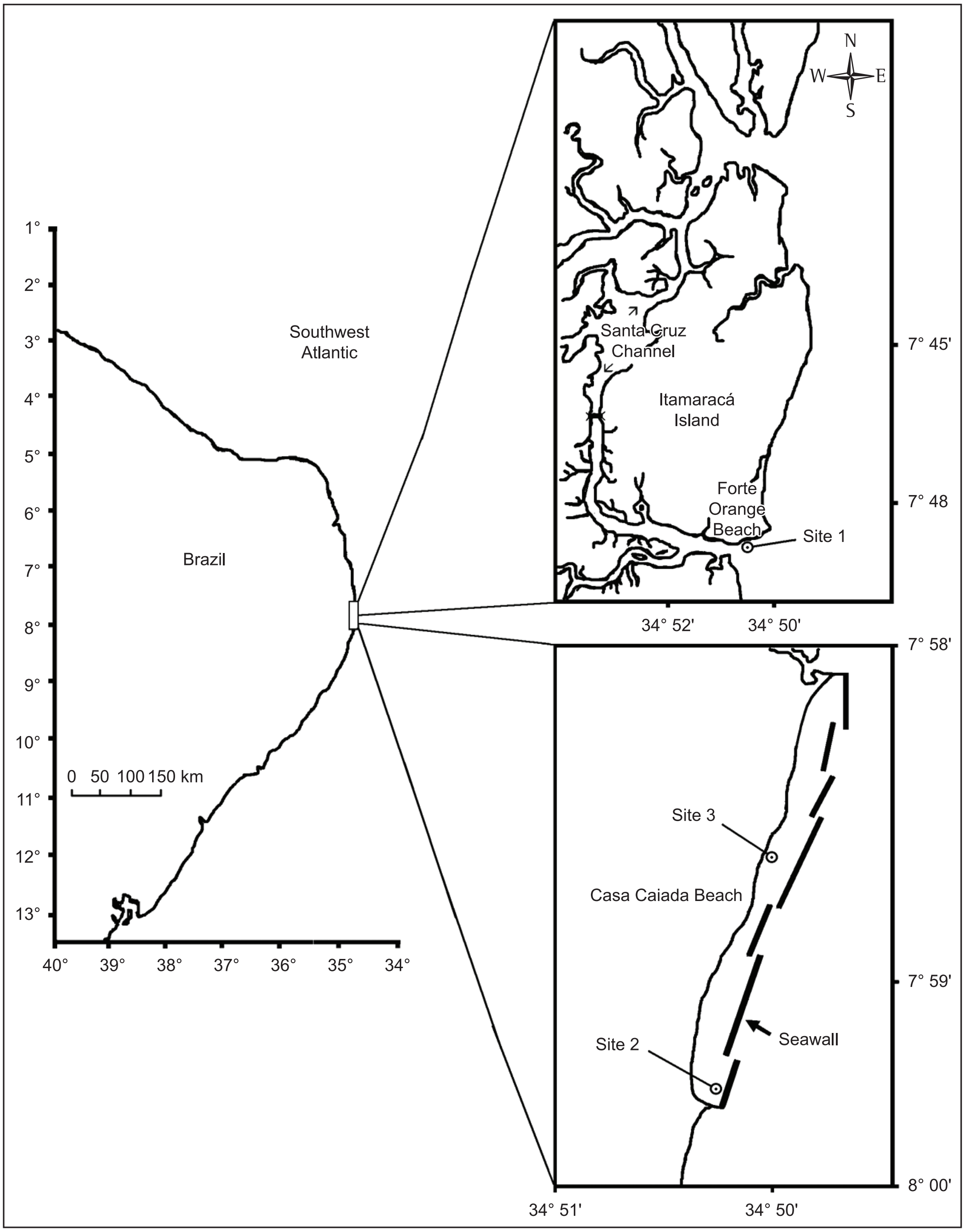

Figure 1. Map of the northeastern Brazilian coast showing localities of sampling sites.

the second most abundant "thalassinidean" on the outer continental shelf in the northwestern Gulf of Mexico (off southern Texas).

Distribution: Western Atlantic. USA: Atlantic coast from Massachusetts to Florida and Gulf of Mexico coast from Florida to Texas (Biffar 1971a, Rabalais et al. 1981, Williams 1984, Prezant et al. 2002, Heard et al. 2007); Brazil: Pernambuco (present study).

Remarks: The Brazilian specimens agree with the majority of the diagnostic features of *B. biformis* (as *Callianassa biformis*) given by Biffar (1971b). The major cheliped of Brazilian male individuals resembles the "strong" cheliped described by Biffar (1971b), differing from it only in the absence of fine elongate setae on the dorsal and ventral margins of the ischium and ventral margins of the merus, carpus and palm (Figure 2). On the other hand, the median spine on the telson mentioned as a diagnostic feature of *B. biformis* by Sakai (1999b), was not observed in the Brazilian material, which agrees with the description of Biffar (1971b). The paired lateral spiniform setae at each posterolateral corner of the telson described in the holotype by Biffar (1971b) are rather inconspicuous in the Brazilian material. Finally, in the Brazilian specimens, the distal margin of the telson is straight (Figure 2), whereas in the holotype of *B. biformis*, it was illustrated as slightly convex (Biffar 1971b). Generally, the tail fan of the Brazilian specimens matches more the drawing of individuals from the western Gulf of Mexico (Texas) provided by Rabalais et al. (1981).

Rodrigues & Manning (1992a) compared the main diagnostic features of *B. biformis* and *B. delicatulus* from southeastern Brazil and concluded that the two species are morphologically very close. However, the specimens examined here and identified as *B. biformis* clearly differ from *B. delicatulus*, for instance, in the armed ischium of the larger male cheliped, the eyestalks bearing a small rounded denticle on the dorsomesial surface, and the lateral margins of the telson being convergent and approximately of the same length as the uropodal endopod (Figure 2).

Biffarius fragilis **(Biffar, 1970)**

Callianassa fragilis Biffar 1970: 45, Figure 3 – Biffar 1971b: 667.

Callianassa fragilis – Sakai 1999b: 27.

Biffarius fragilis – Manning & Felder 1991: 769. – Tudge et al. 2000: 133.

Biffarius cf. *fragilis* – Heard et al. 2007: 21.

Material examined: Brazil, Pernambuco: Itamaracá Island, Praia do Forte Orange, Site 1, 1 ♀ (6.91 mm CL), 23.XII.1995 (MZUSP 19068); Olinda, Praia da Casa Caiada, Site 2, 1 ovigerous ♀ (4.95 mm CL), 06.III.1996 (MZUSP 19069); Itamaracá Island, Praia do Forte Orange, Site 1, 1 ♂ (5.08 mm CL, 23.5 mm TL), 22.III.1996 (MZUSP 19066); Itamaracá Island, Praia do Forte Orange, Site 1, 1 ♂ (4.29 mm CL), 21.IV.1999 (MZUSP 19067); Olinda, Praia da Casa Caiada, Site 3, 1 ♂ (4.91 mm CL), 23.XII. 2003. (MZUSP 19071); Olinda, Praia da Casa Caiada, Site 3, 1 ovigerous ♀ (3.52 mm CL), 23.XII.2003 (MZUSP 19070).

Ecology: At all sampling sites, burrow openings of *B. fragilis* were very scarce, small (~1 mm in diameter), and without mounds. At Site 3, the sympatric fauna included callianassids *Neocallichirus maryae*, *Callichirus major* and *Lepidophthalmus siriboia* Felder and Rodrigues, 1993. As for the previous species, no commensals were observed in galleries of *B. biformis*. Elsewhere, *B. fragilis* was also collected mainly on near-shore sandy habitats (Biffar 1971a, Manning & Felder 1991).

Distribution. Western Atlantic. Southern Florida; Caribbean Sea: Puerto Rico, Antigua, Venezuela (Biffar 1970, 1971b; Manning & Felder 1991); Brazil: Pernambuco (present study). Eastern Pacific. Galapagos and Costa Rica (Biffar 1972; Vargas & Cortes 1999) [eastern Pacific records require both morphological and genetic confirmation].

Remarks: The Brazilian material of *B. fragilis* generally agrees with the descriptions of *B. fragilis* (as *Callianassa fragilis*) in Biffar (1970, 1971a), except for some subtle differences. The Brazilian

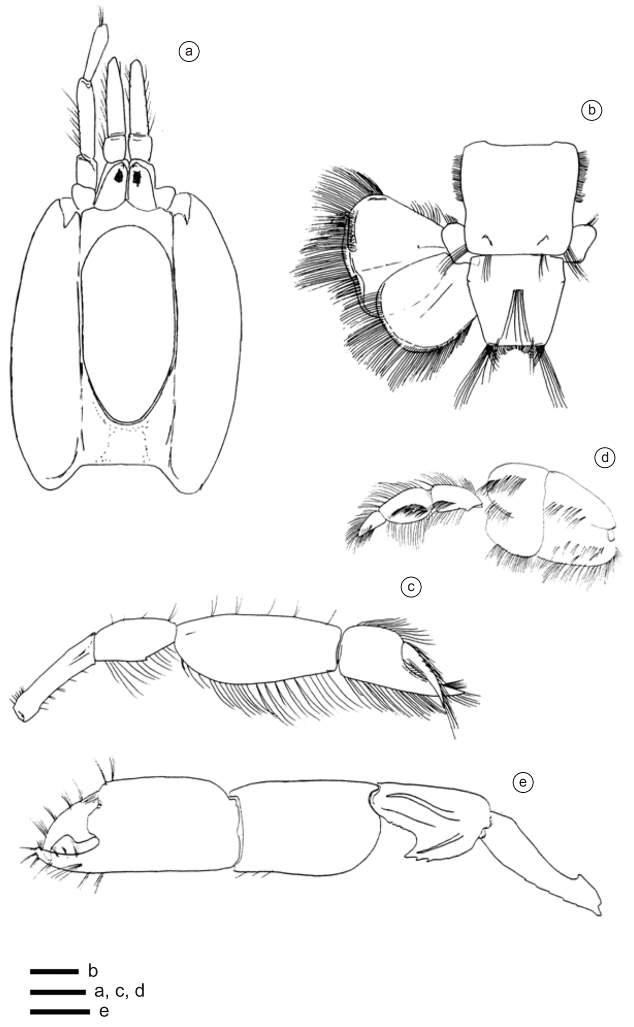

Figure 2. *Biffarius biformis* (Biffar, 1971): a) carapace and anterior appendages (dorsal view); b) sixth abdominal somite, telson and uropods (dorsal view); c) male minor cheliped (mesial view); d) third maxilliped (mesial view); e) male major cheliped (lateral view). Scale bars = 1 mm.

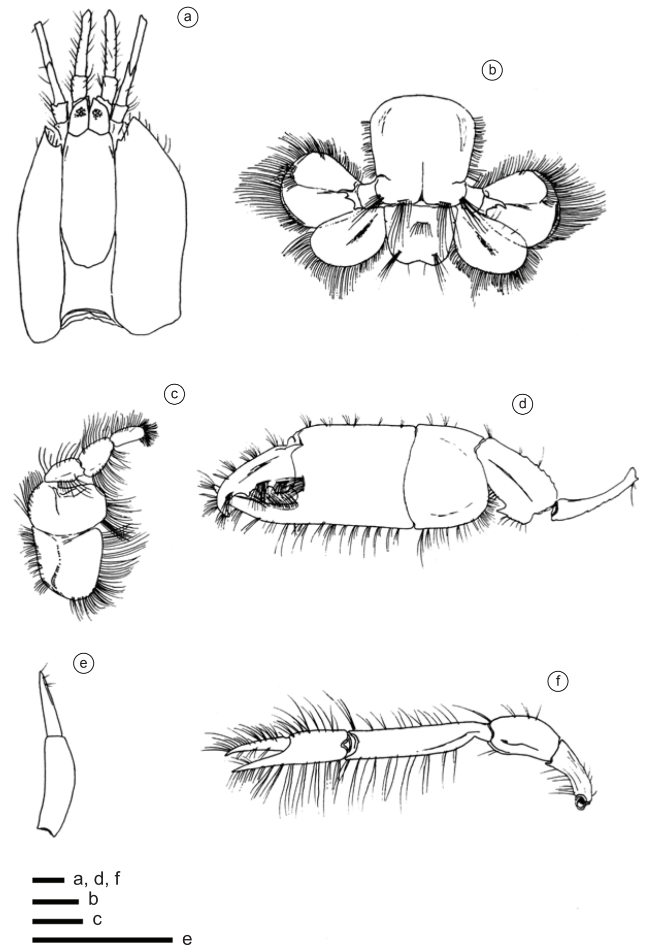

Figure 3. *Biffarius fragilis* (Biffar, 1970): a) carapace and anterior appendages (dorsal view); b) sixth abdominal somite, telson and uropods (dorsal view); c) third maxilliped (mesial view); d) male major cheliped (lateral view); e) male first pleopod; f) male minor cheliped (mesial view). Scale bars = 1 mm.

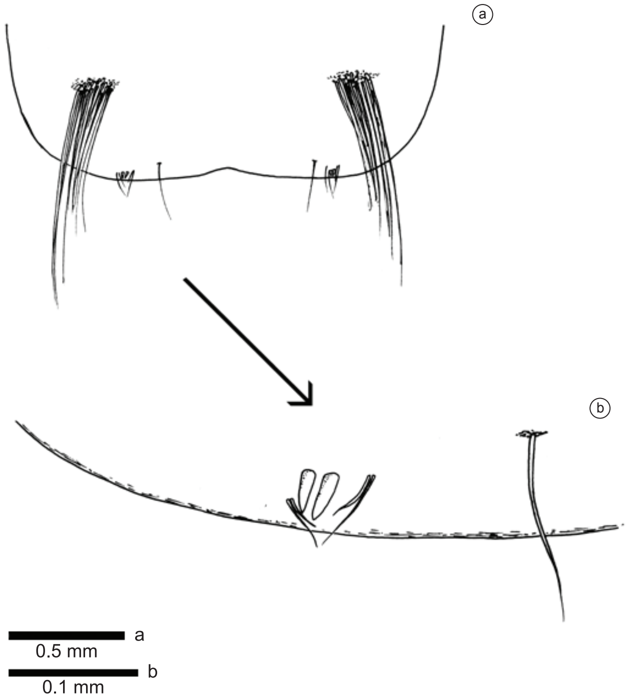

Figure 4. *Biffarius fragilis* (Biffar, 1970): a) posterior margin of telson; b) detail of spiniform setae near posterior margin.

specimens have 4–6 serrations on the ventral "hook" of the merus of the male major cheliped, as opposed to 3-4 as described by Biffar (1971a); the ventral margin itself has 10-13 denticles compared to the consistent 11 observed by Biffar (1971a). In the present material, the ischium of the third maxilliped bears 16-19 weak denticles on the mesial surface, whereas Biffar (1971a) observed 16-18 denticles. A pair of small spiniform setae on each posterolateral corner of the telson was observed in the Pernambuco material (Figure 4), but not mentioned or illustrated by Biffar (1970, 1971a). The Brazilian material partially agrees with the description in Heard et al. (2007), who mentioned the presence of only one spiniform setae in the material of *B. fragilis* from South Carolina. Therefore, our observations support the suggestion of Heard et al. (2007) that this character may be variable.

Discussion

The family Callianassidae has been revised first by Manning & Felder (1991), and then by Sakai (1999b). Manning & Felder (1991) erected the genus *Biffarius* for *Callianassa biformis* and *C. fragilis*, the former being its type species. Sakai (1999b, 2005) treated *Biffarius* along several other genera established by Manning & Felder (1991) again under *Callianassa* Leach 1814. However, a preliminary phylogenetic analysis of the Callianassidae (Tudge et al. 2000), did not support *Callianassa sensu lato* = *sensu* Sakai (1999b). *Callianassa* was also recovered as possibly polyphyletic group in a recent DNA-based analysis (Robles et al. 2009). Therefore, in the present study, both species were retained in the genus *Biffarius sensu* Manning & Felder (1991).

The present records from Pernambuco extend considerably the geographic ranges of *B. biformis* and *B. fragilis* from the Caribbean/Florida region south to Brazil. These two species now have the widest north-south ranges among the species of *Biffarius*. Their apparent disjunctive distribution may be simply due to the paucity of sampling along the northern and eastern coast of Brazil.

Acknowledgements

The authors are extremely grateful to Drs. Arthur Anker and Patricio Hernáez for comments provided on an earlier version of the manuscript. The authors also thank Janet W. Reid for revision of the English.

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Received 26/03/2012
Revised 07/08/2012
Accepted 15/08/2012

Composition and assemblage structure of demersal fish from São Cristóvão beach, Areia Branca, RN

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DANTAS, N.C.F.M., FEITOSA, C.V. & ARAÚJO, M.E. **Composition and assemblage structure of demersal fish from São Cristóvão beach, Areia Branca, RN**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02512032012

Abstract: Fish assemblages are an important element of sandy beaches, as they are fundamental for these ecosystems' balance of energy. Descriptions of the structure of fish assemblages in the sandy beaches of northeastern Brazil are scarce; this is especially true for the state of Rio Grande do Norte, which northern coast is poorly studied. This study aimed to identify the fish fauna of São Cristóvão Beach and to determine their assemblage structure. Three trawlings, considered as replicates, were undertaken monthly, in the same day, during 10 minutes each time, parallel to the coastal line, and in the direction of current, from February 2010 to January 2011. To describe the general pattern of the fish assemblage, the abundance, frequency and trophic categories of each species were estimated. On São Cristóvão Beach, 8894 individuals were captured, belonging to 58 species, 48 genera and 28 families. The most abundant and frequent species were *Pomadasys corvinaeformis* (Steindachner, 1868)*, Cathorops spixii* (Agassiz, 1829)*, Stellifer rastrifer* (Jordan, 1889)*, Pellona harroweri* (Fowler, 1917)*, Stellifer stellifer* (Bloch, 1790)*, Chirocentrodon bleekerianus* (Poey, 1867)*, Larimus breviceps* Cuvier, 1830*, Menticirrhus americanus* (Linnaeus, 1758) and *Conodon nobilis* (Linnaeus, 1758). The most abundant trophic category was first order carnivores. The ichthyofauna of São Cristóvão Beach is diversified and the most representative families match those observed in sandy beach ecosystems from other Brazilian regions. The results presented here reflect the basic knowledge necessary to conduct further research in the region.
Keywords: *sandy beaches, bottow otter trawl, ichthyofauna.*

DANTAS, N.C.F.M., FEITOSA, C.V. & ARAÚJO, M.E. **Composição e estrutura da assembléia de peixes demersais da praia de São Cristóvão, Areia Branca, RN**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02512032012

Resumo: As assembléias íctias são um elemento importante das praias arenosas, pois são fundamentais no balanço energético desses ecossistemas. Descrições da estrutura da assembléia de peixes de praias arenosas do nordeste brasileiro são escassas, em especial no estado do Rio Grande do Norte, cujo litoral norte é pobremente estudado. A presente pesquisa teve como objetivo inventariar a ictiofauna da praia de São Cristóvão, bem como conhecer a estrutura desta assembléia. Foram realizados três arrastos mensais com portas, com 10 minutos de duração cada (considerados como réplicas), paralelos à linha da costa, na direção da corrente, no período de fevereiro de 2010 a janeiro de 2011. Para descrever o padrão geral da comunidade de peixes, foram calculadas as abundâncias, frequências e os hábitos alimentares das espécies. Na praia de São Cristóvão foram capturados 8.894 indivíduos, pertencentes a 58 espécies, 48 gêneros e 28 famílias. As espécies mais abundantes e frequentes foram *Pomadasys corvinaeformis* (Steindachner, 1868)*, Cathorops spixii* (Agassiz, 1829)*, Stellifer rastrifer* (Jordan, 1889)*, Pellona harroweri* (Fowler, 1917)*, Stellifer stellifer* (Bloch, 1790)*, Chirocentrodon bleekerianus* (Poey, 1867)*, Larimus breviceps* Cuvier, 1830*, Menticirrhus americanus* (Linnaeus, 1758) *e Conodon nobilis* (Linnaeus, 1758). Quanto às proporções das categorias tróficas das espécies, a predominante é carnívora de primeira ordem. A ictiofauna da praia de São Cristóvão pode ser considerada diversificada e as famílias mais representativas coincidem com aquelas observadas nos ecossistemas praiais de outras regiões brasileiras. Os resultados aqui apresentados refletem o conhecimento básico necessário para a realização de pesquisas futuras na região.
Palavras-chave: *praias arenosas, arrasto com portas, ictiofauna.*

Introduction

Fish assemblages are an important element of sandy beach ecosystems, and carry out one of the most important roles in energy balance (Lowe-McConnell 1999). The common capture of juvenile individuals may affect the ecosystem's entire trophic structure, compromising the efficiency of energy transfer, since they act as primary and secondary consumers within the trophic chain (Veloso & Neves 2009). Besides, this catch interferes in prey availability (Alverson et al. 1994) and hinders fish stocks' regeneration, once captures mainly juvenile individuals (Kaiser et al. 2001). The great presence of juvenile fish in sandy beach environments draws attention to the role of this ecosystem in the life cycle and maintenance of several fish species' population stocks (Vasconcellos et al. 2007, Santana & Severi 2009) – both resident and migrant. It also reinforces the concept of connectivity between sandy beaches, adjacent ecosystems and regions that are more distant from the continental shelf to more protected coastal areas (Félix et al. 2006).

The beach environments are used both by resident species (as nurseries, as well as for feeding, spawning, shelter and protection against predators due to the high turbidity levels and low depths) (Lasiak 1986, Giannini & Paiva Filho 1995) and by visiting species, which include sandy beaches in their migration routes (Vasconcellos et al. 2007, Veloso & Neves 2009). Consequently, great seasonal variability in the fish assemblage can be observed in these areas throughout entire year (Brown & McLachlan 1990, Veloso & Neves 2009).

Considering the size of the Brazilian coast, there are relatively few studies that focus on the fish fauna of beach environments – most research available focuses on describing assemblage structure and its spatial and temporal variations. For the southern and southeastern regions of the country, we can highlight the work of Giannini & Paiva Filho (1995), Araújo et al. (1998), Godefroid et al. (2003) and Araújo et al. (2008), while the work of Teixeira & Almeida (1998), Oliveira-Silva et al. (2008) and Santana & Severi (2009) can be highlighted for the northeastern region.

Approximately three quarters of the world's coasts are made up of sandy beaches (Bascom 1980). Most of the artisanal fishing carried out by local communities in the country occurs within the coastal line (Instituto... 2007). Among the most common fishing techniques used along the Brazilian coast, bottom otter trawling stands out as one of the most damaging to natural resources for being multiespecific and due to its low selectivity (Franco et al. 2009, Vianna & Almeida 2005). This result in a great capture of bycatch, which encompass small-sized species, juvenile individuals and benthic invertebrates (Kumar & Deepthi 2006, Davies et al. 2009). Besides, great damage is caused to the substrate (Kaiser et al. 2001). The long term use of this type of fishing technique may affect the local ichthyofauna assemblage (Kaiser et al. 2001, Vianna & Almeida 2005).

The rapid expansion of human populations has been causing severe impacts throughout the world, especially due to the degradation of ecosystems and the consumption of natural resources (Defeo et al. 2009). Most of these impacts occur along the coastal line, which is composed mainly of sandy beaches (McLachlan & Brown 2006). Thus, there is a need to know the dynamics of sandy beach ecosystems and to emphasize their importance for the fish species that live in these areas and for the development of the species that use this kind of environment in different phases of their life cycles; such information is extremely relevant to understand anthropic impacts on such beach environments, as well as to subsidize possible management decisions in these regions. This study aimed to survey the ichthyofauna to compare the seasonal variations found within the assemblage structure of the fish of São Cristóvão Beach, state of Rio Grande do Norte, Brazil.

Materials and Methods

1. *Study area*

São Cristóvão Beach, which is part of the Areia Branca municipality (4° 55' 29.83" S and 36° 57' 2.91" W), is located on the northern coast of the state of Rio Grande do Norte, 330 km from the state capital, Natal (Figure 1). This region's climate is semi-arid and hot (700 mm precipitation), with a rainy season (February through May) with rainfall peaks in March and April, and a dry season (June-January) (Instituto... 2008). The region's tides are semi-diurnal; average sealevel is 133.1 cm, the amplitude of the neap tide is of 127.79 cm and the amplitude of the spring tide is of 284.55 cm (Instituto... 2008).

2. *Sampling*

Sampling was carried out from February 2010 through January 2011 at São Cristóvão Beach. Three trawlings, considered as replicates, were undertaken monthly, in the same day, during 10 minutes each time, parallel to the coastal line, totalling 36 trawls, a 15 m long and 8.6 m wide otter trawl net (4 cm mesh) was used, pulled by a shrimp boat with a 46 Hp, six cylinder motor, at a speed of 2.5 knots. The captured fish were stored in a Styrofoam box, identified and photographed at the Marine Fish Biology and Population Dynamics Laboratory. Specialized literature was used to identify the species (Figueiredo 1977, Figueiredo & Menezes 1978, 1980, 2000, Menezes & Figueiredo 1980, 1985, Carvalho-Filho 1999, Marceniuk 2005). The samples are deposited at the Marine Fish Biology and Population Dynamics Laboratory Collection under the numbers 1-50.

3. *Characterizing the assemblage structure*

Species were analyzed in relation to abundance and frequency and classified based on the criteria adopted by Paiva et al. (2008) and Garcia & Vieira (2001). Species were considered abundant (A) and not very abundant (NA) when the capture percentage (CP%) was higher or lower than 100/S, respectively, where S is the number of species. Similarly, in order to classify species according to their frequency of occurrence (FO%), the following intervals were designated: infrequent (IF), for values lower than 50%; frequent (F), for values within the interval 50% ≤ FO% < 85%; and very frequent (VF), for values equal to or greater than 85%. After this analysis, species were classified according to their CP% and FO% (Table 1).

Species were classified according to the trophic levels determined by Bouchon-Navaro et al. (1992), which place fish into the following categories: planktivores (P) – food is composed mainly of plankton; omnivores (O) – species that feed on invertebrates and algae; herbivores (H) – from algae to marine phanerogams; first order carnivores (IC) – small benthic invertebrates; second order carnivores (IIC) – invertebrates and fish; third order carnivores (IIIC) – fish makes up 80% of the food ingested. The species that were not evaluated by Bouchon-Navaro et al. (1992) were classified based on their feeding habit, as available in the following website: www.fishbase.org. (Fishbase 2011).

In order to characterize the assemblage, two diversity measurements were used: Margalef's richness index (R1), according to the formula R1 = (S – 1)/ln N, where "S" is the total number of species and "N" is the total number of individuals in the sample (Magurran 1988); and Shannon's diversity index (H'), as expressed in the formula $H' = -\Sigma\ (pi)\ (\log_2 pi)$, where "pi" is equal to the

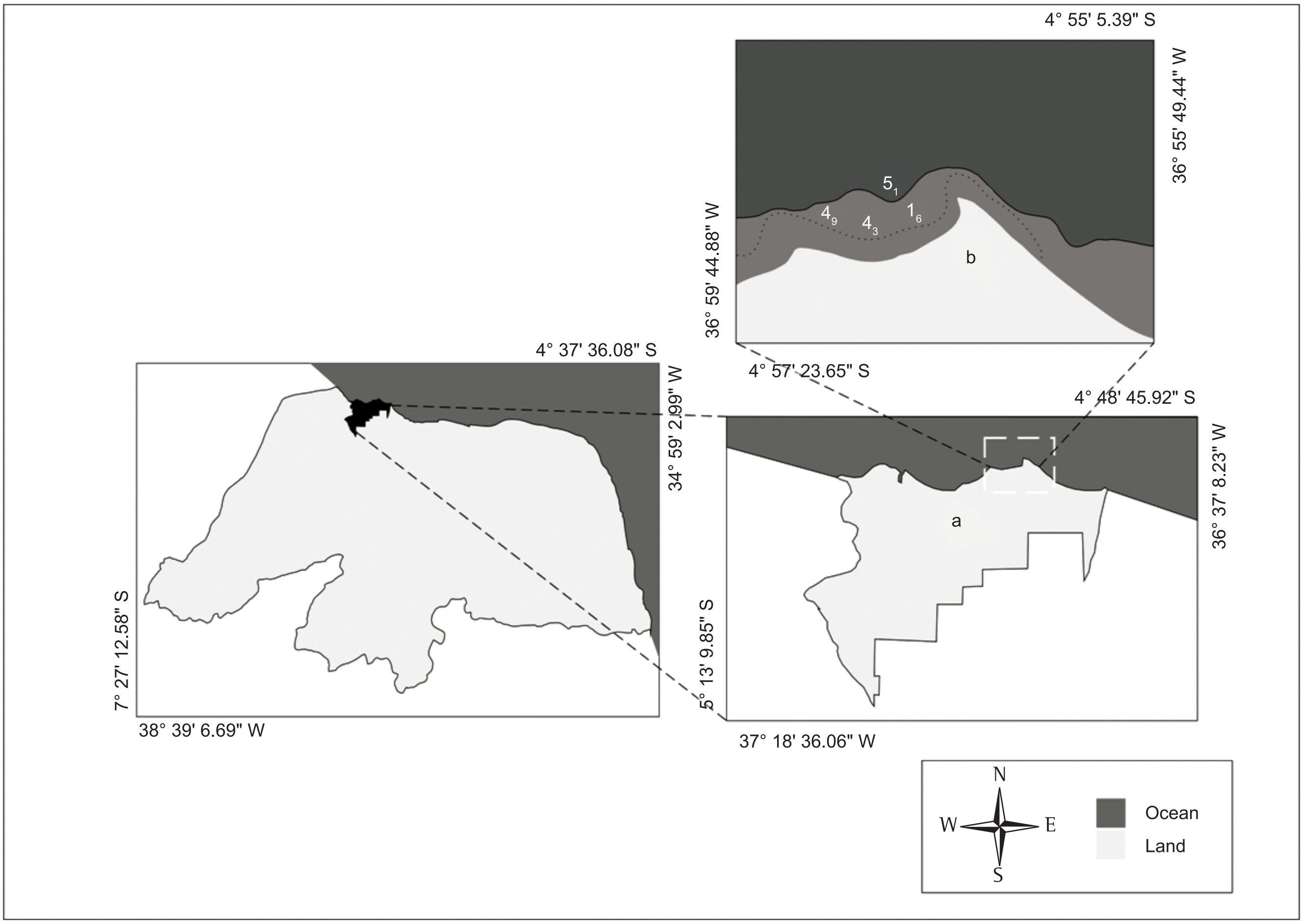

Figure 1. Location map of the São Cristóvão beach (b), Areia Branca (a) (RN).

Figura 1. Mapa de localização da praia de São Cristóvão (b), Areia Branca (a) (RN).

Table 1. Classification of fish species captured at São Cristóvão Beach (Rio Grande do Norte, Brazil) according to abundance and frequency of occurence, based on the criteria proposed by Paiva et al. (2008) and Garcia & Vieira (2001).

Tabela 1. Classificação das espécies de peixes capturadas na praia de São Cristóvão (Rio Grande do Norte, Brasil) de acordo com a abundância e frequência de ocorrência, baseado no critério proposto por Paiva et al. (2008) e Garcia & Vieira (2001).

NA-IF	$CP\% < 100/S$ and $FO\% < 50\%$
NA-F	$CP\% < 100/S$ and $50\% \leq FO\% < 85\%$
NA-VF	$CP\% < 100/S$ and $FO\% \geq 85\%$
A-IF	$CP\% > 100/S$ and $FO\% < 50\%$
A-F	$CP\% > 100/S$ and $50\% < FO\% < 85\%$
A-VF	$CP\% > 100/S$ and $FO\% \geq 85\%$

quotient of the number of individuals of species "i" divided by the total number of individuals (Magurran 1988); Primer 5.0 software was used (Primer-E 2000).

4. *Data analysis*

Trawlings perfomed per month were grouped for the purpose of analysis and treated as one (month). The variable's mean values were used. As the data were not well modeled by a normal distribution (Kolmogorov-Smirnov test) and the variances were homoscedastic (Bartlett test), nonparametric tests were used.

Kruskall-Wallis' nonparametric test was applied to check for significant differences between the ecological indexes throughout the months studied. To compare the richness index between dry (June until January) and rainy (February until May) season, Mann Whitney's nonparametric test was applied. BioEstat 5.0 software was used for this purpose (Ayres et al. 2007). To test the differences in Shannon diversity index between seasons, the t- test of Hutcheson (Diversity t-test) procedures was applied and the software PAST was used for this (Hammer et al. 2001). A Bray-Curtis similarity matrix was calculated using log-transformed species abundance data (X + 1). In order to express the association between species abundance and the dry and rainy seasons (factors), non-metric multidimensional scaling analysis (NMDS) was used. Analyses of similarity (ANOSIM) were used to test the significance of groups formed with the above-mentioned data. Additionally, an analysis of similarity percentages (SIMPER) was conducted to examine the main species contributing for differences in fish assemblage structure between seasons. Primer 5.0 was the software used in both cases (Primer-E 2000).

Spearman's correlation was used to verify for possible correlations between the richness and diversity indexes and monthly rainfall (BioEstat 5.0 software) (Ayres et al. 2007). Rainfall data for the Areia Branca municipality (2010-2011) was obtained from the company Salina Morro Branco, F. Souto – Indústria, Comércio e Navegação S/A .

Results

Fifty-eight species of 48 genera and 28 families were captured – a total of 8.894 individuals sampled. The most representative families regarding the number of species and individuals were Sciaenidae (nine species and 3195 individuals), Ariidae (five species and 1493 individuals), Carangidae (five species and 186 individuals), Engraulidae (four species and 271 individuals), Haemulidae (four species and 1794 individuals) and Pristigasteridae (three species and 1552 individuals). The data collected show sample stability from the 5th survey on, when almost all of the species identified (50) had already been captured (Figure 2).

Of the 58 species sampled, 35 were classified as not very abundant and infrequent (NA-IF); 11 as not very abundant and frequent (NA-F); three as abundant and frequent (A-F); and six as abundant and very frequent (A-VF). No species fit into the category "abundant and infrequent" (A-IF) (Table 2). The nine species that were dominant in terms of quantity (A-VF and A-F) in the samples from São Cristovão Beach contributed with 87.2% of the total fish captured (Figure 3).

The greatest abundance values for individuals were recorded during the months of February (1.497) and May (1.262), while the lowest values occurred in October (167) and November (250). The multidimensional scaling analysis showed that two distinct groups were formed, which suggests a separation between the two seasons (rainy and dry) (Figure 4). The analysis of similarity (ANOSIM) used to test the significance of these groups showed a significant distinction between them ($R = 0.392$; $p = 0.001$). However, the last months (January and May) of each season overlapped. Abundance change of species between seasons was confirmed considering the species contributing for the dissimilarity between samples (Table 3).

The average richness (R1) and diversity values (H') were of 2.79 ± 0.13 (S.E) and 1.73 ± 0.12 (S.E), respectively. Figure 5 shows the variation of the ecological indexes throughout the year, in addition to the mean precipitation data for the period studied. The month with the greatest richness was April (3.43), while November had the lowest (2.01) – although the Kruskall-Wallis test did not show significant differences throughout the year for the indexes that were analyzed ($H = 13.2557$ and $p = 0.2769$). For the Shannon-Wiener index, variations in diversity could be observed throughout the months, and the highest values were recorded during the rainy season (March = 2.210 and April = 2.357). Significant differences were recorded between April and June and April and October ($H = 23.979$ and $p = 0.0128$, Dunn test pos-hoc, $p < 0.005$). June and October were the months with the lowest diversity. Comparing the richness ($z(u) = 0.5095$ and $p = 0.6104$) and diversity ($t = 0.0447$ and $p = 0.9643$) indexes between dry and rainy seasons, significant differences were not detected. According to Spearman's correlation test, there was no correlation between the monthly rainfall and richness ($p = 0.38$) and diversity indexes ($p = 0.46$).

The most abundant trophic categories were first order carnivore (IC) (435 ± 84.08) and second order carnivore (IIC) (228 ± 38.08). The other categories third order carnivore (26 ± 16.36), herbivore (0.08 ± 0.04) omnivore (22.08 ± 5.75) and planktivore (0.16 ± 0.08) were unrepresentative.

Discussion

The data indicates that the size of the sample was adequate to survey the species that occurred at São Cristóvão Beach, as 86% of the total species known for the region was sampled during the period studied. Ninety-six species have been recorded for the region (J. Garcia Júnior 2006). The great disparity of species surveyed in this study when compared to that of J. Garcia Júnior (2006) can be explained by the several types of fishing apparatus used (gill nets, purse seine nets, hand lines, dip nets, cast nets and trammel net) in the different environments sampled (estuary and sandy beach) by the author mentioned above.

The results presented here are similar to those of Santana & Severi (2009), where species *Polydactylus virginicus* (Linnaeus, 1758),

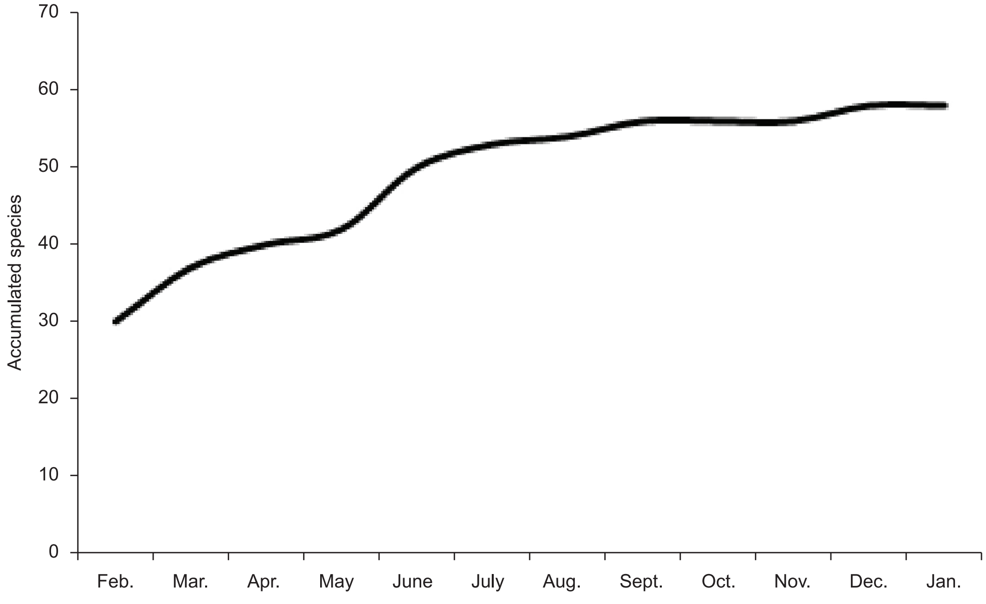

Figure 2. Number of accumulated species related to the number of trawls performed monthly in São Cristovão in the years 2010 to 2011.

Figura 2. Número de espécies acumuladas em função do número de arrastos mensais realizados em São Cristóvão nos anos de 2010 a 2011.

Table 2. List of species and families recorded at São Cristovão Beach (Rio Grande do Norte, Brazil) with their respective trophic categories, capture percentage (CP%), frequency of occurrence (FO%) and the classification that assorts the capture percentage and the frequency of occurrence (CPF).

Tabela 2. Lista das espécies e famílias registradas na praia de São Cristóvão (Rio Grande do Norte, Brasil) com suas respectivas categorias tróficas, percentual de captura (CP%), frequência de ocorrência (FO%) e classificação que associa o percentual de captura e frequência de ocorrência (CPF).

Family	Species	Trophic Cat.	CP%	FO%	CPF
Dasyatidae	*Dasyatis guttata* (Bloch & Schneider, 1801)	Carnivore II	0.13	33.33	NA-IF
Gymnuridae	*Gymnura micrura* (Bloch & Scheneider, 1801)	Carnivore II	0.08	33.33	NA-IF
Pristigasteridae	*Chirocentrodon bleekerianus* (Poey, 1867)	Carnivore III	7.41	66.67	A-F
Pristigasteridae	*Pellona harroweri* (Fowler, 1917)	Carnivore I	9.88	91.67	A-VF
Clupeidae	*Opisthonema oglinum* (Lesueur, 1818)	Carnivore II	0.16	41.67	NA-IF
Engraulidae	*Anchoa filifera* (Fowler 1915)	Carnivore II	0.04	8.33	NA-IF
Engraulidae	*Anchoa spinifer* (Valenciennes, 1848)	Carnivore II	1.36	91.67	NA-VF
Engraulidae	*Anchoa tricolor* (Spix & Agassiz, 1829)	Omnivore	0.81	33.33	NA-IF
Engraulidae	*Cetengraulis edentulus* (Cuvier, 1829)	Omnivore	0.83	58.33	NA-F
Ariidae	*Bagre bagre* (Linnaeus, 1766)	Carnivore II	0.24	25.00	NA-IF
Ariidae	*Bagre Marinus* (Mitchill, 1815)	Omnivore	0.62	75.00	NA-F
Ariidae	*Cathorops spixii* (Agassiz, 1829)	Carnivore II	15.64	91.67	A-VF
Ariidae	*Genidens barbus* (Lacépède, 1803)	Omnivore	0.25	8.33	NA-IF
Ariidae	*Notarius grandicassis* (Valenciennes, 1840)	Omnivore	0.04	8.33	NA-IF
Synodontidae	*Synodus intermedius* (Spix & Agassiz, 1829)	Piscivore	0.02	8.33	NA-IF
Dactylopteridae	*Dactylopterus volitans* (Linnaeus, 1758)	Carnivore I	0.11	50.00	NA-F
Serranidae	*Rypticus randalli* Courtenay, 1967	Carnivore II	0.01	8.33	NA-IF
Batrachoididae	*Thalassophryne nattereri* Steindachner, 1876	Carnivore II	0.01	8.33	NA-IF
Triglidae	*Prionotus punctatus* (Bloch, 1793)	Carnivore II	0.16	50.00	NA-F
Carangidae	*Chloroscombrus chrysurus* (Linnaeus, 1766)	Omnivore	0.19	58.33	NA-F
Carangidae	*Selene setapinnis* (Mitchill, 1815)	Carnivore II	1.23	91.67	NA-VF
Carangidae	*Selene vomer* (Linnaeus, 1758)	Carnivore II	0.63	83.33	NA-F
Carangidae	*Trachinotus falcatus* (Linnaeus, 1758)	Carnivore II	0.01	8.33	NA-IF
Carangidae	*Uraspis secunda* (Poey, 1860)	Carnivore I	0.03	16.67	NA-IF
Lutjanidae	*Lutjanus synagris* (Linnaeus, 1758)	Carnivore II	0.13	33.33	NA-IF
Gerreidae	*Diapterus rhombeus* (Cuvier, 1829)	Carnivore I	0.07	16.67	NA-IF
Gerreidae	*Eucinostomus melanopterus* (Bleeker, 1863)	Omnivore	0.19	33.33	NA-IF
Haemulidae	*Conodon nobilis* (Linnaeus, 1758)	Carnivore II	2.00	100.00	A-VF
Haemulidae	*Genyatremus luteus* (Bloch, 1790)	Carnivore II	0.12	33.33	NA-IF
Haemulidae	*Haemulon aurolineatum* Cuvier, 1830	Omnivore	0.01	8.33	NA-IF
Haemulidae	*Pomadasys corvinaeformis* (Steindachner, 1868)	Carnivore I	18.03	91.67	A-VF
Sparidae	*Archosargus probatocephalus* (Walbaum, 1792)	Carnivore I	0.08	25.00	NA-IF
Sparidae	*Archosargus rhomboidalis* (Linnaeus, 1758)	Omnivore	0.03	8.33	NA-IF
Sciaenidae	*Bairdiella ronchus* (Cuvier, 1830)	Carnivore II	0.2	50.00	NA-F
Sciaenidae	*Isopisthus parvipinnis* (Cuvier, 1830)	Carnivore II	0.99	41.67	NA-IF
Sciaenidae	*Larimus breviceps* Cuvier, 1830	Carnivore II	6.21	100.00	A-VF
Sciaenidae	*Menticirrhus americanus* (Linnaeus, 1758)	Carnivore I	3.06	100.00	A-VF
Sciaenidae	*Nebris microps* Cuvier, 1830	Carnivore I	0.07	25.00	NA-IF
Sciaenidae	*Paralonchurus brasiliensis* (Steindachner, 1875)	Planktivore	0.02	16.67	NA-IF
Sciaenidae	*Stellifer brasiliensis* (Schultz, 1945)	Carnivore I	0.36	33.33	NA-IF
Sciaenidae	*Stellifer rastrifer* (Jordan, 1889)	Carnivore I	15.35	66.67	A-F
Sciaenidae	*Stellifer stellifer* (Bloch, 1790)	Carnivore I	9.67	83.33	A-F
Mullidae	*Pseudupeneus maculatus* (Bloch, 1793)	Carnivore I	0.01	8.33	NA-IF
Acanthuridae	*Acanthurus chirurgus* (Bloch, 1787)	Herbivore	0.01	8.33	NA-IF
Aphipiidae	*Chaetodipterus faber* (Broussonet, 1782)	Carnivore I	0.3	83.33	NA-F
Sphyraenidae	*Sphyraena guachancho* Cuvier, 1829	Carnivore III	0.02	16.67	NA-IF
Polynemidae	*Polydactylus virginicus* (Linnaeus, 1758)	Carnivore I	1.18	100.00	NA-VF
Trichiuridae	*Trichiurus lepturus* Linnaeus, 1758	Carnivore II	0.44	75.00	NA-F
Scombridae	*Scomberomorus cavalla* (Cuvier, 1829)	Carnivore II	0.01	8.33	NA-IF
Paralichthydae	*Citharichthys spilopterus* Günther, 1862	Carnivore II	0.1	25.00	NA-IF
Paralichthydae	*Citharichthys macrops* Dresel, 1885	Carnivore II	0.29	25.00	NA-IF
Achiridae	*Achirus declivis* Chabanaud, 1940	Carnivore II	0.07	16.67	NA-IF
Achiridae	*Trinectes paulistanus* (Miranda Ribeiro, 1915)	Carnivore II	0.09	33.33	NA-IF
Cynoglossidae	*Symphurus plagusia* (Bloch & Schneider, 1801)	Carnivore I	0.02	16.67	NA-IF
Cynoglossidae	*Symphurus tessellatus* (Quoy & Gaimard, 1824)	Carnivore I	0.26	83.33	NA-F
Tetraodontidae	*Sphoeroides greeleyi* Gilbert, 1900	Carnivore II	0.1	41.67	NA-IF
Tetraodontidae	*Sphoeroides testudineus* (Linnaeus, 1758)	Carnivore I	0.01	8.33	NA-IF
Diodontidae	*Chilomycterus spinosus spinosus* (Linnaeus, 1758)	Carnivore II	0.37	75.00	NA-F

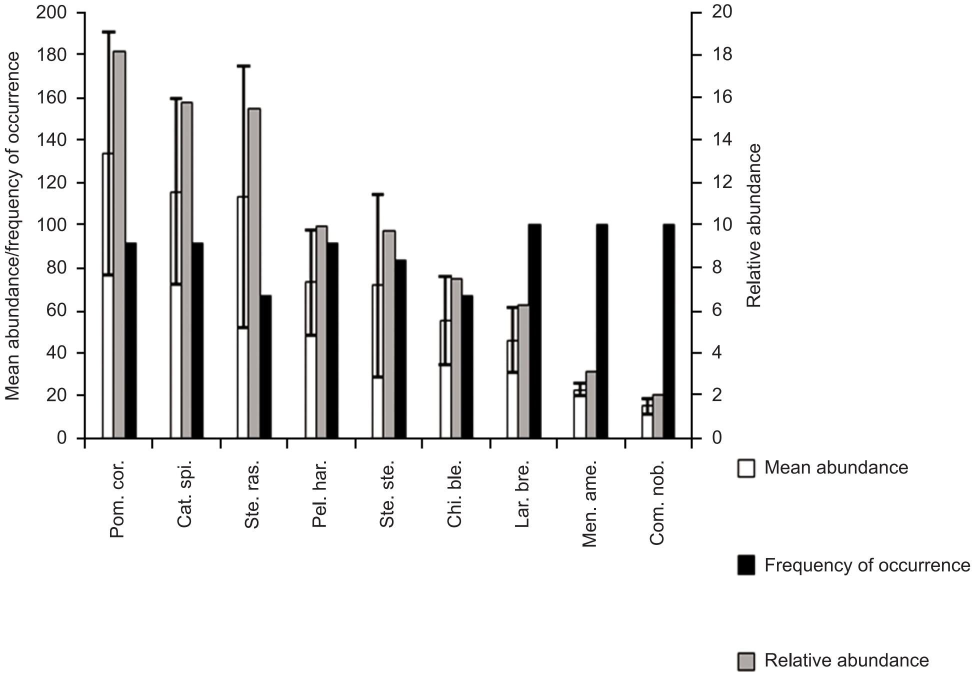

Figure 3. Frequency of occurrence, relative and mean abundance of the most representative fish species from São Cristovão beach, with their respective standard error. Legend: EP = standard error, Pom cor = *Pomadasys corvinaeformis* (Steindachner, 1868), Cat spi = *Cathorops spixii* (Agassiz, 1829), Ste ras = *Stellifer rastrifer* (Jordan, 1889), Pel har = *Pellona harroweri* (Fowler, 1917), Ste ste = *Stellifer stellifer* (Bloch, 1790), Chi ble = *Chirocentrodon bleekerianus* (Poey, 1867), Lar bre = *Larimus breviceps* Cuvier, 1830, Men ame = *Menticirrhus americanus* (Linnaeus, 1758), Con nob = *Conodon nobilis* (Linnaeus, 1758).

Figura 3. Frequência de ocorrência, abundâncias numérica relativa e média das espécies de peixe mais representativas da praia de São Cristovão, com seus respectivos erro padrão. Legenda: EP = Erro Padrão, Pom cor = *Pomadasys corvinaeformis* (Steindachner, 1868), Cat spi = *Cathorops spixii* (Agassiz, 1829), Ste ras = *Stellifer rastrifer* (Jordan, 1889), Pel har = *Pellona harroweri* (Fowler, 1917), Ste ste = *Stellifer stellifer* (Bloch, 1790), Chi ble = *Chirocentrodon bleekerianus* (Poey, 1867), Lar bre = *Larimus breviceps* Cuvier, 1830, Men ame = *Menticirrhus americanus* (Linnaeus, 1758), Con nob = *Conodon nobilis* (Linnaeus, 1758).

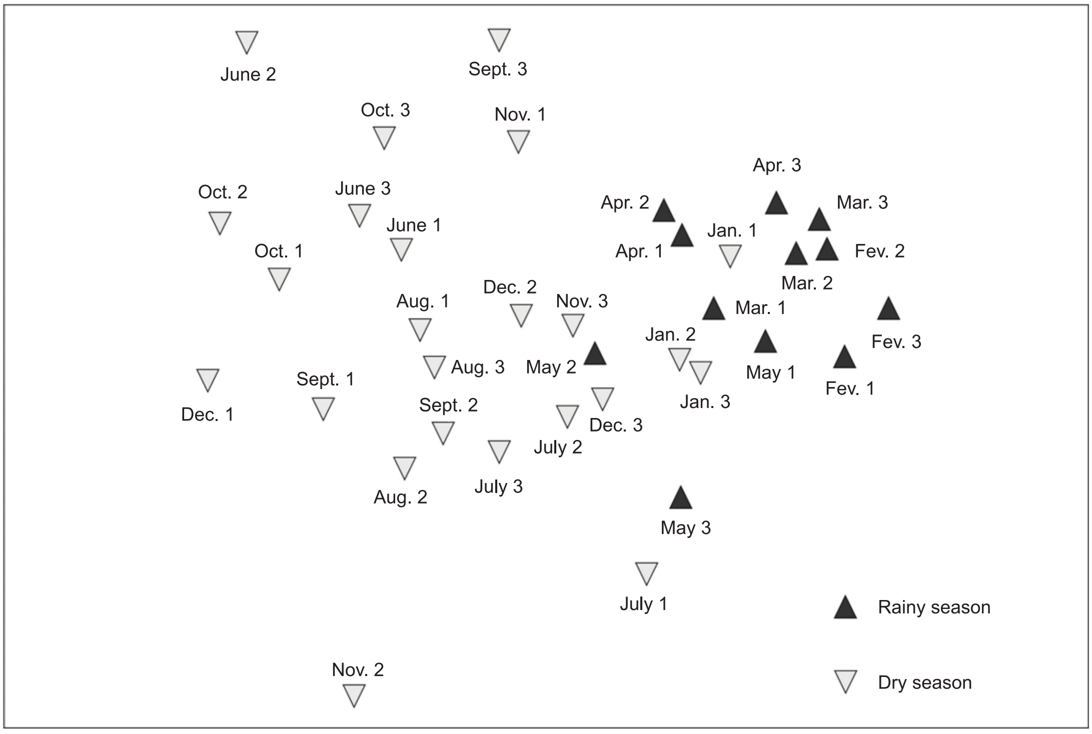

Figure 4. Non-metric multidimensional scaling (NMDS) of monthly samplings carried out on São Cristovão beach-RN. The symbols represent the two groups formed in relation to the abundance and the dry and rainy season.

Figura 4. Escalonamento não-métrico multidimensional (NMDS) das amostragens mensais realizadas na Praia de São Cristovão-RN. Os símbolos representam os dois agrupamentos formados em relação à abundância e ao período seco e chuvoso.

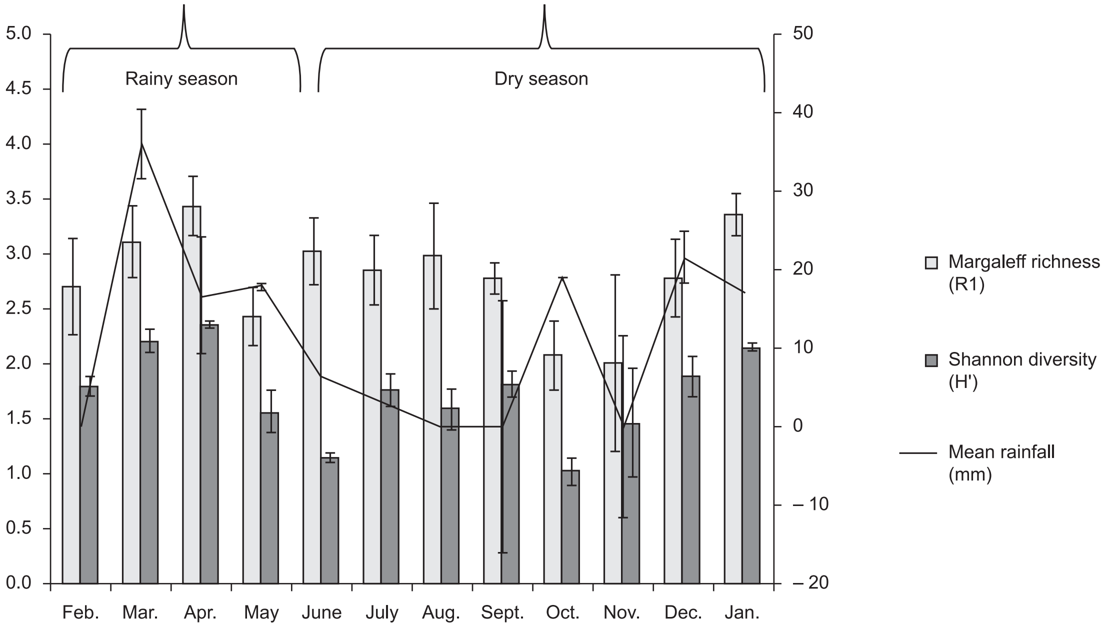

Figure 5. Representation of ecological indices throughout the samplings carried out in São Cristóvão beach in the years 2010 to 2011. The bars indicate the standard error and the curve represents mean rainfall in the months of sampling.

Figura 5. Representação dos índices ecológicos ao longo das amostragens realizadas em São Cristóvão nos anos de 2010 a 2011. As barras indicam o erro padrão e a curva representa a média da precipitação pluviométrica nos referentes meses de amostragens.

Table 3. Main species contributing for differences in fish assemblages structure among samples.

Tabela 3. Principais espécies que contribuem para as diferenças na estrutura da assembléia de peixes entre as amostras.

Species	Av. Dissim.	Dissim/SD	Contrib%	Cum.%
Ste. ras.	5.82	1.92	9.08	9.08
Pel. har.	5.41	1.62	8.43	17.51
Pom cor.	5.14	1.57	8.01	25.52
Cat. spi.	4.83	1.45	7.52	33.04
Ste. ste.	4.71	1.55	7.34	40.38
Chi. ble	4.13	1.35	6.43	46.81

Ste. ras – Stellifer rastrifer, Pel. har – Pellona harroweri, Pom. cor – Pomadasys corvinaeformis, Cat. spi – Cathrops spixii, Ste. ste. – Stellifer stellifer, Chi. ble – Chirocentrodon bleekerianus, Av. Dissim. – average dissimilarity, Dissim/SD – dissimilarity, Contrib% - % Contribution, Cum.% - % Cumulative.

Ste. ras – Stellifer rastrifer, Pel. har – Pellona harroweri, Pom. cor – Pomadasys corvinaeformis, Cat. spi – Cathrops spixii, Ste. ste. – Stellifer stellifer, Chi. ble – Chirocentrodon bleekerianus, Av. Dissim. – dissimilaridade média, Dissim/SD – dissimilaridade, Contrib% - % Contribuição, Cum.% - % Cumulativo.

Larimus breviceps Cuvier, 1830, *Chirocentrodon bleekerianus* (Poey, 1867), *Pomadasys corvinaeformis* (Steindachner, 1868), *Stellifer stellifer* (Bloch, 1790), *Stellifer rastrifer* (Jordan, 1889), *Conodon nobilis* (Linnaeus, 1758) and *Pellona harroweri* (Fowler, 1917) are among the most abundant at Jaguaribe Beach (state of Pernambuco). According to Oliveira-Silva et al. (2008), *P. virginicus* (Linnaeus, 1758), *L. breviceps* Cuvier, 1830 and *S. rastrifer* (Jordan, 1889) are among the most representative species at Cabuçu Beach (state of Bahia), while *C. nobilis* (Linnaeus, 1758) and *P. corvinaeformis* (Steindachner, 1868) were very expressive at Berlinque Beach (Bahia). At Pajuçara Beach (Maceió, state of Alagoas), Teixeira & Almeida (1998) reported that *P. virginicus* (Linnaeus, 1758) and *L. breviceps* Cuvier, 1830 were the most representative species among those captured. It is possible that these eight species represent the sandy beaches of northeastern Brazil's oriental region and form an ichthyological unit that is typical of this ecosystem.

The information provided above agrees with the data of Guedes et al. (2005) regarding the fish fauna's uniformity along the Brazilian coast in terms of families. The number of species per family is only different from study to study, mainly due to distinctions in sampling and variations between years. Nevertheless, the dominant families are usually the same, and are especially represented by Sciaenidae.

The great abundance and frequency of *P. corvinaeformis* (Steindachner, 1868), *C. spixii* (Agassiz, 1829), *S. rastrifer* (Jordan, 1889), *P. harroweri* (Fowler, 1917), *S. stellifer* (Bloch, 1790), *C. bleekerianus* (Poey, 1867), *L. breviceps* Cuvier, 1830, *Menticirrhus americanus* (Linnaeus, 1758) and *C. nobilis* (Linnaeus, 1758) in this study suggests that these species' life cycle is connected to sandy beach ecosystems, as they were dominant during the entire sampled period. The same pattern was observed for the species *Anchoa tricolor* (Spix & Agassiz, 1829), *Anchoviella lepidentostole* (Fowler, 1911), *Bairdiella ronchus* (Cuvier, 1830), *L. breviceps* Cuvier, 1830, *Lycengraulis grossidens* (Agassiz, 1829) and *P. virginicus* (Linnaeus, 1758) at Jaguaribe Beach (F. M. S. Santana 2009).

The fact that no species fit into the "abundant and infrequent" category (A-IF) shows that visiting, schooling fish species were not sampled, such as *Albula vulpes* (Linnaeus, 1758), *Caranx hippos* (Linnaeus, 1766), *Caranx latus* Agassiz, 1831, *Harengula clupeola* (Cuvier, 1829) and *Hemiramphus brasiliensis* (Linnaeus, 1758) (Carvalho-Filho 1999). These are considered visiting marine species in northeastern Brazilian estuaries and based on literature records (Carvalho-Filho 1999, Barros et al. 2000, Araújo et al. 2004) it was expected that the species cited above should be more representative.

Juvenile individuals of *Acanthurus chirurgus* (Bloch, 1787) and *Scomberomorus cavalla* (Cuvier, 1829) were each represented by a single individual, captured in only one trawling event, and are characteristic of other environments (Carvalho-Filho 1999). The surgeonfish species are typical of reef environments (Smith 1997), while adult horse-mackerels live in pelagic zones (Smith 1997). However, the fact that these species were present in a sandy beach ecosystem substantiate these areas as migration routes, and are possibly regions where juvenile individuals of several fish species can find shelter and food (Araújo et al. 2008, Veloso & Neves 2009). These individuals' occurrence strengthens the hypothesis of connectivity between more distant regions of the continental shelf and more protected coastal areas (Félix et al. 2006).

In this study, the increase in fish abundance during the rainy months was favored by the great amount of schooling fish species. During the rainy season the concentration of nutrients increases and salinity decreases, which favors primary productivity and, consequently, the higher trophic levels (Trujillo & Thurman 2008, Frédou et al. 2009). This is the case of *Pellona harroweri* (Fowler, 1917), *Stellifer rastrifer* (Bloch, 1790), *Stellifer stellifer* (Bloch, 1790), *Pomadasys corvinaeformis* (Steindachner, 1868) and *Chirocentrodon bleekerianus* (Poey, 1867) which form dense schools (Carvalho-Filho 1999) and also *Cathorops spixii* (Agassiz, 1829) which is the most common species of catfish in the brazilian littoral (Figueiredo & Menezes 1978) being thus privileged at this time of the year. This explains the high values of abundance found for these species.

P. harroweri, *S. rastrifer*, *S. stellifer*, *P. corvinaeformis*, *C. spixii* and *C. bleekerianus* individuals, as well as other species, also feed on benthic invertebrates and several different crustaceans (Figueiredo & Menezes 1978, Menezes & Figueiredo 1980, Carvalho-Filho 1999, Sazima et al. 2004) and are benefitted during the rainy season. For this reason, these species' abundance peaks match with the shrimp, whose peaks also occur during the rainy season (Frédou et al. 2009). A similar pattern was found by Teixeira & Almeida (1998) in three beaches along the coast of Alagoas and by Araújo et al. (2008) at Frade Island (state of Espírito Santo), which associated the increase in the number of fish to the high primary productivity promoted by the rainy season.

Species richness was greater than that found in other studies carried out along the Brazilian coast, such as Avenida and Sobral beaches (Maceió, Alagoas), Berlinque beach (Vera Cruz, Bahia) and Frade Island (Espírito Santo) (Teixeira & Almeida 1998, Araújo et al. 2008, Oliveira-Silva et al. 2008). The greatest richnes's value (3.43) observed in this research was recorded in April, the month with rainfall peak. This value was below to that registered (6.17) in Cabuçu beach (Bahia state) Oliveira-Silva et al. 2008. As pointed out in the present research, this greatest richness was observed during the rainy season. However, no difference was detected among months for this index. The data presented are in accordance with other authors (Godefroid et al. 2004, Santana & Severi 2009), which recorded a lack of seasonality for richness index. It is very difficult to compare this index between different studies, since such a variation may be due to differences in sampling procedures, greater coverage of the sampled area, long period of sampling, number of trawlings and period of trawling (day/night). Besides, the studies cited above undertook manual beach trawling, while this study was based on otter trawling – which captures more species and individuals. The use of doors increases the weight of the net and results in direct contact with the soil, digging up the substrate and disturbing the species that live there (Jennings et al. 2001).

In relation to the Shannon-Wiener index, the results presented here showed significant differences only between the months April and June and April and October, however these differences were not recorded when the index values were compared between dry and rainy seasons. Similar results were reported by Araújo et al. (2008) and Santana & Severi (2009) for Frade Island (state of Espírito Santo) and Jaguaribe beach (state of Pernambuco), respectively. In these studies, the diversity throughout seasons did not differ significantly. It is believed that the occurrence of only two seasons (rainy and dry) in tropical regions influences the local fish community diversity, providing a homogeneous pattern among areas, once a great similarity between seasons are observed during the entire year. However, the rainy season tends to present higher values of diversity due to the increase in primary productivity (Araújo et al. 2008, Frédou et al. 2009)

In relation to feeding habits, the most abundant trophic category was first order carnivores, which were represented mainly by *P. corvinaeformis* (Steindachner, 1868). This category is usually observed in different ecosystems, as its species present varied ecomorphologies with diverse oral and sensorial apparatus that allow them to explore different kinds of food from a variety of environments (Ferreira et al. 2004).

The benthic invertebrate assemblages of sandy beaches include different species; however crustaceans, mollusks and polychaetas are generally dominant and may attain high abundance and biomass. It is possible that most invertebrates typical of sandy beaches do not occur in any other environment (Schlacher et al. 2008). These species present unique adaptations to survive in a dynamic environment, such as protective exoskeletons, mobility and burrowing ability, endogenous rhythms and behavioural plasticity (Veloso & Neves 2009). Zooplankton and shrimp of different sizes are quite abundant in sandy beaches, and fish are usually classified as top-level predators of this kind of ecosystem (Defeo et al. 2009). Such information strengthens the results of this study, where the category of the first order carnivores was favored by the great availability of these organisms.

This study confirmed what several other Brazilian authors have highlighted (Giannini & Paiva Filho 1995, Teixeira & Almeida 1998, Godefroid et al. 2003, Godefroid et al. 2004, Araújo et al. 2008, Monteiro-Neto et al. 2008, Oliveira-Silva et al. 2008) about the fish fauna of sandy beaches – an ecosystem with great species richness, yet with few dominant species. São Cristóvão Beach's fish assemblage is characterized by the great richness and abundance of Sciaenidae, which is similar to what has been observed in other studies. Individuals from Sciaenidae are commonly captured by trawler boats, and are one of the most important resources for coastal demersal fishing (Giannini & Paiva Filho 1990, Souza et al. 2008). Due to this family's great representativity – as in the case of *Stellifer rastrifer* (Jordan, 1889), *Stellifer stellifer* (Bloch, 1790) and *Larimus breviceps* Cuvier, 1830 – the category of the first order carnivores was the most abundant.

Conclusions

This study presents new data and is one of the first of its kind to focus on the northern coast of the Brazilian state of Rio Grande do Norte. Such research is important because few studies have been carried out on this state's coast and it is imperative to acquire knowledge on its biodiversity due to the anthropic actions that have been increasingly affecting beach ecosystems.

São Cristóvão Beach is characterized by the great abundance and richness of fish species, especially that of Family Sciaenidae. The occurrence of reef and pelagic fishes strengthens the connectivity concept among the most distant regions of the continental shelf and the more protected coastal areas. This suggests that this ecosystem acts as a migration route and is possibly an area where juvenile individuals of several fish species find shelter and food. Segregation in the monthly and seasonal abundance patterns of this region was observed – some species were significantly more abundant during the rainy season. The great availability of mobile invertebrates that is recorded in sandy beach ecosystems favored the most representative trophic categories: first and second order carnivores. The results presented here show the importance of sandy beaches for the development of the several fish species that use this environment for different purposes.

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Received 29/02/2012
Revised 22/08/2012
Accepted 24/08/2012

Germination of native grasses with potential application in the recovery of degraded areas in Quadrilátero Ferrífero, Brazil

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FIGUEIREDO, M.A., BAÊTA, H.E. & KOZOVITS, A.R. **Germination of native grasses with potential application in the recovery of degraded areas in Quadrilátero Ferrífero, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02912032012

Abstract: Native grasses are potential species to be used in land rehabilitation. However, due to the lack of better knowledge of their performance, preference is given to exotic plants, which may be invasive and negatively affect the local biodiversity. In order to better understand the propagation of native species of the Quadrilátero Ferrífero (Minas Gerais, Brazil) using their seeds, and in so doing, indicate possible candidates for land rehabilitation, this study investigated the germination patterns of the following grasses: *Andropogon bicornis* L.; *Andropogon leucostachyus* Kunth; *Setaria parviflora* (Poir.) Kerguélen; *Cenchrus brownii* Roem. & Schult; *Echinolaena inflexa* (Poir.) Chase, and *Apochloa euprepes* (Renvoize) Zuloaga & Morrone. The spikelets (depending on the species, removing or not the structures that surround the caryopsis) were treated as follows: T1-Control, T2- moistening with 0.2% potassium nitrate, T3-heating at 80 °C for 2 minutes, T4- scarification with sulfuric acid (except genus *Andropogon*) and, for genera *Andropogon* and *Setaria* T5- storage at room temperature and T6- refrigerated storage. The treatment was repeated four times for 25 caryopses incubated at 25 °C and constant light. Significant variation was observed when comparing germination rates from week to week, treatment to treatment and species to species. The most efficient treatment for genus *Andropogon* was T6, followed by T2 for *A. bicornis* and T3 for *A. leucostachyus*. T6 was also the most effective treatment for *S. parviflora,* followed by T5 and T2. *C. brownii* showed similar results when applying T1, T2 and T3 (mean 39%). *E. inflexa* and *A. euprepes* showed high levels of dormancy that were not overcome by the proposed treatments. *A. bicornis, A. leucostachyus, S. parviflora* and *C. brownii* showed higher germination potential, thus being possible candidates for the recovery of degraded areas. Future studies are indicated to find the most effective treatments for germination in field conditions.
Keywords**:** *poaceae, seed dormancy, storage time, heating, potassium nitrate, caryopsis.*

FIGUEIREDO, M.A., BAÊTA, H.E. & KOZOVITS, A.R. **Germinação de gramíneas nativas do Quadrilátero Ferrífero com potencial aplicação na recuperação de áreas degradadas**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02912032012

Resumo: As gramíneas nativas apresentam potencial para revegetação de áreas degradadas, no entanto, devido ao pouco conhecimento sobre sua biologia, dá-se preferência ao uso de espécies exóticas, que podem ser invasoras, afetando assim a biodiversidade local. No intuito de ampliar o conhecimento acerca da propagação via sementes de espécies nativas do Quadrilátero Ferrífero (QF), e desta forma, indicar possíveis candidatas a aplicação na recuperação de áreas degradadas da região, este trabalho objetivou avaliar os padrões germinativos das seguintes gramíneas: *Andropogon bicornis* L.; *Andropogon leucostachyus* Kunth; *Setaria parviflora* (Poir.) Kerguélen, *Cenchrus brownii* Roem. & Schult; *Echinolaena inflexa* (Poir.). Chase e *Apochloa euprepes* (Renvoize) Zuloaga & Morrone. As espiguetas (com presença ou não das estruturas que envolviam a cariopse, dependendo da espécie) foram submetidas aos seguintes tratamentos: T1-controle; T2- umedecimento do substrato com 0,2% de nitrato de potássio, T3- aquecimento a 80 °C por 2 minutos, T4- escarificação com ácido sulfúrico (exceto gênero *Andropogon*) e para os gêneros *Andropogon* e *Setaria,* T5- armazenamento a temperatura ambiente e T6- armazenamento sob refrigeração. Os tratamentos foram realizados em 4 repetições de 25 cariopses colocadas para germinar a temperatura de 25 °C e iluminação constante. Variação significativa foi observada quando comparadas as quantidades de germinações ocorridas entre as semanas, entre os tratamentos e entre as espécies. Para o gênero *Andropogon* o tratamento mais eficiente foi T6, seguido por T2 em *A. bicornis* e T3 em *A. leucostachyus*. T6 também foi o tratamento mais eficiente para *S. parviflora,* seguido por T5 e T2. C. *brownii* apresentou resultados próximos sob T1, T2 e T3 (média 39%). *E. inflexa* e *A. euprepes* apresentaram altos índices de dormência que não foram superadas pelos tratamentos propostos. *A. bicornis, A. leucostachyus, S. parviflora* e *C. brownii* apresentaram maiores potenciais de germinação, sendo possíveis candidatas para recuperação de áreas degradas no QF. No entanto, ainda são necessários estudos complementares com os tratamentos mais eficientes e testes de germinação e estabelecimento em condições de campo.
Palavras-chave: *poaceae, dormência de sementes, tempo de armazenamento, aquecimento, nitrato de potássio, cariopse.*

Introduction

The Quadrilátero Ferrífero, located in the southern portion of the Espinhaço Range, is one of the richest areas in biodiversity and endemic species of the Minas Gerais State (Brazil), and should receive priority attention when it comes to conservation (Drummond et al. 2005). The region has also received much attention for its contribution to the country's economy, accounting for approximately 70% of the Brazilian iron ore production (Brasil 2011), which is the second largest of the world (Instituto... 2011). To reconcile these two important aspects and in order to minimize the impacts of mining on local biodiversity, among other actions, recovery projects in degraded areas should prioritize the restoration of natural environment conditions and use native species (Gardner 2001).

Unfortunately, the knowledge on the tolerance of certain plants to the extreme conditions found in abandoned mining areas is restricted to a few exotic species (Ginocchio & Baker 2004). African grasses are a group of exotic plants most used for recovery of degraded areas in Brazil. Here, they have found soil and climate conditions similar to or more favorable than those of their original habitat, thus causing them to develop faster than the native species (Freitas & Pivello 2005).

The attributes that make exotic grasses efficient in recovering unprotected soil are probably the same as those that make them better competitors than native species. According to Freitas & Pivello (2005), the establishment and spreading of plant species from other regions in natural or managed ecosystems can reduce, extinguish and misbalance populations of original flora and thus alter the ecosystem equilibrium, which is today one of the worst environmental problems.

The substitution of exotic by native species in soil recovery projects has already attracted the interest of some mining companies. However, the ignorance regarding botany and ways of propagation of native species on the different areas of Brazil is no doubt the most impeding factor for the development of satisfactory recovery practices (Negreiros et al. 2002). With respect to native grasses, in fact, management is still difficult because studies are lacking (Filgueiras & Fagg 2008).

Jacobi et al. (2008) and Filgueiras & Fagg (2008) highlighted the potential of some native grasses as pioneer vegetation in the recovery of degraded areas. According to Filgueiras & Fagg (2008), native grasses such as *Andropogon bicornis* L., *A. leucostachyus* Kunth, *Echinolaena inflexa* (Poir.) Chase and *Setaria parviflora* (Poir.) Kerguelen among others, present morphological and physiological characteristics that enable them to survive in harsh environments, thus making them good candidates for land rehabilitation. In addition to these species, we can also mention *Apochloa euprepes* (Renvoize) Morrone & Zuloaga, a native grass (Filgueiras et al. 2010) with high importance value index in some grasslands developing on rocky (quartzite) outcrops in the Itacolomi State Park and the Ouro Branco range, where some soil features (Lemes 2009) and microclimatic conditions may have selected adaptations that made such plants potential candidates for application in the recovery of degraded areas. *Cenchrus brownii* Roem & Schult is a native grass (Filgueiras et al. 2010) with wide distribution in Central and South America (Clayton et al. 2010), showing good spreading capacity in disturbed environments.

In this study we investigated the germination patterns of species widely distributed in the Quadrilatero Ferrífero: *A. bicornis, A. leucostachyus, Apochloa euprepes, C. brownii, E. inflexa* and *S. parviflora*, so as to establish a basis for future studies focusing on the use of these native grasses in programs of biodiversity preservation in rocky regions and in the recovery of degraded areas.

Materials and Methods

Most of the spikelets were collected in the municipalities of Ouro Preto and Mariana (Minas Gerais), from January to March 2010. *C. brownii* spikelets, in particular, were collected in July 2009. The spikelets of several individuals (more than 30 per species) within a population were randomly sampled, excepting *E. inflexa*, because the propagation through rhizomes does not allow the distinction of individual plants. The spikelets were collected manually from branches that had started natural release of spikelets. Immediately after harvest, they were dried in the shade at room temperature. The spikelets that were not used in germination tests were divided into two sets immediately after drying. These were stored at (1) room temperature in paper bags or (2) in paper bags wrapped in plastic bags and stored under refrigeration at about 8 °C (Salomão 2003).

Specimens in the reproductive period were collected, identified by experts and deposited in the Professor José Badini Herbarium collection (Herbarium OUPR) of the Universidade Federal de Ouro Preto (UFOP).

Andropogon spikelets were selected for the removal of impurities with no distinction between empty and full spikelets. Due to their small size, differences between full and empty spikelets are minimal, thus making the manual selection very slow, as also reported by Carmona et al. (1999). The *Andropogon* spikelets were tested without the removal of any structure surrounding the caryopsis. The structures surrounding the caryopsis of *E. inflexa* and *Apochloa euprepes* were removed by rubbing a small amount of spikelets on the palm of one hand with the thumb of the other. This mixture of caryopses and straw was homogenized in a 1000 mL beaker containing water. A few seconds after homogenization, the supernatant material was discarded and the caryopses at the bottom of the beaker were collected after pouring the beaker's content through a sieve. For preliminary analysis, two groups of caryopsis with different densities were sectioned and the presence of endosperm was observed under the magnifying glass. All caryopses collected from the bottom of the beaker presented endosperm, whereas the floating material did not. Immediately after this selection, caryopses were taken to germinate.

Filled spikelets of *S. parviflora* were separated from the empty ones by applying a light pressure with a clamp on each spikelet. The filled ones were resistant to pressure. In *C. brownii* the structures surrounding the caryopses were removed, and the selection of full/empty caryopses was visually possible. For simplicity, from now on both caryopses and spikelets will be referred to as seeds.

Germination Tests

Germination tests were performed in the UFOP Laboratory of Plant Ecophysiology. Each test consisted of four petri dishes, where 25 seeds were placed to germinate on two sheets of filter paper. In each plate, 4 mL Nystatin (1000 IU/L) were added (Oliveira & Garcia 2005) to promote seed hydration and reduce fungal contamination. The petri dishes were sealed with tape to avoid moisture loss and placed in a germination chamber at 25 °C under continuous illumination. The position of the plates inside the chamber was randomly changed every 24 hours.

In order to reduce contamination by microorganisms, especially fungi, all pieces of glassware used for seed germination were previously immersed in a solution of hydrochloric acid (HCL) 1% for thirty minutes and then rinsed three times with distilled water and dried in an oven at 100 °C.

1. *Treatment*

Seeds were treated as follows:

Control (T1) - germination in the presence of light and hydration with Nystatin solution.

Potassium nitrate (T2) - hydrated germination with a solution of potassium nitrate (KNO_3) 0.2 %.

Pre-heating (T3) - Seeds were placed in an oven for two minutes at 80 °C and then transferred to the germination chamber.

Scarification with sulfuric acid (T4) - seeds were soaked in sulfuric acid (H_2SO_4) for three minutes and then washed in running water to avoid contamination of the embryo and then transferred to the germination chamber. This treatment was not applied to *Andropogon* seeds because, due to their small size, immersion in acid could destroy them.

Storage - *A. bicornis, A. leucostachyus* and *S. parviflora* seeds were also tested for the effects of storage on germination rate. The seeds were stored at room temperature **(T5)** or refrigerated **(T6)** to about 8 °C for eight months and then taken to the germination chamber.

Germination was evaluated daily. Seeds with at least a 2-3 mm radicle and / or coleoptile were considered germinated, counted and taken from the plates. The experiments were finished seven days after the last germination. The statistical analysis involved Generalized Linear Models (GLM) with quasi-binomial error distribution. The germination time, kind of treatment and species were established as fixed parameters, as well as the interaction between this fixed parameters. GLM was chosen because of the binomial nature of the data and was applied by means of the free software R (R Development Core Team 2011).

Results

Table 1 shows the variations observed in the germination percentages from week to week (week), treatment to treatment (trat) and species (sp.). It also shows the variations observed among treatments in each week (week: trat), among species in each week (week: sp), and among treatments in each species (trat: sp).

The most effective treatments in overcoming dormancy of *Andropogon bicornis* seeds were refrigerated storage (28%) and germination in treatment with KNO_3 solution (24%). These treatments produced much better results than treatment control (18%), whereas the other treatments led to germination rates lower than treatment control (Figure 1a). It took a maximum of 27 days for *A. bicornis* to germinate, with a notable difference in the distribution of germination rates among the treatments during this period. Most treatments promoted higher percentage of germination in the first week (Figure 1a), specially the pre-heating, in which about 86% of the total germination occurred in the first seven days. Despite germination was accelerated by pre-heating, the total number of seed germination was not favored.

Although they belong to the same genus and are sympatric, the germination patterns of *A. leucostachyus* and *A. bicornis* were not similar. The best *Andropogon leucostachyus* germination occurred after storing under refrigeration (58%), whereas the worst results occurred after storing *Andropogon leucostachyus* seeds at room temperature (11%). The second most effective treatment was pre-heating, which resulted in 51% germination. In average, 37% germination occurred after the other treatments were applied to the seeds (Figure 1b).

Table 1. Results of statistical analysis using generalized linear models with distribution of errors quasibinomiais for period of observation , treatments and species.

Tabela 1. Resultados da análise estatística utilizando modelos lineares generalizados com distribuição de erros quasibinomiais para período de observação, tratamentos e espécies.

Factor	Df	F	Significant
Time	1	343,33	p < 0,01
Tratament	5	13,76	p < 0,01
Species	5	56,52	p < 0,01
Time:tratament	5	2,61	p = 0,03
Time:species	5	25,02	p < 0,01
Specie:tratament	17	2,48	p < 0,01

In general, *A. leucostachyus* germination occurred in 17 days. Except for the treatment of storage at room temperature, more than 90% germination happen for all the other treatments in the first seven days (Figure 1b).

S. parviflora germination was much higher than treatment control (11%) after the following three treatments: storage under refrigeration (29%), storage at room temperature (27%) and germination in KNO_3 solution (25%). The pre-heating values were slightly higher than control, while scarification in sulfuric acid promoted germination rates lower than treatment control (Figure 1c).

It took a maximum of 19 days for *S. parviflora* to germinate, with most of the germination concentrated in the first week. Germination was the fastest after storage under refrigeration, completely occurring in the first seven days of testing (Figure 1c).

The treatments assessed were inefficient or promoted only low germination rates (less than 5%) for *E. inflexa* in two treatments and 1% for *A. euprepes* in the KNO_3 treatment (Figure 1e, f).

With the exception of scarification with sulfuric acid, the other treatments promoted an average of 39% germination of *Cenchrus brownii* (Figure 1d). It took a maximum of 28 days for *C. brownii* to germinate. Treatment with KNO_3 promoted the highest germination percentage (42%), which was concentrated in the first week, while other treatments led to higher germination in the second week of the experiment (Figure 1d).

Discussion

As a whole, the results showed that the studied species, even if native of a relative small area, responded very differently to the proposed treatments. This reinforces the need for more specific work on each species in order to identify better germination conditions.

The germination rates found for the *A. bicornis* seeds in the two most effective treatments were similar to those obtained by Carmona et al. (1998), who worked with seeds collected in the Federal District, which were previously mechanically selected and stored for six months at room temperature. The authors obtained a germination percentage of 27%. However, it is important to note that in the present study, seeds were not pre-selected or pre-prepared as in Carmona et al. (1999), suggesting that refrigerated storage and germination in KNO_3 solution were more efficient in promoting *A. bicornis* germination than the treatments applied by these authors.

According to Carmona et al. (1999), the percentage of full seeds in *A. bicornis* is only about 35% of the total seed set. Taking it as a reference, hypothetically, the storage under refrigeration for 8 months would promote about 80% germination of the viable seeds in the present study.

Despite pre-heating of *A. bicornis* only accelerated the germination process, the results of this treatment applied to *A. leucostachyus* were better in terms of total number of germination. The enhancement of germination rates in treatments that simulate the effects of fire events is expected for native species of seasonal environments, where fires occur naturally. The stimulation of germination after fire may be a result of evolutionary adaptation. After burning, more nutrients are available, competition with other plants is less intense and herbivores are less menacing (Lamont et al. 1993, Tyler 1995), which can facilitate the establishment of seedlings that have germinated just after fire. Temperatures between 80 °C and 100 °C at 0.3-cm and 1-cm depth in topsoil have been observed in

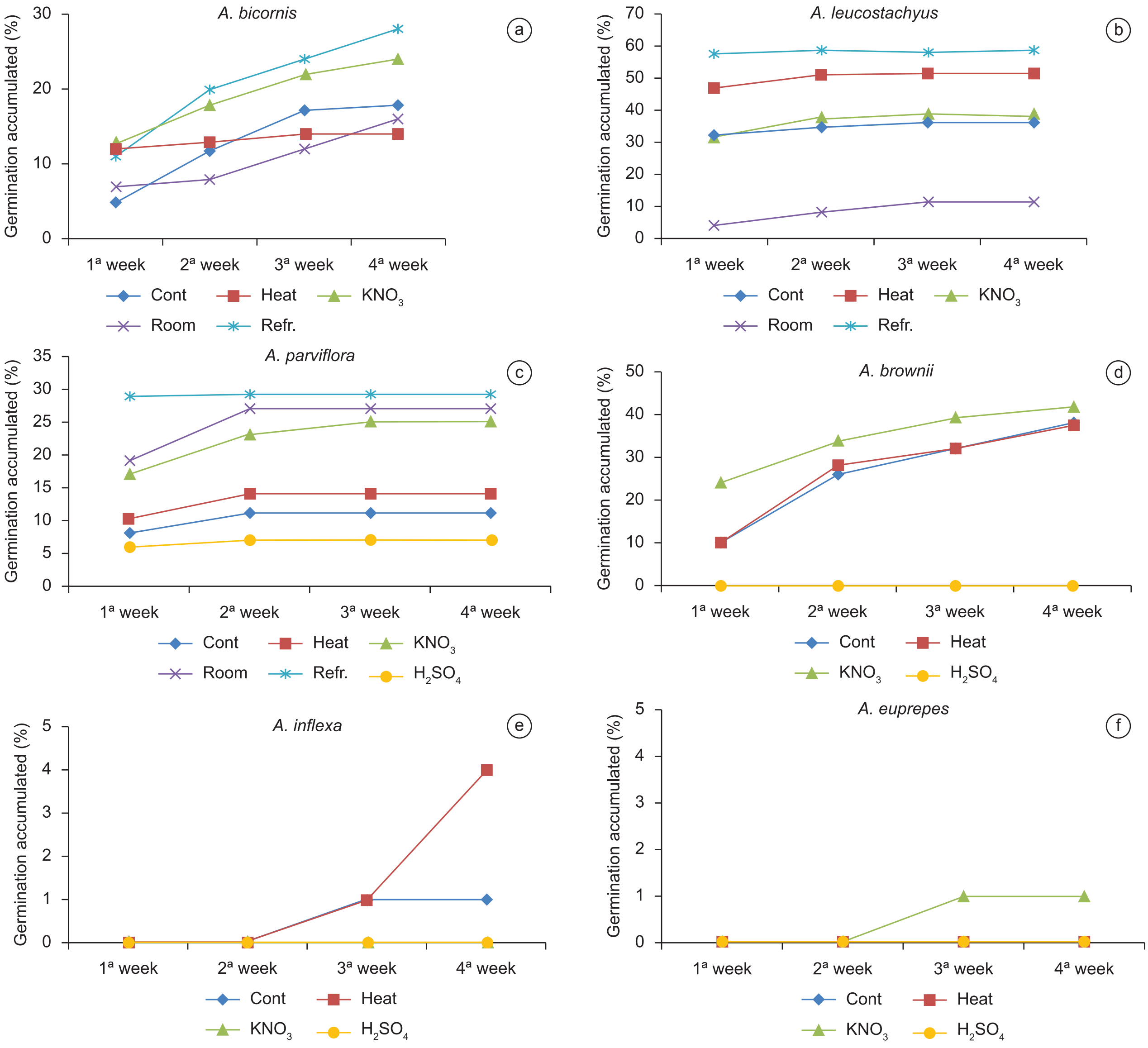

Figure 1. Accumulated percentage of germination after different treatments, under 25 °C and continuous illumination. (a) *Andropogon bicornis;* (b) *Andropogon leucostachyus;* (c) *Setaria parviflora;* (d) *Cenchrus brownii;* (e) *Echinolaena inflexa;* (f) *Apochloa euprepes*. Cont - control; Heat- heating; KNO_3 - potassium nitrate; H_2SO_4 - sulfuric acid; Room - storage room temperature; Refr - storage refrigerate temperature. (Note different scales for axis Y).

Figura 1. Porcentagem de germinação acumulada das gramíneas avaliadas em diferentes tratamentos à temperatura de 25 °C e iluminação continua. (a) *Andropogon bicornis,* (b) *Andropogon leucostachyus* (c) *Setaria parviflora;* (d) *Cenchrus brownii;* (e) *Echinolaena inflexa;* (f) *Apochloa euprepes*. Cont - controle; Heat- pré- aquecimento; KNO_{3-} nitrato de potássio; H_2SO_4 – Ácido sulfúrico; Room- Armazenamento a temperatura ambiente; Refr- Armazenamento sob refrigeração. (Notar que as escalas do eixo Y são diferentes).

seasonal savanna environments during fire events, which is the same temperature used in the present study and that caused germination rates to increase. Temperatures above 120 °C, however, seemed to be lethal to seeds (Williams et al. 2003, 2004).

The highest *A. leucostachyus* germination rates observed in the present study were close to the best germination rates obtained by Giotto (2010), who performed tests at alternating temperatures of 20-35 °C and during a 12-hour photoperiod. The author obtained 59% germination in a solution of potassium nitrate and by removing the structures surrounding the caryopsis. However, when working with seeds stored for 10 months, at room temperature or at 4 °C, she obtained much lower germination rates of 6% and 28%, respectively. Dissimilarities between the results obtained by us and by Giotto (2010) may be related to differences in both temperature and luminosity applied, besides the period and the temperature of storage. Adaptations of the two *A. leucostachyus* populations to climatic conditions may also differ, since the study regions where the seeds were collected are about 800 km distant from each other. However, it is clear that pre-heating and refrigerated storage as proposed in our study are the most suitable treatments to overcome *A. leucostachyus* seed dormancy.

The interference caused by temperature in *A. leucostachyus* germination suggests the need for more detailed studies. Different temperature variations should be tested in future studies in order to find the best germination conditions, including also pre-cooling treatments, as proposed for some species of the same genus (Brasil 2009). Another *A. leucostachyus* germination behavior also evidenced by Giotto (2010) is its low response in KNO_3 solution, which is uncommon for some species of the genus (Brasil 2009). The *A. leucostachyus* population sampled in our study occupies organic matter-free environments, which may have unfavorably alter their germination pattern in the presence of nitrate. According to Carmona et al. (1997), *Gymnopogon Doellii* Boechat & Valls, a native savanna grass, tend to respond positively to KNO_3 because this treatment simulates part of the optimal conditions for species germination under field conditions where organic matter is decomposing.

The fact that germination rates of *Andropogon* seeds were higher after storage for eight months under refrigeration may indicate that dormancy in this species can be overcome by aging, as has been observed in other species of the same genus (Eira 1983) and in other grasses (Carmona et al. 1998, Giotto 2010). On the other hand, storage at room temperature reduced germination rate, suggesting that storage under refrigeration allows the overcoming of dormancy (Brasil 2009) and reduces the degradation process. According to Peterbauer & Richter (2001), storage at low temperatures may reduce the enzymatic activity, better preserving the cellular components.

The dormancy of *S. parviflora* seeds seemed to be sensitive to storage or KNO_3, but the germination percentages obtained with both treatments were still low, considering that all the seeds were filled. Perhaps the storage for a longer time interval or a combination of storage and use of KNO_3 can contribute to higher germination percentages than those obtained in the present work. Another treatment with potential to enhance *S. parviflora* germination rates is the removal of structures surrounding the caryopsis. Working with *Setaria poirentiana* (Schult.) Kunth, a native grass, Giotto (2010) observed that this treatment caused a large increase in the number of germinations. The dormancy of *S. parviflora* seeds was sensitive to storage, a feature that contrasts with the results found for native grasses of the same genus (Carmona et al. 1998, Giotto 2010). Since *S. parviflora* seed size is big enough, in future studies tests should be applied in order to define the real number of viable seeds, as has been proposed for the genus by Brasil (2009).

Despite the low *E. inflexa* germination percentages obtained in the present study, another study found 90% of seed viability (Silva & Rocha Filho 1991). Klink (1993) tested seeds stored for six months under a constant temperature of 25 °C and using soil as substrate. This author obtained 30% germination, which started from the seventh day of the experiment and was much earlier than that observed in the present study. Apparently, the overcoming of *E. inflexa* seed dormancy should also be favored by storing, as proposed by Giotto (2010). The author also suggested the removal of structures surrounding the caryopsis in association with germination under alternated temperature of 20-35 °C and a 12-hour photoperiod, which can be positive in overcoming *E. inflexa* dormancy. A good alternative to restrictions on sexual propagation of *E. inflexa* is to improve its spreading with vegetative material (rhizomes), as has successfully been done by Miranda (2009) and Marques et al. (2010).

Despite high seed production and large number of filled seeds (our observations), *Apochloa euprepes* germination percentages were not satisfactory enough to recommend this species for recovery of degraded areas. *Apochloa euprepes* seeds did not respond to any of the treatments, suggesting that the overcome of dormancy may be enhanced by aging. Another factor that might be linked to the interruption of *A. euprepes* dormancy is fire, since the species is commonly found in rocky fields in dense mats. The pre-heating treatment proposed here, however, did not stimulate germination, probably because it did not simulate all the changes promoted by fire in natural environments, such as smoke, for example (Keith 1997, Fidelis et al. 2007).

In experiments with *Cenchrus echinatus* L., Martins et al. (1997) obtained similar results to those found for *C. brownii* in the present work, where no germination was observed in H_2SO_4 treatment, but in KNO_3. The authors found higher *Cenchrus echinatus* germination rates after removal of the casing bracts and glumes. Further experiments should be conducted with *C. brownii* in order to check whether removal of these parts will facilitate germination. Such a procedure is time-consuming, which may be a major impediment to large-scale *C. brownii* spreading.

Conclusions

Seeds of all the species studied here presented some kind of dormancy. *A. bicornis, A. leucostachyus, S. parviflora* and *C. brownii* were sensitive to, at least, one of the treatments proposed. Refrigerated storage of *Andropogon* and *S. parviflora* for eight months was the most efficient treatment to overcome dormancy. Storage at room temperature of *S. parviflora* also produced good results. The pre-heating treatment stimulated *A. leucostachyus* germination and interfered in the time of *A. bicornis* germination, whereas scarification with H_2SO_4, as applied in this work, was detrimental to germination of all species. The use of KNO_3 was the most suitable treatment for *A. bicornis, S. parviflora* and *C. brownii* germination immediately after harvest. In contrast, this treatment caused no positive effect in *A. leucostachyus* germination.

A. bicornis, A. leucostachyus and *S. parviflora,* besides their morphological and physiological characteristics that make them suitable for the recovery of degraded areas, also presented good germination rates under laboratory conditions.

Acknowledgements

The authors thank the staff of the Herbarium Prof. José Badini for preparation of plant material, Pedro Viana (UFMG) for help in identifying some grasses and IEF for allowing collections in PEIT. The study was supported by grants from FAPEMIG (Pesquisador Mineiro 2009) and CNPq (Nº 577323/2008-3). Maurilio A. Figueiredo was supported by UFOP-fellowship.

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Received 26/01/2012
Revised 07/09/2012
Accepted 10/09/2012

Edge effects and the impact of wildfires on populations of small non-volant mammals in the forest-savanna transition zone in Southern Amazonia

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MENDES-OLIVEIRA, A.C., SANTOS, P.G.P., CARVALHO-JÚNIOR, O., MONTAG, L.F.A., LIMA, R.C.S., MARIA, S.L.S. & ROSSI, R.V. **Edge effects and the impact of wildfires on populations of small non-volant mammals in the forest-savanna transition zone in Southern Amazonia**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn00912032012

Abstract: The impact of fire and edge effects on the community of small non-volant mammals was investigated in transitional Amazon forest within a matrix of soybean plantations. The animals were live trapped on 24 line transects, of which 16 were distributed in unburned areas and 8 in a burned area. A total of 11 species was recorded, including six rodents and five marsupials. The abundance and richness of small mammals appeared to decrease in burned areas, although this impact appeared to mask edge effects. In the absence of fire impacts, a positive relationship was found between mammal abundance and the distance from the forest edge. The impact of the edge effect on the diversity of small mammals appears to be influenced by the type of anthropogenic matrix and the ecological characteristics of the different species.

Keywords: *Cricetidae, Didelphidae, diversity, soybean matrix, experimental fire.*

MENDES-OLIVEIRA, A.C., SANTOS, P.G.P., CARVALHO-JÚNIOR, O., MONTAG, L.F.A., LIMA, R.C.S., MARIA, S.L.S. & ROSSI, R.V. **Efeito de borda e do fogo sobre pequenos mamíferos não-voadores (Rodentia e Didelphimorphia) em uma zona de transição Floresta-Cerrado ao sul da Amazônia**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn00912032012

Resumo: O efeito de borda e do fogo sobre a comunidade de pequenos mamíferos não-voadores foi investigada em uma área de transição entre Cerrado e Floresta em uma área de matriz de soja na Amazônia Oriental. Os indivíduos foram coletados em 24 transectos, dos quais 16 foram distribuídos em área sem efeito do fogo e oito distribuídos com efeito do fogo. Um total de 11 espécies foi registrado, incluindo seis roedores e cinco marsupiais. A espécie *Hylaeamys megacephalus* foi a mais abundante em áreas sem efeito do fogo. A abundância e riqueza de pequenos mamíferos não-voadores apresentaram uma diminuição em áreas queimadas, entretanto o efeito do fogo parece mascarar o efeito de borda nestas mesmas áreas. Em relação ao efeito de borda, sem nenhum efeito de fogo, a relação entre a abundância de pequenos mamíferos não-voadores com a distância da borda foi positiva. A relação entre a diversidade de pequenos mamíferos e efeito de borda pode ser ligada à vegetação matriz e características ecológicas de cada espécie.

Palavras-chave: *Cricetidae, Didelphidae, diversidade, sojicultura, fogo experimental.*

Introduction

The expansion of beef ranching and industrialized soybean plantations in the northern extreme of the Brazilian state of Mato Grosso has been identified as the main threat to biodiversity on this Amazon frontier (Fearnside 2001, 2006, Barreto et al. 2006, Queiroz 2009). The area encompasses a transition zone between the Amazon rainforest and the central Brazilian savanna (Cerrado), a distinct forested system with a poorly-known biota (Ferreira-Junior et al. 2008, Araujo et al. 2009). This area suffered reduced impact in the past, but in the present day, the landscape has become highly fragmented, despite government legislation requiring the maintenance of forest reserves on private properties (Nepstad et al. 2006).

Forest fragmentation leads to increased tree mortality and reduced precipitation, making the remaining forests more vulnerable to fire (Mesquita et al. 1999, Laurance & Williamson 2001, Monteiro et al. 2004, Balch et al. 2008). Edge effects constitute an additional negative ecological consequence of forest fragmentation, which involves physical and biological changes in the forest, resulting from the abrupt transition between the forest and the surrounding matrix (Kapos 1989, Williams-Linera 1990, Benitez-Malvido 1998, Laurance et al. 2002, Laurance 2008, Laurance & Vasconcelos 2009).

Unfortunately, the impact of deforestation on the fauna of transitional Amazon forest has received little attention (Lacher & Alho 2001, Silva & Bates 2002). Despite their considerable diversity, this lack of data includes the small non-volant mammals, such as rodents and marsupials (Bonvicino et al. 2002, Mares & Ernest 1995, Carmignotto 2004, Costa et al. 2005). In fact, this group of mammals has been poorly studied anywhere in the Amazon basin (Silva et al. 2001).

Few studies have focused on the impacts of edge effects on small non-volant mammals in tropical habitats (Laurance 1994, Goosem 2000, Asquith & Mejía-Chang 2005, Fuentes-Montemayor et al. 2009). In Brazil, most of the available studies have involved the fauna of the Atlantic Forest or Cerrado. Stevens & Husband (1998) recorded increasing diversity as a function of the distance from the edge in the Atlantic forest. In the same ecosystem, Pardini (2004) found significantly richer small mammal community in edge habitats in comparison with the interior of mature forest and concluded that arboreal species are more affected by edge effects. In all cases, edge effects have different consequences for different species (Figueiredo & Fernandez 2004, Santos-Filho et al. 2008).

The effects of wildfires on the diversity of small mammals are as complex and poorly understood as edge effects. Studies in non-tropical ecosystems, including deserts, grasslands, and temperate forests have recorded a decrease in the abundance of some species immediately after a wildfire (Quinn 1979, Fox 1982, Ojeda 1989, Fa and Sanchez-Cordero 1993, Churchfield 1997, Simon et al. 2002, Converse et al. 2006), reduced abundance in areas that are burned regularly (Sherburne-Junior 1959, Rana 1985) or the dominance of a few species in burned areas (Krefting & Ahlgren 1974, Kern 1981, Clark & Kaufman 1990). In most cases, the time elapsed since the disturbance seems to be an important variable determining the composition of the mammalian community (Vieira & Marinho-Filho 1998, Ford et al. 1999, Simon et al. 2002, Torre & Diáz 2004, Fisher & Wilkinson 2005). In the Cerrado, Briani et al. (2004) and Vieira (1999) found that small mammals were relatively tolerant to such impacts, and were especially abundant during the early successional stages.

The present study evaluates the potential impacts of edge effects and wildfires on the species richness and abundance of small rodents and marsupials in the transitional forest of the southern Amazon basin. Specifically, the study area is located within a typical fragmented landscape within a matrix of soybean plantations.

Methods

1. *Study area*

The study was conducted in an area of transitional Amazon forest (Instituto... 2004), located on Tanguro Farm (13° 04’ 35.39” S and 52° 23’ 08.85” W), 75 km north of Canarana, in the Brazilian state of Mato Grosso (Figure 1a). This farm encompasses 82,000 ha, of which 38,000 were used for soybean cultivation. The remaining area is covered by transitional Amazon forest affected by different levels of disturbance (Figure 1b). The climate is humid tropical, with mean annual precipitation of 1739 mm and a marked dry season from May to September (Balch et al. 2008).

This transition zone is a complex mosaic of Amazonian forest and Cerrado vegetation, with a lower plant species richness, lower canopy height, and lower leaf area index in comparison with the proper Amazon forest (Ackerly et al. 1989, Ivanauskas et al. 2004, Balch et al. 2008). These forests currently suffer some of the highest deforestation rates in Brazil due to the ongoing expansion of cattle ranching and soybean plantations (Instituto... 2006, Soares-Filho et al. 2006).

2. *Data collection*

Data collection was conducted between August 2005 and August 2007, during five field expeditions of twenty days each, three in the dry season and two in the rainy season. Samples were collected simultaneously in two forest plots with similar vegetation characteristics, defined as Plots 1 and 2 (Figure 1b). Just on the last expedition it was not possible to access the Plot 1, on the last few days. Both plots contained 150 ha of continuous forest, and were bordered on one side by an abrupt transition between forest and soybean plantations. The distance between Plot 1 and 2 was about ten kilometers. Plot 1 was divided into three contiguous subplots of 50 ha (Figure 1c), including an unburned area as control (treatment UbA), a subplot in which experimental fires (inside the forest) were set in 2004 and 2007 (treatment F3), and a subplot in which experimental fires (inside the forest) were set annually (treatment F1). In these plots, data were collected shortly before the experimental fires were set. Plot 2, which was the same size as Plot 1, was unaltered throughout the study period, although it did present the same edge configuration of Plot 1.

Mammals were live trapped with small (23 cm × 6 cm × 5 cm), medium (23 cm × 9 cm × 8 cm) and large (38 cm × 12 cm × 10 cm) Sherman traps and Tomahawk traps (51 cm × 19 cm × 19 cm). In both plots, the traps were distributed along 12 parallel transects 250 m apart (Figure 1c). Sixteen traps were set along each transect, 11 medium Sherman live-traps at a distance of 25 m from each other, together with 2 Sherman (large or small) and 3 Tomahawk traps chosen at random. A total of 192 traps were used in each plot, all of which were always set on the ground, where the effects of the experimental fire were more visible. Balch et al. (2008) noted that the forest at Tanguro Farm burned most intensely at ground level, probably because the layer of dry debris acts as fuel, while the more humid vegetation above dampens the flames (Barlow & Peres 2003). The traps were baited with fruits, bacon and mixture of peanut with oil fish, and inspected every morning during sampling days.

For the investigation of edge effects was considered the distance from transect to the edge of the forest (adjacent to the soybean plantation). In both Plots, these distances varied from 30 m to 750 m, with four treatments – the first row of transects at 30 m from the edge, the second 250 m, the third 500 m, and the fourth, 750 m (Figure 1c). Twelve transects were sampled in each Plot. The parallel distance between transects was 250 m and the distance between transects of

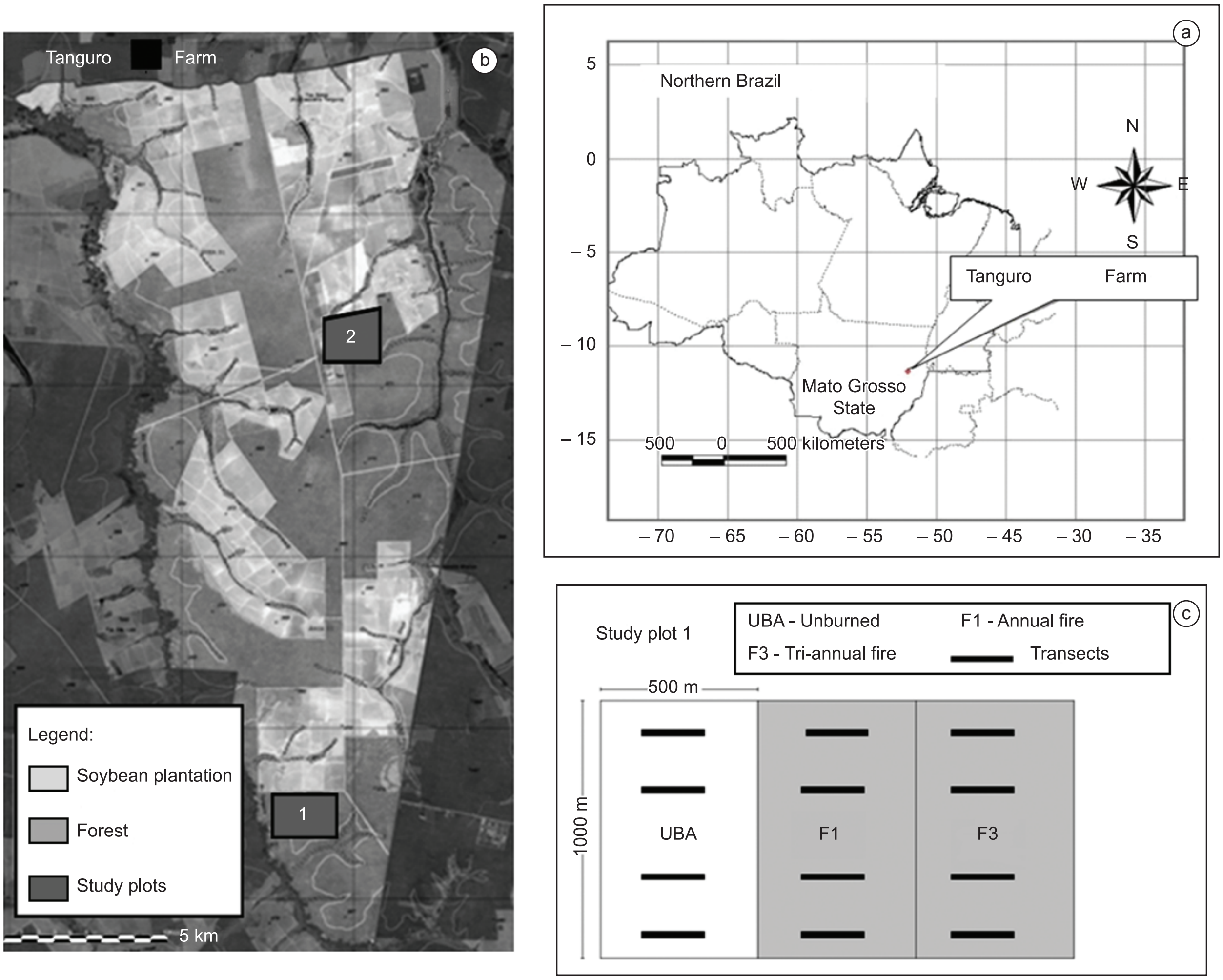

Figure 1. Location of the study area. a) Location of Tanguro Farm in southern Amazonia; b) Tanguro Farm; c) Details of sample plot 1.

Figura 1. Localização da área de estudo. a) Localização da Fazenda Tanguro na Amazônia Oriental; b) Fazenda Tanguro; c) Detalhes da parcela amostral 1 (queimada).

each subplot was 500 meters. For statistical analysis, each transect was considered to be an independent sample, given that, with the exception of *Didelphis marsupialis* Linnaeus, 1758, animals were only recaptured within the same transect, and not between them. The independence distance of samples at this study can be corroborated by the literature about habitat use by small mammals (Nupp & Swihart 2000, Jorgensen 2004, Dalmagro & Vieira 2005)

3. *Data analysis*

The data were checked for normality and homogeneity of variance, which permitted the use of a parametric two-factor ANOVA, which was applied to verify the effects of the distance from the edge and of fire, and the interaction between these factors. The significance level was 5%. A linear regression was used to verify edge effects in the unburned transects, including all transects in Plot 2 and those in subplot UbA of Plot 1. The approach was repeated omitting subplot UbA, in order to assess the possible indirect effects of fire. A temporal analysis comparing the effects of fire between treatments (F1 and F3) were impeded by the inadequate number of transects in each subplot for replication.

For the comparative analysis of transects between plots, considering edge and fire effects together, a MDS ordination were applied, using the Bray-Curtis coefficient of similarity with the abundance transformed to (ln(N+1)). The adequacy of the MDS analyses was assessed by stress values, with values below 0.5 being considered reliable (Clarke & Warwick 2001).

The autocorrelation was treated with spatial filters. To test if the distance between transects could be affecting the results of the tested effects on abundance and richness of non-volant small mammals, was applied a Mantel test using a spatial matrix of filters and geographical coordinators. The incidence was treated with Jaccard similarity and the spatial matrix by Euclidean distance.

Results

Total sampling effort in plot 1 was 9,792 trap nights, resulting in the capture of 26 individuals belonging to six species, including two rodents: *Hylaeamys megacephalus* (Fischer, 1814) (n = 12) and *Rhipidomys nitela* Thomas, 1901 (n = 7), and four marsupials: *Didelphis marsupialis* Linnaeus, 1758 (n = 2), *Micoureus demerarae* (Thomas, 1905) (n = 3), *Marmosops bishopi* (Pine, 1981) (n = 1), and *Marmosa murina* (Linnaeus, 1758) (n = 1). In plot 2, with a total of 10,752 trap nights, 367 individuals of 10 species were captured, including six rodents: *H. megacephalus* (n = 302), *R. nitela* (n = 16), *Necromys lasiurus* (Lund, 1841) (n = 11), *Oligoryzomys* cf. *microtis*

(Allen, 1916) (n = 7), *Akodon* sp. (n = 2), and *Calomys* cf. *tocantinsi* Bonvicino, Lima & Almeida, 2003 (n = 2), and four marsupials: *D. marsupialis* (n = 16), *M. demerarae* (n = 4), *Metachirus nudicaudatus* (É. Geoffroy, 1803) (n = 5), and *M. bishopi* (n = 2).

Considering only the edge effect, no difference was found between transects in either in species richness (F = 0.895; p = 0.461) or abundance (F = 1.852; p = 0.171). However, the effect of fire decrease the abundance (F = 11.435; p < 0.01) and richness (F = 9.701; p < 0.01) of small mammals on the burning sample Plots. Considering the two effects together, the statistical analyses presented an interaction between then, for both abundance (F = 16.808; p < 0.01) and richness (F = 59.364; p < 0.01).

The linear regression analysis found no significant tendency in abundance with increasing distance from the edge (r^2 = 0.24; p = 0,142) when all unburned transects were analyzed together (Figure 2a). However, when Plot 1 was excluded from the analysis, i.e. with no indirect fire effect, abundance increased significantly with distance from the edge – r^2 = 0.77; F = 33.84; D.F. = 10; p < 0.01 (Figure 2b). The reduced abundance of mammals in subplot UbA appears to be an indirect consequence of the successive fires in the adjacent Plots (F1 and F3). The results of this analysis may also have been influenced by the significantly greater abundance of *H. megacephalus* in Plot 2.

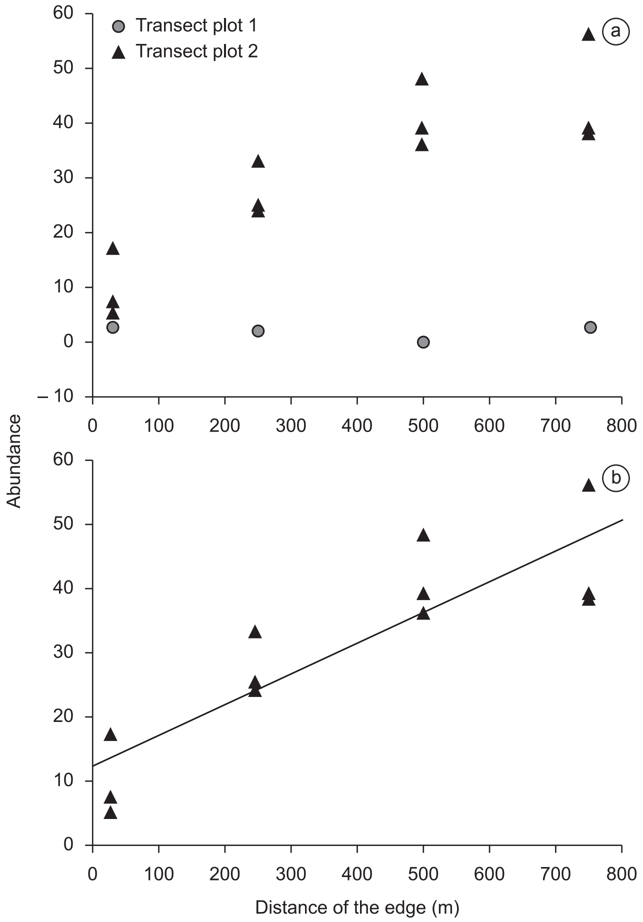

Figure 2. Relationship between the abundance of small mammals and the distance from the edge in the unburned transects (n = 16) of plots 1 and 2 (a), and in plot 2, n = 12 (b).

Figura 2. Relação entre abundância de pequenos mamíferos não-voadores e a distância da borda em transectos não queimados nas parcelas 1 e 2 (N = 16) (a), e apenas em transectos não queimados na parcel 2 (N = 12) (b).

The MDS analysis identified two main groups (Figure 3), supported by the stress value of 0.01. The ANOSIM analysis of the groups, including both edge and fire effects, confirmed significant differences between groups (p = 0.013). Two of three transects in Plot 2 located closest to the edge did not fit in with the general pattern for this Plot, possibly because the abundance of mammals was considerably lower, even in the case of *H. megacephalus*.

The Mantel test showed that there was no autocorrelation between samples using the spatial filters (Mantel 0.779; p = 0.00009).

Discussion

The results of the present study indicate that experimental fires had a highly negative effect on the abundance and richness of communities of small non-volant mammals (Krefting & Ahlgren 1974, Fox 1982, Vieira 1999, Briani et al. 2004, Figueiredo & Fernandez 2004). The relative abundance of *H. megacephalus* in plot 2 may have influenced the results, especially for the analysis of species abundance. This species is found mainly in upland forests in the Brazilian Amazon basin, but is also associated with the open forest formations of the Cerrado and Atlantic Forest (Fonseca et al. 1996, Oliveira & Bonvicino 2006). Carmignotto (2004) reported that *H. megacephalus* prefers forested environments and is only occasionally found in open areas.

The absence of the terrestrial species *Necromys lasiurus* (Lund, 1840) and *Oligoryzomys* cf. *microtis* (Allen, 1916) from the burned areas may be related to the typical combustion pattern of wildfires in humid Amazonian forests, which are typically restricted to the forest floor (Barlow & Peres 2003, Balch et al. 2008). It seems likely that these ground-dwelling species (Vieira et al. 2005, Oliveira & Bonvicino 2006) are extremely vulnerable to the effects of fire over the short term. Similar considerations may be relevant to *D. marsupialis* and *M. nudicaudatus*, in particular the latter, which is exclusively terrestrial, and burrows beneath the leaf litter (Passamani 1995, Vieira & Monteiro-Filho 2003, Rossi et al. 2006).

As the study only covered a two-year period, it was not possible to assess the long-term effects of experimental fire reliably. A series of different microhabitats may be created following successive wildfires, depending on the time passed since the previous fire, probably through the selection of different mammal species (Fox 1982, Briani et al. 2004, Vieira 1999). In any case, the small mammal assemblage may differ considerably between successional stages (Krefting & Ahlgren 1974, Torre & Diáz 2004, Fisher & Wilkinson 2005).

Almeida et al. (2007) described an increase in the predation of seeds in burned areas at Tanguro Farm, especially those of smaller size such as *Ormosia paraensis* Ducke (Fabaceae), *Trattinickia burseraefolia* Mart (Burseraceae) and *Maprounea guinanensis* Aubl (Euphorbiaceae). These authors concluded that, over the medium term, fire would favor plants with smaller seeds, facilitating their predation by small-bodied species such as mammals. Barlow & Peres (2003) observed a reduction in medium- and large-bodied vertebrates in burned areas, which would lead to a reduction in competition for food, favoring an increase in frugivorous-insectivorous species such as small mammals (Talamoni et al. 2008).

In the present study, the edge effect appeared to reduce species abundance, at least in the absence of fire. A similar pattern was observed by Santos-Filho et al. (2008), who recorded the highest richness and abundance in transects within forest fragments (300 m from the edge) compared to those located closer to the pasture (50 m from the edge) and at the edge of the forest. However, Pardini (2004) recorded a significantly higher species richness of small mammals at the edge of forest fragments in Atlantic Forest, while Malcolm (1997)

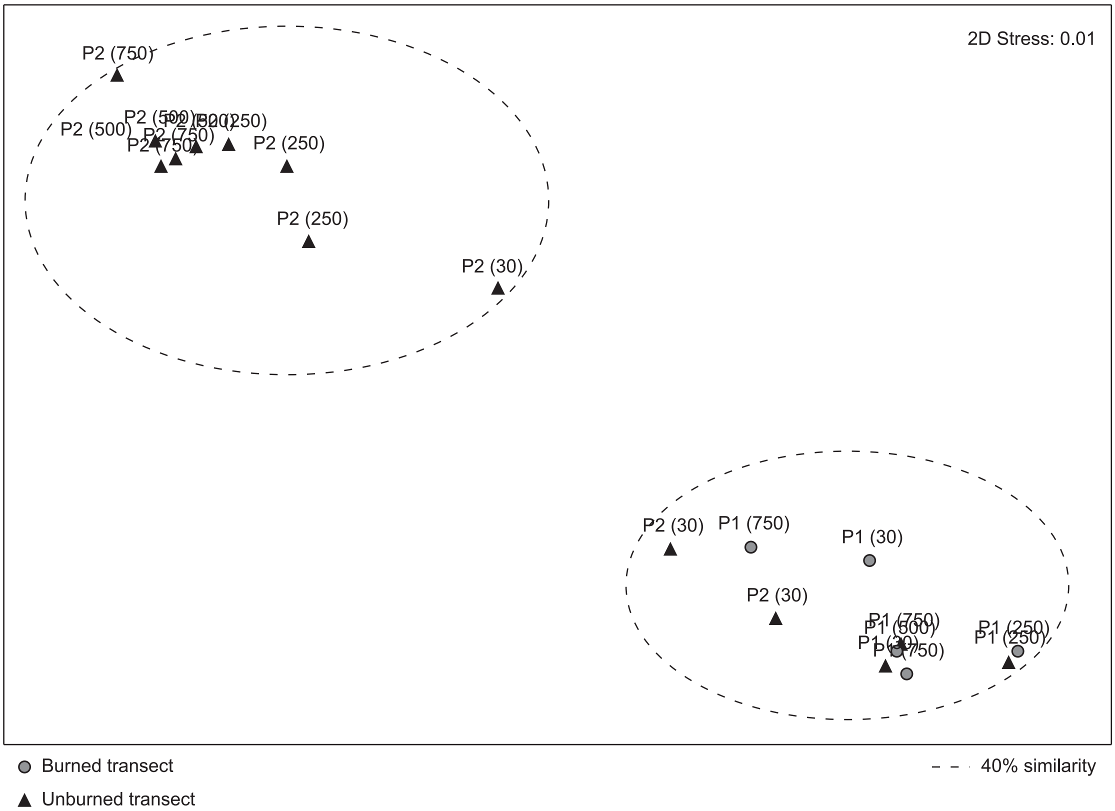

Figure 3. MDS analyses of the abundance of small mammals on all transects of plots 1 (P1) and 2 (P2) based on the Bray-Curtis coefficient of similarity. The numbers between parentheses indicate the distance from the edge.

Figura 3. Análise de ordenação MDS de pequenos mamíferos não voadores em todos os transectos de ambas as parcelas 1 (P1) e 2 (P2) (com coeficiente de similaridade de Bray-Curtis). Os números entre parênteses indicam a distância a partir da borda.

observed an increase in the abundance of small mammals in smaller forest fragments (1-10 ha) in central Amazonia.

The influence of the edge effect on the diversity of small mammals may be linked to the type of vegetation in the matrix and the ecological characteristics of the mammalian species. In a study of Amazonian forest fragments, Gascon et al. (1999) recorded a higher species richness and abundance of fauna in fragments set in a matrix of secondary forest in comparison with those surrounded by pasture. In the present study, most of the anthropogenic matrix was composed of soybean plantations in areas that had previously been pasture. The native vegetation of these areas was totally suppressed, and while the soybean plantation provides some cover, this was only short-lived due to annual harvesting.

However, the characteristics of the matrix may have had a positive effect on some species. For example, grass mice (*Akodon* sp.) were only recorded at the edge of the sample plots. This genus seems to have a preference for open areas, and Pardini (2004) recorded a greater abundance of *Akodon cursor* Winge, 1887 on the edges of fragments of Atlantic Forest, while the species was rare within the fragments. By contrast, *M. nudicaudatus* was only captured in transects at least 250 m from the edge, which suggests they prefer forest habitats. Santos-Filho et al. (2008) classified this species as "intermediate" in terms of habitat use, while the classified *H. megacephalus* as a "generalist", present throughout the forest, as observed in the present study. However, *R. nitela*, which was classified as an "intermediate" species by Santos-Filho et al. (2008) was also captured at all distances from the edge in the present study, even though this is an arboreal species, which was likely under-sampled in this study. The reduced number of specimens captured for some species, in particular scansorial and/or arboreal forms such as *Micoureus demerarae* (Thomas, 1905) and *Oligoryzomys* cf. *microtis* (Oliveira & Bonvicino 2006), hampered the definition of ecological patterns in the present study.

Overall, the results of this study indicate that fire may be masking edge effects in plot 1, given the lower abundance of mammals on all transects, even those furthest from the edge. This conclusion is supported by other studies, which have shown that edge effects may be intensified by recurrent disturbances such as wildfires (Laurance et al. 2002).

Acknowledgements

We are grateful to CNPq/PPG7/MCT and the Moore Foundation for financial support and the Maggi Group for permission to conduct research on Tanguro Farm. We also thank Daniel Nepstad, Jenniffer Balch, Claudia Stickler, Gina Cardinot and Paulo Brando for their scientific contributions, Oswaldo Portela and Arlindo Junior for their assistance in the field and Dr. Stephen Ferrari for his help in correcting text, particularly the english.

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Received 16/02/2012
Revised 25/06/2012
Accepted 23/07/2012

Effect of *Typha domingensis* cutting: response of benthic macroinvertebrates and macrophyte regeneration

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SILVEIRA, T.C.L., RODRIGUES, G.G., COELHO DE SOUZA, G.P. & WÜRDIG, N.L. **Effect of *Typha domingensis* cutting: response of benthic macroinvertebrates and macrophyte regeneration**. Biota Neotrop. 12(3):http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn03012032012

Abstract: Wetlands are important because they have high biodiversity and are considered, by environmental agencies, permanently protected areas due to their importance to conservation. In Southern Brazil the aquatic macrophyte *Typha domingensis* is harvested to be used in the manufacture of handicraft, being an important income source to small farmers. This work aims to test the cut effect of *T. domingensis* on benthic macroinvertebrates as well as on macrophyte regeneration. These phenomena were analyzed in small areas (1 m²) in a *T. domingensis* stand by comparing cut treatments and control treatments. Macroinvertebrate were sampled with a corer in the following time sequence after the cut event in both treatments: one day, 26 days, 60 days, 89 days, and 182 days. Macrophyte regeneration was monitored through monthly measurements at each treatment. The macroinvertebrate density did not differ between treatments (ANOVA, $p < 0.05$). Among the 23 taxa identified, Tubificidae was the only family to response to cut treatment. DCA showed an overlapping between treatments indicating a not clear pattern. The growth of *T. domingensis* shoots was not affected by the disturbance. Macrophyte regeneration was quick when comparing the treatments and statistical differences were found in one day after the disturbance and 26 days after the disturbance, whereas no differences were found in the remaining sampling dates (60, 89 and 182 days). Observing the macroinvertebrate response and the *T. domingensis* regeneration, our results suggest that sustainable use of this macrophyte is possible on a small scale.

Keywords: *disturbance, bioindication, vegetal management, aquatic macrophytes, non-wood products.*

SILVEIRA, T.C.L., RODRIGUES, G.G., COELHO DE SOUZA, G.P. & WÜRDIG, N.L. **Efeito do corte de *Typha domingensis*: resposta dos macroinvertebrados bentônicos e a regeneração da macrófita**. Biota Neotrop. 12(3):http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn03012032012

Resumo: As áreas úmidas são importantes, pois apresentam alta biodiversidade e são consideradas pelos órgãos ambientais áreas de proteção permanente devido à sua importância para conservação. No Sul do Brasil a macrófita aquática *Typha domingensis* é colhida para ser usada na fabricação de artesanato, sendo uma fonte de renda importante para pequenos agricultores. Este trabalho teve como objetivo testar o efeito de corte de *T. domingensis* sobre os macroinvertebrados bentônicos, bem como sobre a regeneração da macrófita. Para avaliar o efeito do corte foram analisadas pequenas áreas (1 m²) em uma formação de *T. domingensis* onde comparou-se o tratamento de corte com tratamentos controle. Macroinvertebrados foram amostrados com um “corer” na seguinte sequência de tempo após o corte, em cada tratamento: um dia, 26 dias, 60 dias, 89 dias e 182 dias. A regeneração da macrófita foi monitorada através de medições mensais em cada tratamento. Não houveram diferenças significativas na densidade de macroinvertebrados entre os tratamentos (ANOVA, $p < 0.05$). Entre os 23 táxons identificados, Tubificidae foi a única família a responder ao tratamento de corte. A DCA mostrou uma sobreposição entre os tratamentos, indicando um padrão não claro. O crescimento dos ramos de *T. domingensis* não foi afetado pelo distúrbio. A regeneração da macrófita foi rápida quando se compararam os tratamentos, diferenças estatísticas foram encontradas em um dia e 26 dias após o corte, enquanto não foram encontradas diferenças nas datas de amostragem restantes (60, 89 e 182 dias). Observando a resposta dos macroinvertebrados e a regeneração de *T. domingensis*, sugere-se que o uso sustentável desta macrófita é possível em pequena escala.

Palavras-chave: *distúrbio, bioindicação, manejo vegetal, macrófita aquática, produtos não-madeireiros*

Introduction

Wetlands are considered the most productive ecosystems in the world, mainly due to their high biodiversity (Tinner 1983). Therefore, wetlands are important areas for aquatic conservation being legally protected by environmental agencies. However, aquatic ecosystems have been severely affected by adverse circumstances (Santamaría & Klassen 2002), more than half of wetland areas in the world disappeared during the last century as a consequence of urban and agricultural expansions (Shine & Klem 1999). Thus, due to this not so optimistic background, it is necessary to develop environmental evaluation tools able to detect and measure human disturbances in these ecosystems, aiming their management and sustainable use.

Typha domingensis Pers is emergent and rhizomatous, being palustrine or aquatic. Their importance in wetland ecosystems is due to the large amount of organic matter produced by decomposition (Gonçalves Junior 2004, Santos & Esteves 2006, Thomaz & Cunha 2010). Macrophytes play an essential role in aquatic ecosystems, since they promote a spatial complexity linked to abundance, diversity and structure of macroinvertebrate communities (Dowing 1991, Thomaz et al. 2008, Thomaz et al. 2010, Mormull et al. 2011). Moreover, ecosystems dominated by aquatic macrophytes provide protection against macroinvertebrates predators, and food sources to grazers, detritivores and predators (Oertli & Lachavanne 1995, Shaffer 1998).

Human activities are the main type of disturbance over wetlands integrity (e.g. artificial drought, fire, effluent discharge). Intensity, frequency, and extension of disturbances may influence the response of biological communities (Sousa 1984, Townsend et al. 1997, McCabe & Gotteli 2000). Several works have aimed to evaluate the benthic macroinvertebrate responses to different kinds of disturbances in wetlands. These studies suggest a broad variation of responses (Szalay & Resh 1997, Szalay & Cassidy 2001, Martin & Neely 2001, Kostecke et al. 2005, Schmidt et al. 2005, Rehage & Trexler 2006, Silveira et al. 2011b). Benthic macroinvertebrates are a useful tool for environmental agencies (Rodrigues et al. 2006), providing consistent information related to multiple sources of disturbance and response (Rosenberg & Resh 1992).

T. domingensis is present in dense stands, occurring in marshlands, lagoon banks, lakes, rivers and artificial channels; it is widespread throughout the Brazilian territory (Kissmann 1997). In some cases it is considered undesirable, once can be invasive with fast growth where conditions are favorable. Management of this species and other macrophyte species has been done via traditional practices in many parts of the world: small farmers harvest the stems for handicrafts fabrication, serving as an important income source (Coelho de Souza 2003, Silveira et al. 2011a).

Therefore, considering the importance of maintenance and conservation of wetlands and their biota, and the growing environmental threats that they have suffering, this work aims to go into the cut effect on benthic macroinvertebrates and evaluate macrophyte regeneration after cutting. We want to test the following hypothesis: (i) *T. domingensis* cutting affect the macroinvertebrate biota and (ii) the cutting affect the new shoots development and biomass production. In order to test our hypothesis we carried out a field experiment in which we conducted an experimental cuting of *T. domingensis* evaluating the macroinvertebrate response and the regeneration.

Methods

1. Study area

The experiment was carried out in a wetland area with approximately 1 ha, characterized by a dense stand of *T. domingensis* (29° 40’ 59, 4” S and 50° 12’ 21,2” W), on a private property nearby Maquiné town. The site consists of a swamp area belonging to the Maquiné River watershed, located on the northern coast of Rio Grande do Sul, in the southern portion of the Brazilian Pluvial Atlantic Forest (Figure 1). According to the classification system proposed by Malthick et al. (2004), the selected site is classified as a palustrine system with a water column presenting emergent vegetation. This site was chosen due to easy access to the experiment and logistical support. In addition, it is an area where local inhabitants harvest *T. domingensis*. The experiment was carried out in 2005, starting on June 21 and lasting 182 days.

2. Experimental design

Five areas with dimensions of 2.5 m × 5 m were delimited inside the macrophyte stand in a transect of 50 m in length parallel to border, this approach were used to avoid environmental variations provided by border effect. Each delimited area was subdivided in to eight squares (1 m²), totalizing 40 squares delimited, 20 cut and 20 uncut. The experiment started after we performed the cutting on *T. domingensis* in four subdivisions at each five delimited areas distributed alternately. We randomly choose to sample one of the delimited area in the following time sequence after cutting: 1 day, 26 days, 60 days, 89 days, and 182 days.

3. Macroinvertebrate sampling

Macroinvertebrate were sampled with a corer (0.5 m length; 10 cm diameter) at each treatment. The sampling was carried out by introducing the corer about 20 cm into the sediment at the center of each square. Once sampled, the sediment was conditioned in plastic bags and preserved in 95% ethanol. In the laboratory, the samples were stained with Rose Bengal during 24 hours and washed in a 250 μm sieve; the retained macroinvertebrates were sorted out under stereomicroscope. The benthic macroinvertebrates were assigned to the family level according to the following identification keys: McCafferty (1981), Brinkhurst & Marchese (1989), Pennak (1989), Trivinho-Strixino & Strixino (1995) and Merrit & Cummins (1996). Turbellaria and Collenbola were assigned to the class level. We assigned morphospecies and for the consistency in determination, we made a reference collection.

4. T. domingensis regeneration

The regeneration of *T. domingensis* was monitored in monthly sampling campaigns (n = 7) between July 30 and December 17, 2005. Eight squares (1 m²) were chosen among the five delimited areas, four cut areas and four control areas. All *T. domingensis* individuals were identified with numbered plastic tags in both treatments (cut and control areas). They were measured with a ribbon beginning at 20 cm from the rhizome upwards. Each new shoot was identified, measured and monitored as well. All stem were classified as shoot, mature, dead and with absence or presence of inflorescence. Shoots were characterized as < 80 cm high, mature > 80 cm high, and dead as predominantly yellow-brown color. During the experiment new shoots of *T. domingensis* (< 80 cm) were monitored in order to assess the cut influence on their growth. To estimate the biomass of *T. domingensis*, 53 individuals of different sizes were measured in height and the dry mass obtained after all stems were dried at 60 °C during 120 hours and weighed in December 2005. The values were transformed into log (x + 1) and the biomass estimated by linear regression.

5. Data analysis

The macroinverbrates total density (individuals/m^2) were tested by means of Analysis of Variance (ANOVA), we considered $p < 0.05$

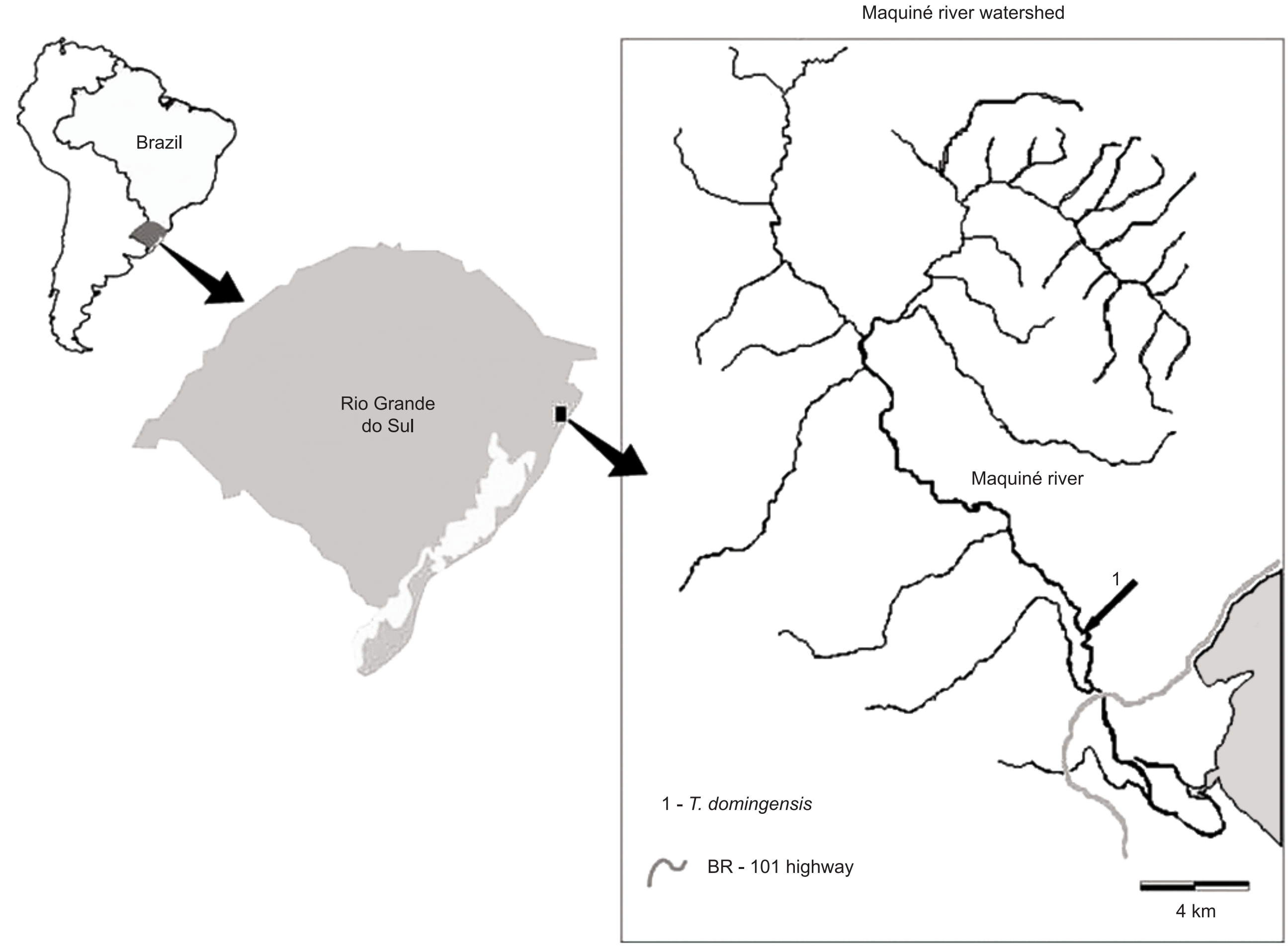

Figure 1. Study area at Maquiné. Rio Grande do Sul. Brazil. The arrow indicates the *T. domingensis* stand site.

statistically significant. Two factors were considered: sampling date and treatment. Only taxa with abundance > 4% were considered, we used this criteria of matrix reduction because rare species do not present analyzable patterns (Field et al. 1982, Szalay & Resh 1997). The macroinvertebrate densities were log transformed log (x + 1) to reduce data variations. A t-test was used to test the cutting effect on shoot growth, biomass production and reproductive structures production.

We performed a DCA (Detrended Correspondence Analysis) ordination in order to segregate samples by time and treatment. To perform the DCA, all macroinvertebrate densities were within-sample percent transformed followed by a second trans-formation, a within-taxon percent maximum transformation (relativization by maximum of McCune & Grace 2002; standardization to species maximum of Jongman et al. 1995) to equalize differences in abundance among taxa and prevent the ordination results from being dominated by the most abundant taxa. ANOVA, t-test, DCA and linear regression were performed with R software (The R Development Core Team 2012). DCA and data transformations were performed using DECORANA from the VEGAN package in R software.

Results

In this work, 1056 benthic macroinvertebrates belonging to 23 taxonomic groups were collected (Table 1). Ceratopogonidae (36.3%), Naididae (11.4%), Tubificidae (11.7%), Enchytraeidae (9%), Sphaeridae (9.6%), Chironomidae (4.7%), Glossiphonidae (4.7%) and Hirudinidae (4.1%) were the dominant families that comprise 84.8% of the total macroinvertebrate sample. The macroinvertebrate densities are presented in Figure 2.

Only minimal differences among sampling dates were found with regard total density of macroinvertebrates (Figure 3). The ANOVA detected statistical differences total density of macroinvertebrates to the factor sampling date. This result allows inferring a temporal variability occurrence (Table 2). The interaction between period and treatment didn't show significant differences.

Although during the whole experiment Tubificidae showed significant statistical differences in relation to treatment (Table 2), it showed strong differences in relation to the densities in the treatments that were carried out every 26 days, 60 days, and 182 days. The remaining dominant taxa showed statistical differences in relation to the sampling date factor (Table 2). Significant differences were detected in regard to the sampling date factor of Naididae, which had an accentuated variation especially during the last sampling date (Figure 3a). Glossiphonidae also presented statistical differences regarding its sampling date factor. Sphaeridae presented statistical differences only to the sampling date factor, with elevated densities on the first day and on the 182th day (Figure 3f). Ceratopogonidae

Table 1. Mean macroinvertebrate density (ind/m^2) sampled in the *T. domingensis* treatments (S.D).

Taxa	1 day		26 days		60 days		89 days		182 days	
	control	cut	control	cut	control	cut	control	cut	control	cut
Oligochaeta										
Naididae	352.6(302.9)	192.3(165.5)	416.7(192.3)	256.4(277.0)	352.6(396.9)	128.2(104.7)	256.4(148.0)	544.9(396.9)	544.9(320.5)	929.5(448.7)
Enchytraeidae	64.1(74.0)	96.2(64.1)	160.3(122.7)	128.2(104.7)	384.6(523.4)	256.4(277.0)	352.6(161.3)	641.0(953.7)	609.0(436.3)	448.7(305.2)
Tubificidae	384.6(148.0)	416.7(833.3)	737.2(712.9)	224.4(192.3)	224.4(219.0)	128.2(0.0)	673.1(567.3)	512.8(377.4)	641.0(863.2)	128.2(104.7)
Mollusca										
Limnaeidae	-	32.1(64.1)	64.1(128.2)	64.1(74.0)		128.2(181.3)	32.1(64.1)	32.1(64.1)	-	-
Biomphallaria	-	-			-	32.1(64.1)	96.2(122.7)	-	-	-
Sphaeridae	673.1(697.3)	1282.1(2225.5)		32.1(64.1)	96.2(192.3)	-	-	32.1(64.10	512.8(479.7)	705.1(706.1)
Turbellaria	-	-			96.2(122.7)	64.1(128.2)	64.1(74.0)	32.1(64.1)	-	-
Hirudinea										
Glossiphonidae	64.1(74.0)	32.1(64.1)	160.3(242.7)	705.1(698.3)	128.2(181.3)	96.2(122.7)	128.2(181.3)	256.4(347.2)	-	64.1(74.0)
Hirudinidade	64.1(74.0)	64.1(128.2)	224.4(192.3)	192.3(165.5)	96.2(64.1)	160.3(192.3)	160.3(161.3)	352.6(705.1)	32.1(64.1)	64.1(74.0)
Diptera										
Ceratopogonidae	641.0(377.4)	737.2(648.5)	1602.6(847.2)	993.6(219.0)	1538.5(18106.1)	1378.2(1000.6)	1538.5(702.2)	2948.7(1869.6)	769.2(543.9)	480.8(495.2)
Chironomidae	64.1(74.0)	160.3(192.3)	160.3(242.7)	352.6(622.6)	64.1(128.2)		448.7(266.9)	576.9(165.5)	224.4(219.0)	352.6(368.2)
Culicidae	-	-	-	-	-	-	96.2(192.3)	-	-	-
Tabanidae	64.1(128.2)		-	-	-	-	-	-	32.1(64.10	-
Tipulidae	32.1(64.1)		-	-	-	32.1(64.1)	32.1(64.1)	96.2(122.7)	-	-
Chaoboridae	-	-	-	-	-	-	-	32.1(64.1)	-	-
Morfotype 1	-	-	32.1(64.1)	-			-	-	-	-
Morfotype 2	-	-	-	-	32.1(64.1)	-	-	160.3(320.5)	-	-
Odonata										
Zigoptera	32.1(64.1)	-	-	-	-	-	-	32.1(64.1)	-	-
Coleoptera										
Dysticidae	-	-	32.1(64.1)-	-			-	-	-	-
Hidrophilidae	-	-	64.1(74.0)	-			-	-	-	-
Heteroptera										
Belostomatidae	-	-	-	-	-	32.1(64.1)	-	-	-	-
Crustacea										
Hyallelidae	32.1(64.1)		-	-	32.1(64.1)	-	160.3(64.1)	-	64.1(128.20	96.2(192.3)
Collembola	-	-	96.2(122.7)	32.1(64.1)	128.2(148.0)	160.3(192.3)	384.6(347.2)	64.1(74.0)	96.2(122.7)	64.1(128.2)

and Chironomidae showed slight differences between treatments and sampling dates after the disturbance (Table 2).

According to the DCA ordination plot (Figure 4), the first axis explained for 42% of variation and the axis 2 explains 30% of this amount. The ordination indicates a clear overlapping between treatments and sampling dates (Figure 4a) being not showed a clear group separation. In relation to taxa we observed a distribution not well defined, suggesting that the cut was not a strong enough disturbance to cause acute effects.

The density of intact *T. domingensis* stems prior to the experiment was 38 ± 3.7 stems/m² (n = 4). At the end of the experiment, 182 days after the cut event, the density was 28.0 ± 2.3 and 28.0 ± 2.5 stems/m² in controls and cut treatments, respectively. The growing of new shoots that were monitored during the experiment did not showed statistical differences between treatments and sampling dates ($p \geq 0.05$) (Figure 5).

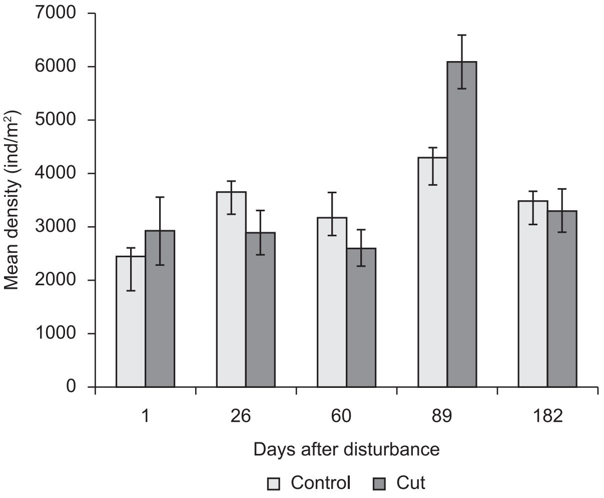

Figure 2. Mean density in disturbed and control treatment, black bars indicate the standard error.

The model used to estimate the biomass was $y = -0.3133508 [-\exp(0.203461x)]$ ($r^2 = 0.89$). During the experiment, only sampling dates 1 and 26 after cut disturbances presented statistical differences ($p < 0.05$) between treatments; on the remaining sampling dates cutting treatment did not differ from control. However, biomass decrease in the treatments was observed in the period comprised between the 26th day and the 60th day after the cut disturbance (Figure 5). In regard to *T. domingensis* classification, statistic differences on the sampling date 1 after the cut disturbance were observed in relation to the number of adult stems (Table 3). Other *T. domingensis* classification did not present statistical differences at any sampling date.

Discussion

The environmental characteristics of *T. domingensis,* as analyzed in this study, are common in wetland areas and are similar to those found in the Paraná River watershed, according to Zozaya & Neiff (1991). Low concentrations of dissolved oxygen are expected for these areas, due to its high consumption that is mediated by the decomposition process and accelerated by warm temperatures. Based on this background, it was assumed that in the present study a hypoxic macroinvertebrate assemblage would be found, such as oligochaets and dipterans. Besides, considering some characteristics of *T. domingensis* stand, such as a palustrine area with low water column oscillation (only a few centimeters), and also considering the sampling method, a low diversity of macroinvertebrates was noticed in the study area. Thus, our assumptions seem to be in agreement with those found by Kostecke et al. (2005) and Szalay & Resh (1997).

Our first hypothesis is that the cut of *T. domingensis* affect the macroinvertebrate fauna were corroborated only to Tubificidae. Concerning the climatic factor, our experiment began in winter and finished in summer, and variations in the composition of macroinvertebrates taxa are expected for aquatic invertebrates

Table 2. ANOVA with macroinvertebrates density and dominant families sampled.

Effect	d.f.	Macroinvertebrates density	Naididae	Enchytraeidae	Tubificidae	Ceratopogonidae
		F	F	F	F	F
S	4	2.19	2.53*	2.22	1.26	4.00*
T	1	0.34	0.17	0.05	4.85*	0.06
S*T	4	0.34	1.06	0.06	0.43	0.62
		Chironomidae	**Sphaeridae**	**Glossiphonidae**	**Hirudinidae**	
		F	F	F	F	
S	4	6.42	7.07	2.39*	0.91	
T	1	0.71	0.0009	1.78	0.54	
S*T	4	0.81	0.17	0.93	0.36	

S = sampling date; T = treatment; S*T = interaction between sampling date and treatment.* = $p < 0.05$.

Table 3. Mean number of *T. domingensis* stem classification demonstrated during the experiment (S.D).

Sampling date	Dead		Shoots		Adult		Inflorescence	
	control	cut	control	cut	control	cut	control	cut
1	0	0	1.7(2.2)	3(1.7)	43.7(3.6)	0	0	0
26	10(6.7)	22(16.6)	31(1.2)	5(3.8)	18.5(7.7)	5(2.5)	0	0
60	8(7.2)	25(15.7)	1.5(1.8)	2.7(5.3)	16.2(5.6)	17.5(2.1)	0	0
89	14(6.3)	14.7(3.6)	2.2(1.5)	1(0.5)	21.5(8.9)	15.5(2.2)	2.2(1.5)	0
118	5.5(0.57)	3.2(1)	0.5(0.57)	1.7(0.9)	22.5(6.9)	23.2(1.6)	0.2(0.5)	0
153	0.7(1)	0.2(0.5)	1.2(2.5)	0.2(0.5)	29.0(3.4)	19.0(2.6)	4.7(5.1)	5.2(3.3)
182	0.2(0.5)	0.2(0.5)	0.7(2.4)	1(2)	25.7(3.3)	23.2(3.5)	8(3.1)	7.2(5)

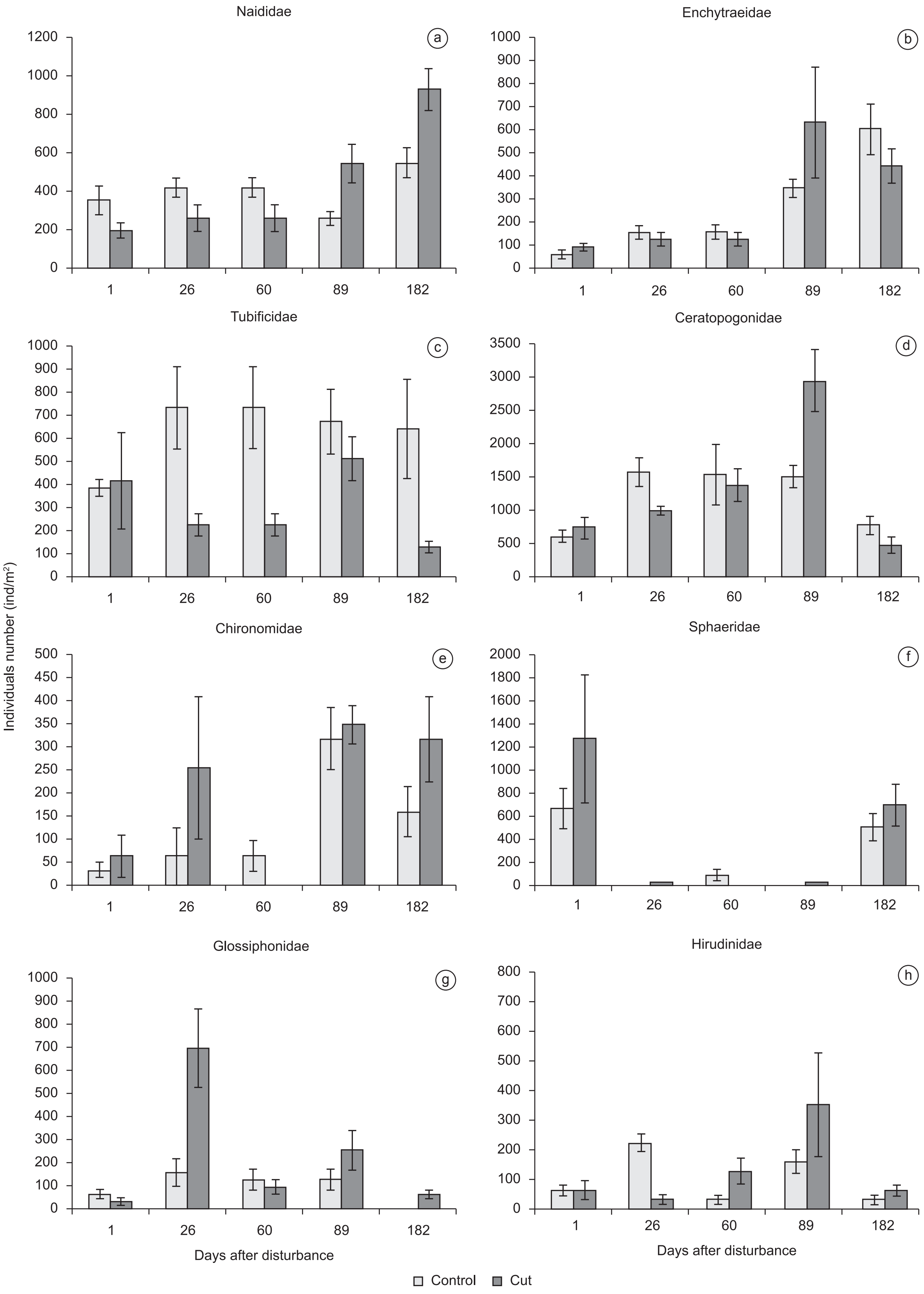

Figure 3. Mean density of dominant macroinvertebrates, black bars indicate the standard error.

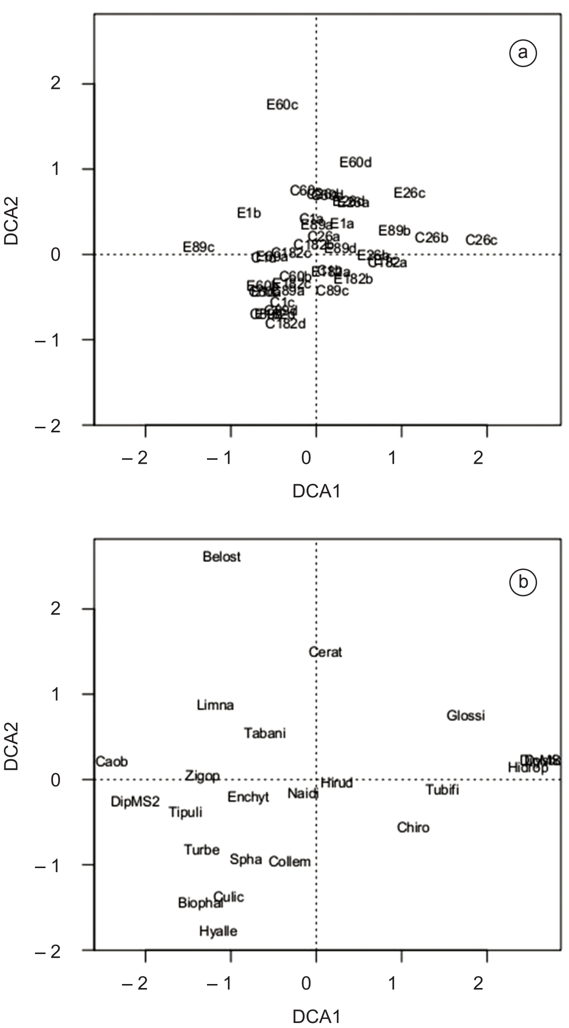

Figure 4. Detrended Components Analysis (DCA) of macroinvertebrate density. a) Sample plot ordination. c) Control, e) Cut, numbers indicates the days after disturbance event. b) Taxa plot ordination of taxa. Taxa names were abbreviated.

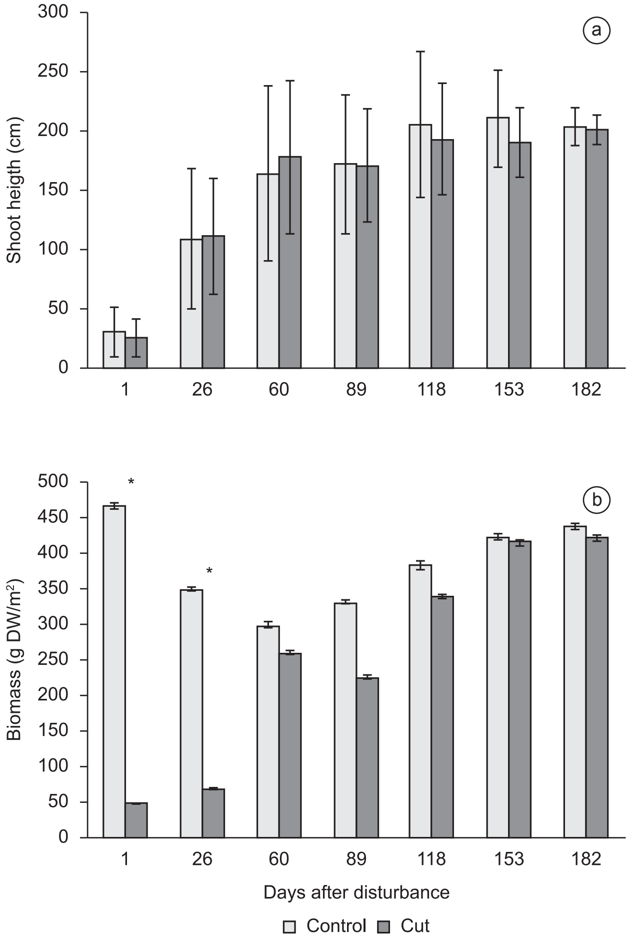

Figure 5. Stem growth (a) and regeneration of *T. domingensis* after cut (b). Black lines indicate the standard deviation. * = $p < 0.05$.

during this period. A variation in the composition of taxa, in relation to treatment and temporal factors, was detected most likely due the variations in periods of invertebrate's colonization and emergence of insects. Szalay & Resh (2000) obtained similar results regarding the effects of these variations on macroinvertebrate assemblages. Furthermore, the macroinvertebrate response to the *T. domingensis* cut event, no significant statistical differences were verified in relation to the interaction between treatment and sampling date. The only observed variations are related to the taxonomic composition and to an expected temporal variation of density. The weak response of aquatic invertebrates to mechanical disturbances has been observed by Frid et al. (1997), who evaluated the response of aquatic invertebrates to light management in stands of *Spartina anglica* (Poaceae). Kostecke et al. (2005) also detected little difference in the response of aquatic invertebrates to mechanical management in *Typha* spp. However, Szalay & Resh (1997) observed that areas colonized by *Distichlis spicata* (Poaceae) subjected to fire and cut disturbances tend to show elevated abundances of Chironomidae, Hemiptera and Oligochaeta. Also, Szalay & Resh (1997), verified that the abundance of the latter (Oligochaeta) maybe be decreased as a response to the cut disturbance. Our results are in according with Szalay & Resh (1997), suggesting that Tubificidae responded negatively to the cut disturbance in the treatment. In another study Frid et al. (1997) observed that Oligochaeta are subject to disturbances of low or intermediate strength.

Another important cause of the no response of majority of macroinvertebrate taxa could be determined by the size of the disturbed area, disturbance intensity and/or frequency. An adult fauna could easily reestablish in small areas with a reasonable dispersion in disturbed areas < 2000 m² (Frid et al. 1999). In our study the frequency of disturbances in the delimited disturbed areas could be one of the reasons behind the weak response of aquatic macroinvertebrates; the disturbances may not have been sufficient to induce perceptible structural and functional changes. The intensity of the cut performed on *T. domingensis* could also be insufficient to induce perceptible changes in the macroinvertebrate assemblages. *T. domingensis* was cut only once and the sediment was not disturbed during sampling. A weak macroinvertebrate assemblage response to the disturbance could be linked to water column oscillation throughout the experimental area. The slight variation in water column depth may connect adjacent areas to the experimental location, making possible macroinvertebrate colonization or emigration. This were observed by Sousa (1984) inferring that might be the main factor behind macroinvertebrate assemblage resilience. Some studies utilize the isolation of disturbed vegetation areas with barriers of netting, to prevent the dispersion of invertebrates to other treatments and prevent possible colonization by species from adjacent areas (Szalay & Resh 1997, Martin & Neely

2001). Since this specific technique was not used in our study, we suggest that colonization could indeed be one of the causes of high macroinvertebrate assemblage resilience in our experiment, because macroinvertebrate immigration after the disturbance could disguise direct effects of disturbance.

Concerning our second hypothesis that the cut affect *T. domingensis* development, we found that the quick resilience of macrophyte combined with other environmental factors could be an important force behind the macroinvertebrate resistance to the disturbance. *T. domingensis* have fast growth rates and is able to colonize a broad range of environment due to its striking clonal growth, ensuring for this species a high resilience capacity. A slight biomass variation was detected probably because this period was the coldest of the year. According to Palma-Silva et al. (2005) climatic and environmental factors could affect the mortality and productivity rates in *T. domingensis* stands.

The vegetative classifications observed during the experiment demonstrated a slight effect on the macrophyte, which regenerated 60 days after the disturbance. It should be emphasized that the number of inflorescences in both treatments did not show significant difference at the end of regeneration monitoring. The lack of differences between treatments in the number of inflorescences shows that the cut disturbance did not affected the gamethophyitic reproduction of *T. domingensis*. However, it's necessary to evaluate another structures of *T. domingensis* stands, because these ecosystems are subject to different environmental variables (e.g., geomorphology, water column oscillation and fetch), which could affect the macroinvertebrate response to cut disturbances and could show a broad range of responses.

Conclusions

The experimental cut disturbances did not caused alterations in macroinvertebrate density. Regarding the taxa evaluated we only found significative differences concerning the temporal variation (Figure 2 and 3). The scale intensity and frequency of cut areas utilized in this experiment was insufficient to induce an evident benthic macroinvertebrate response to a disturbance event. Regarding *T. domingensis* resilience, the macrophyte demonstrated quick regeneration and the cut had no effect on shoots growth and the gamethophytic production. Therefore we suggest that the use of this natural resource, in the evaluated area, could be sustainable with few prejudicial effects to the benthic macroinvertebrate and to the macronphyte as well.

Acknowledgements

The authors thank the colleagues from DESMA-UFRGS, ONG ANAMA, Benthic Invertebrates Laboratory - UFRGS and Romarize Klein. We also thank to Thais Paz Alves by english revision and Nelson Ferreira Fontoura by manuscript suggestions. We thank CNPq by the financial support and the scholarships provided by CNPq and CAPES.

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Received 19/03/2012
Revised 29/07/2012
Accepted 12/09/2012

Cougar (*Puma concolor*) vocalization and frequency shift as a playback response

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MACARRÃO, A., CORBO, M. & ARAÚJO, C.B. **Cougar (*Puma concolor*) vocalization and frequency shift as a playback response.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn03212032012

Abstract: Recordings of cougar (*Puma concolor*) vocalizations are rare in the wild. We made two night recordings from the same individual. The first recording was spontaneous whereas the second was made after a playback emission (using a third party recording) allowing for comparisons. We measured the calls before and after playback stimuli using Raven software and noted that only the minimum fundamental frequency presented differences between calls. As fundamental frequency is closely related to body size, a frequency reduction may indicate territoriality engagement. Our recording seems to be the first held in the Brazilian wild. Little is known about cougar natural history and behavior, and our data suggest that acoustic communication may have an important role on the species intraspecific interactions.
Keywords: *bioacoustics, felid, recordings, Brazil, acoustic communication.*

MACARRÃO, A., CORBO, M. & ARAÚJO, C.B. **Vocalização da onça-parda (*Puma concolor*) e mudança de frequência como resposta ao playback.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn03212032012

Resumo: Registros de vocalizações de onça-parda (*Puma concolor*) são raros na natureza. Fizemos uma gravação espontânea da espécie à noite, em seguida tocamos o playback com uma gravação prévia disponível em bibliografia, o que fez com que a onça-parda se aproximasse e vocalizasse, permitindo que pudéssemos gravar novamente e assim comparar. Comparamos os chamados antes e depois do estímulo do *playback*, usando o programa Raven, e constatamos que somente a frequência fundamental mínima apresentou diferenças entre os chamados. Como a frequência fundamental está diretamente relacionada com o tamanho corporal, uma redução neste parâmetro pode significar defesa territorial. Nossas gravações aparentemente são as primeiras realizadas na natureza no Brasil. Pouco se sabe sobre história natural e comportamento da onça parda no Brasil, e nossos dados sugerem que a comunicação acústica tem um papel importante nas interações intraespecíficas desta espécie.
Palavras-chave: *bioacústica, felino, gravação, Brasil, comunicação acústica.*

Introduction

The Cougar (*Puma concolor* Linnaeus, 1771) has the widest distribution among felids in Americas and has the greatest range of any large wild terrestrial mammal in the Western Hemisphere, living in many kinds of habitats, ranging from the southern Chile (Patagonia) across North America from the Pacific to the Atlantic, covering the wider range of latitude than any other wild felid (Wainwright et al. 2010). It's the second largest felid in Brazil, weighting from 22 to 74 kg and presenting a length of 0.9 to 2.30 m. It has solitary and terrestrial habits, with diurnal and nocturnal activities, and a diversified and adaptable diet (Cheida et al. 2011).

Despite its wide distribution, the Cougar is locally rare, threatened by hunting, loss of habitat and prey shortage (Emmons & Feer 1997). The size of the species and type of diet requires large home ranges (Mazzoli 1993). It is threatened of extinction in Brazil as "vulnerable" (Sana & Cullen 2008). Only a few studies were made all over South America, which includes systematics (e.g. Cabrera 1957), growth rates (e.g. Ximenez 1972), use of habitat (e.g. Courtin et al. 1980), but most studies are concentrated in cougar's diet (e.g. Yáñez et al. 1986, Emmons 1987, Rau & Jiménez 2002, Villepique et al. 2011). In southeast Brazil the taxa is *Puma concolor capricornensis*, considered as vulnerable especially due to habitat loss (Mazzoli 1993).

Records of *Puma concolor* vocalizations are rare in the wild (Smallwood 1993, McCollough 2011). Most encounters with the species consist in quick sightings. The few recordings of the species vocalization comprehend scattered reports that include captivity recordings (Rabb 1959).

There are several types of vocalizations in *P. concolor* acoustic communication such as vocalization of the female estrus, purring, contact with juvenile and vocalizations uttered during hunts or persecution (Smallwood 1993, Peters 2002, Potter 2002). There are also reports that the cougar may mimic their prey vocalizations in the Amazon rainforest (Calleia et al. 2009). This indicates a complex acoustic communication system yet to be accurately described.

Considering the small number of studies on the acoustic communication of wild cats, we here describe the vocalization of a *Puma concolor* made in the Brazilian wild, comparing vocalization before and after playback stimuli.

Materials and Methods

We made a spontaneous recording of *Puma concolor* on March 13th 2010 at night at Artur Nogueira city, São Paulo, Brazil (22° 38' 07" S and 47° 08' 18" W). We were on a dirt road between a forest fragment and sugar cane plantation and the animal was around 60 m away from the recordist. After a few minutes recording, we made a playback from Emmons & Feer (1997). A few minutes after the playback stimuli, the cougar approached and vocalized, allowing us to record it again, now around 30 m away from the recordist. We then turned the car lights on and saw the animal, which immediately ran in the opposite direction. The recordings were made with Sennheiser ME67 directional microphone and Marantz PMD 671 digital recorder. Recordings are deposited in the Fonoteca Neotropical Jacques Vielliard of Universidade Estadual de Campinas, Brazil, record number FNJV 12910 (before playback) and FNJV 12911 (after playback).

Based on comparisons (Potter 2002) we assumed that both vocalizations recorded corresponded to an adult, maybe a female in estrus. However, due to the lack of knowledge on the species communication and its vocal repertoire, we may not be certain of this.

We measured the calls using Raven software (FFT size of 1200) and made the statistical analyses using Statistica 7.0. We made the spectrograms with Soundruler (FFT size of 512). Data is presented as mean (± standard deviation). We compared vocalizations using Mann-Whitney test, with the use of the Bonferroni correction for significance threshold (attaining an $\alpha = 0.0125$).

Results

The call is rich in harmonics and presents frequency modulation, resulting in the form of an inverted "U" on the spectrogram (Figure 1). The first vocalization, without playback, lasted 83 seconds (36 calls). Playback induced the cougar's approach, as well as the uttering of a second vocalization, which lasted 73 seconds (36 calls). Only the minimum fundamental frequency presented differences between calls ($p = 0.004$) among the parameters analysed (Table 1, Figure 2).

Table 1. Call parameters of *Puma concolor* before and after playback stimulus.

Parameters	Before playback	After playback
Vocalization duration (seconds)	83	73
Number of calls	36	36
Calls average duration (seconds)	0.65 (0.38)	0.60 (0.22)
Min. FF (Hz)	291 (49)	265 (58)
Max. FF (Hz)	438 (31)	425 (30)
Emission rate (Hz)	0.55 (0.22)	0.56 (0.21)

Min. FF: minimal fundamental frequency; Max. FF: maximum fundamental frequency.

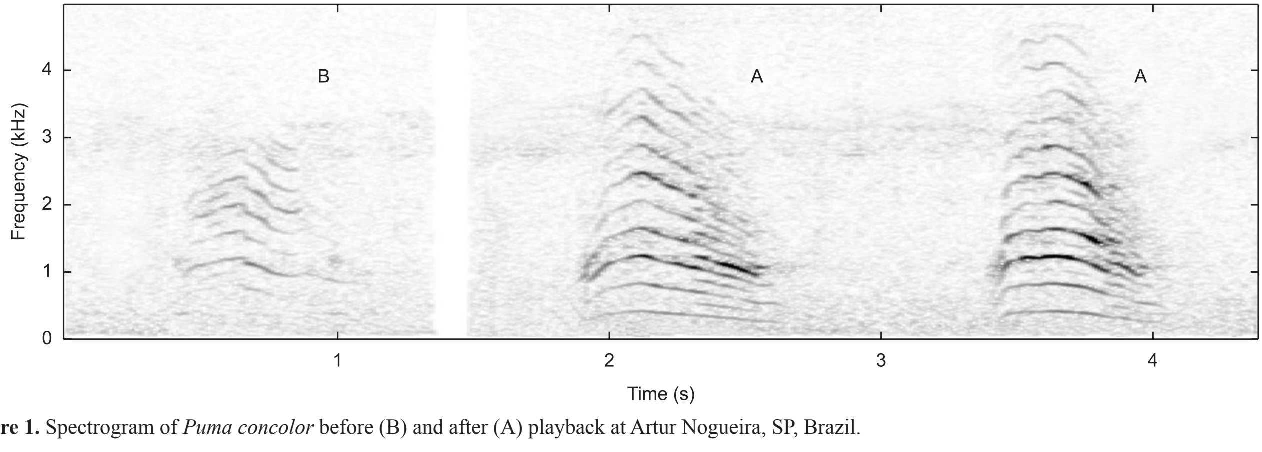

Figure 1. Spectrogram of *Puma concolor* before (B) and after (A) playback at Artur Nogueira, SP, Brazil.

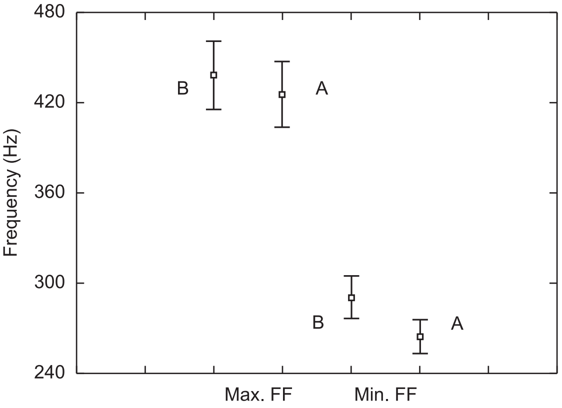

Figure 2. Frequencies values before (B) and after (A) playback for maximum fundamental frequency (Max. FF) and minimum fundamental frequency (Min. FF).

Discussion

Territorial behavior may help explain the differences found between the minimum fundamental frequency, as frequency is negatively correlated to body size (Fletcher 2004) and animals may issue lower frequencies to intimidate a possible rival. As fundamental frequency is closely related to body size, a frequency reduction may indicate territoriality engagement and body mass signaling. Moreover, in spite of the frequency variation found before and after the playback stimuli, the call should be an honest signal of body size, as the animals seems to shift the fundamental frequency to its lowest limit, which should be morphologically determined by body size. That way body size will be the main restriction to frequency shift, so that the larger the animal, the lower the minimum fundamental frequency uttered.

Electronic call boxes have been used successfully to lure puma into snare sites by using prey (e.g., fawn bleats) or puma vocalizations (e.g., screams, yowling). Programmable call boxes that allow vocalizations to be played at specific intervals for short periods (e.g., 30 seconds every hour from 10:00 PM to 6:00 AM) are effective and useful while a reliable attractant is not developed (Shaw et al. 2007).

Our recording appears to be the first held in Brazil in the wild. Despite being a common species, with large distribution in the country (Sana & Cullen 2008), as other top carnivores, it occurs at low densities (Wainwright et al. 2010) so that little is known about its natural history and behavior, and the available data comes from captive individuals or monitored by tracks, cameras trap and telemetry (Rabb 1959, Shaw et al. 2007). Our data indicates that acoustic communication may have a central role within the species intraspecific interactions. That way, more studies are necessary to properly describe the role of acoustic communication on aspects of species biology such as mate attraction or territoriality.

Acknowledgements

We are grateful to Peter Crawshaw, Gustav Peters and Marcel Penteado for the help and additional information.

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Received 12/07/2012
Revised 05/09/2012
Accepted 21/09/2012

Comunidade de morcegos (Mammalia, Chiroptera) no Refúgio de Vida Silvestre Mata do Junco, Sergipe, nordeste do Brasil

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BRITO, D.V. & BOCCHIGLIERI, A. **Bats community (Mammalia, Chiroptera) in Refúgio de Vida Silvestre Mata do Junco, Sergipe, northeastern Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn02112032012

Abstract: The order Chiroptera is the second in mammal species richness in Brazil and the Atlantic Forest is the biome with the best knowledge status for this group. In Sergipe, studies focused on bats are still scarce, being necessary to increase the research on such important taxon. This work aimed to conduct a bat inventory in the Refúgio de Vida Silvestre Mata do Junco (RVSMJ), which is the second largest reserve of Atlantic Forest in the state of Sergipe. Samples were obtained during two nights per month from February 2011 to February 2012, except in June. With a sampling effort of 21,168 m^2.h, we recorded 189 individuals of two families and 14 species. Among these, *Artibeus planirostris*, *Chiroderma doriae*, *Myotis nigricans*, *Phyllostomus discolor*, *Trachops cirrhosus* and *Trinycteris nicefori* are new occurrences for the location, being *T. nicefori* also new record for the state. Phyllostomidae was the richest and most abundant family, and *A. lituratus* (N = 67), *Carollia perspicillata* (N = 45), and *Dermanura cinerea* (N = 45) were the most abundant species. These three species accounted for 83.0% of all captured individuals, and were characterized as generalists in habitat use and diet. With respect to feeding guilds, most of the captured species are frugivores (57.1%), probably due to the methodology and existence of agricultural areas present in RVSMJ. The new records here assigned, along with the parameters obtained for richness, abundance and feeding guild, will increase our knowledge on the bats of Sergipe and can be used as a basis for conservation strategies and management at the studied site location.
Keywords: *Atlantic Forest, richness, trophic guild, abundance, Trinycteris nicefori.*

BRITO, D.V. & BOCCHIGLIERI, A. **Comunidade de morcegos (Mammalia, Chiroptera) no Refúgio de Vida Silvestre Mata do Junco, Sergipe, nordeste do Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn02112032012

Resumo: A ordem Chiroptera é a segunda maior em riqueza de mamíferos no Brasil e a Mata Atlântica é o bioma com o melhor estado de conhecimento para esse grupo. Em Sergipe, estudos sobre quirópteros ainda são escassos, sendo necessário ampliar as pesquisas com esses animais. O presente trabalho teve como objetivo realizar o inventário de morcegos do Refúgio de Vida Silvestre Mata do Junco (RVSMJ), segunda maior reserva de Mata Atlântica do estado de Sergipe. As coletas foram realizadas durante duas noites por mês, entre fevereiro de 2011 a fevereiro de 2012, exceto junho. Com um esforço de captura de 21.168 m^2.h foram registrados 189 indivíduos de duas famílias e 14 espécies. Destas, *Artibeus planirostris*, *Chiroderma doriae*, *Myotis nigricans*, *Phyllostomus discolor*, *Trachops cirrhosus* e *Trinycteris nicefori* correspondem a novas ocorrências para a localidade, sendo *T. nicefori* novo registro para o estado. Phyllostomidae foi a família com maior riqueza e abundância e *A. lituratus* (N = 67), *Carollia perspicillata* (N = 45) e *Dermanura cinerea* (N = 45) foram as espécies mais abundantes. Essas três espécies juntas representam 83,0% dos indivíduos capturados; sendo caracterizadas como generalistas no uso do habitat e dieta. Com relação às guildas alimentares, a maioria das espécies é frugívora (57,1%), devido a metodologia e existência de áreas agrícolas presentes no RVSMJ. O registro de novas espécies para a localidade, juntamente com os parâmetros obtidos de riqueza, abundância e guilda alimentar, contribuem para o aumento do conhecimento dos quirópteros em Sergipe e podem servir de base para estratégias de conservação e manejo dessa área.
Palavras-chave: *Mata Atlântica, riqueza, guilda trófica, abundância, Trinycteris nicefori.*

Introdução

A Mata Atlântica apresenta uma rica fauna e flora, representadas por 22.000 espécies de angiospermas e 2.039 de vertebrados, dos quais são conhecidas 270 espécies de mamíferos, sendo 73 delas endêmicas (Campanili & Schaffer 2010). Nesse sentido, este bioma é considerado o segundo maior em riqueza e taxa de endemismo para a mastofauna brasileira (Reis et al. 2011). Apesar de originalmente ocupar uma área equivalente a 15% do território nacional (Brasil 2002), atualmente a Mata Atlântica apresenta-se com 88,27% de sua área reduzida e fragmentada (Ribeiro et al. 2009). Esses processos de alteração e devastação da paisagem resultaram em poucas áreas conservadas e grandes o suficiente para garantir a manutenção de sua biodiversidade, o que faz desse bioma um dos mais ameaçados do mundo (Campanili & Schaffer 2010) e um dos 34 *hotspots* globais (Mittermeier et al. 2005).

Além de reduzidos, os remanescentes florestais desse bioma estão fragmentados (Campanili & Schaffer 2010), sendo esta uma das maiores ameaças a mastofauna brasileira (Costa et al. 2005). Estudos na Mata Atlântica envolvendo mamíferos revelaram que esses animais têm seus padrões de diversidade, abundância e riqueza influenciados negativamente pelos efeitos da fragmentação (e.g. Vieira et al. 2003, Pardini 2004, Pardini et al. 2005, 2009). Particularmente para os quirópteros, uma variação na disponibilidade dos recursos em ambientes fragmentados pode alterar a estrutura da comunidade desses animais (Faria 2006, Schulze et al. 2000).

A ordem Chiroptera é a segunda maior em riqueza de mamíferos no Brasil, com 172 espécies distribuídas em nove famílias (Reis et al. 2011), sendo a Mata Atlântica o bioma com melhor estado de conhecimento para os representantes desse grupo (Bernard et al. 2011). Atualmente as espécies *Lonchophylla bokermanni*, *Lasiurus ebenus*, *Platyrrhinus recifinus* e *Myotis ruber* encontram-se ameaçadas; sendo que as duas últimas apresentam distribuição para a região Nordeste (Chiarello et al. 2008). Nessa região, a Mata Atlântica cobria aproximadamente 29% do território, restando hoje um pouco mais de 2% distribuídos em pequenos fragmentos remanescentes (Tabarelli et al. 2011). No menor estado brasileiro, Sergipe, esse bioma ocupava toda a faixa litorânea (Landim & Siqueira 2001). Sua área natural foi, entretanto, bastante devastada, principalmente para fins agropastoris (Santos & Santos 2006), restando pouco mais de 9% da sua cobertura florestal original (Fundação... & Instituto... 2011).

Trabalhos com quirópteros realizados em Mata Atlântica no estado tratam sobre a estrutura da comunidade (Mikalauskas 2005, Rocha et al. 2010), padrão de atividade (Mikalauskas et al. 2006a), uso do habitat (Mikalauskas 2005) e novas ocorrências de espécies (Mikalauskas et al. 2006b, 2011, Feijó & Nunes 2010, Rocha et al. 2010, 2011a, b). Mesmo assim, estudos ecológicos sobre os quirópteros em Sergipe ainda são escassos (Rocha et al. 2010).

Considerando a escassez sobre o conhecimento da ocorrência e estrutura da quiropterofauna sergipana, é importante ampliar as pesquisas com esse grupo no estado. Neste contexto, a caracterização das comunidades de morcegos é fundamental para a obtenção de dados ecológicos que servirão de base para futuros estudos, além da adoção de estratégias de conservação desses animais e dos remanescentes florestais que os abrigam. Dessa forma, o presente trabalho tem por objetivo caracterizar a comunidade de morcegos do Refúgio de Vida Silvestre Mata do Junco em Sergipe.

Material e Métodos

O Refúgio de Vida Silvestre Mata do Junco – RVSMJ (10° 46’ S e 37° 01’ W) está localizado ao leste do estado de Sergipe, no município de Capela (Figura 1a). Esta unidade de conservação é considerada a segunda maior reserva de Mata Atlântica do estado, com 1520 hectares (Figura 1b) (Santos et al. 2007). O RVSMJ é caracterizado como um remanescente florestal subdecidual (Santos et al. 2007), constituído basicamente por três estratos arbóreos distintos: o sub-bosque, caracterizado por espécies com folhas largas; o subdossel, composto por arvoretas, lianas e trepadeiras; e o dossel, formado por árvores acima de 15 metros de altura (Dantas et al. 2007).

No presente estudo foram selecionados dois sítios de coleta no fragmento maior que compõe o RVSMJ com o propósito de uma melhor caracterização da fauna de morcegos na área. O primeiro sítio corresponde à uma mancha florestal próxima a sede da unidade de conservação, caracterizada por uma vegetação secundária baixa, com a presença de clareiras e um sub-bosque denso, formado por um emaranhado de cipós e arbustos (observação pessoal). O segundo sítio corresponde ao fragmento florestal associado à nascente do riacho Lagartixo, próximo a Estação de Captação de Água e Esgoto (SAAE), caracterizado por uma vegetação com árvores altas (cerca de 15-18 m de altura) e que apresenta-se preservada (Ferreira et al. 2007).

As campanhas de campo foram realizadas entre fevereiro de 2011 e fevereiro de 2012, com exceção do mês de junho, alternadamente em cada sítio. As coletas ocorreram em duas noites consecutivas por mês utilizando-se sete redes de neblina (7 × 3 m) que permaneceram abertas das 18h00 até 24h00, sendo revisadas em intervalos de meia hora. Para a identificação dos espécimes capturados utilizou-se informações disponíveis em Gardner (2008), Peracchi et al. (2010, 2011), Reis et al. (2007) e Vizotto & Taddei (1973), a partir de caracteres morfológicos, externos e dentários.

Os animais foram marcados na asa esquerda com anilhas plásticas numeradas e depois soltos no mesmo local de captura. Para confirmação da identificação e registro da espécie na localidade amostrada, exemplares foram sacrificados, fixados com formol a 10% e conservados em álcool 70%, sendo posteriormente depositados na Coleção de Mamíferos da Universidade Federal de Sergipe (CMUFS), segundo Licença de Pesquisa e Coleta número 2011.05.0108/00113-011 da SEMARH – SE (Apêndice 1).

Para a identificação de novos registros para a localidade foram utilizados os dados pretéritos de Rocha et al. (2007) e Mikalauskas et al. (2011). Todas as espécies tiveram a abundância contabilizada e foram classificadas de acordo com seus hábitos alimentares predominantes, a partir de informações disponíveis em Peracchi et al. (2010, 2011) e Reis et al. (2007). O esforço de captura foi calculado segundo Straube & Bianconi (2002). Para avaliar se este esforço foi satisfatório e realizar uma estimativa da riqueza na área, foram construídas curvas médias de acumulação de espécies com o aumento do esforço amostral, aleatorizadas 10.000 vezes, através do programa *EstimateSWin* 8.2 (Colwell 2011). Essas curvas foram obtidas para dois estimadores não-paramétricos (Jackknife1 e Jackknife2) que se baseiam na ocorrência de espécies raras e no número de amostras (Santos 2003), sendo escolhido o que apresentou o menor desvio padrão.

Resultados

Com um esforço amostral de 21.168 m².h foram capturados 189 indivíduos, com cinco recapturas, pertencentes a duas famílias, 12 gêneros e 14 espécies (Tabela 1). Destas, seis representam novas ocorrências para o RVSMJ: *Artibeus planirostris* (Spix, 1823), *Chiroderma doriae* Thomas, 1891, *Myotis nigricans* (Schinz, 1821), *Phyllostomus discolor* (Wagner, 1843), *Trachops cirrhosus* (Spix, 1823) e *Trinycteris nicefori* Sanborn, 1949, totalizando 17 espécies registradas nessa localidade (Tabela 1).

Através das curvas médias de acumulação obteve-se uma estimativa de riqueza de 18,58 ± 2,86 espécies por meio do estimador não paramétrico Jackknife 1, sendo que a curva não atingiu a assíntota

(Figura 2). Estes resultados indicam que a riqueza observada ao longo do estudo representa 75,3% das espécies esperadas para o RVSMJ.

A família Phyllostomidae (Figura 3) foi a mais rica e a mais abundante, com 92,8% das espécies registradas e aproximadamente 98,4% das capturas, enquanto a família Vespertilionidae apresentou três indivíduos capturados de uma única espécie. Dos filostomídeos, a subfamília Stenodermatinae foi a mais representativa, com 127 indivíduos e sete espécies capturadas.

As espécies mais abundantes foram *Artibeus lituratus* com 67 indivíduos (35,4%) *Carollia perspicillata* com 45 (23,8%) e *Dermanura cinerea* com 45 (23,8%), representando juntas 83,0% dos indivíduos capturados (Figura 4). Duas espécies (*Tonatia saurophila* e *Trachops cirrhosus*) tiveram somente um indivíduo capturado (Figura 4).

Com relação aos hábitos alimentares das espécies obtidas nesse estudo, 57,1% delas são frugívoras, seguida pelas insetívoras com 21,4% (Tabela 1). Os demais registros foram de espécies nectarívoras, onívoras e carnívoras, com 7,1% cada (Tabela 1).

Discussão

Na comunidade de morcegos do RVSMJ eram conhecidas, até o momento, 11 espécies (Rocha et al. 2007, Mikalauskas et al. 2011), das quais oito (72,7%) foram capturadas no presente estudo. O registro pretérito de *Tonatia bidens* nessa localidade como a primeira ocorrência para Sergipe, apresentado por Rocha et al. (2007), na verdade corresponde a espécie *Tonatia saurophila* (P.A. Rocha, comunicação pessoal), também coletada nesse trabalho. Houve um acréscimo de aproximadamente 54,5% na riqueza do RVSMJ, resultando em 17 espécies. Contudo, a riqueza observada foi menor do que a esperada pela curva de acumulação que não atingiu a assíntota, indicando que o esforço amostral foi incipiente e que novas espécies ainda podem ser amostradas na localidade.

Dos seis novos registros obtidos para a área, um é novo para o estado. A captura de *Trinycteris nicefori* constitui a primeira ocorrência em Sergipe e a ampliação de sua distribuição no Nordeste. Essa espécie possui registro para Mata Atlântica e Floresta Amazônica, podendo ser encontrada nos estados do Acre, Amazonas, Amapá, Bahia, Espírito Santo, Mato Grosso, Pará, Roraima e Tocantins (Peracchi et al. 2010); sendo o registro na Bahia o primeiro a ser obtido para o Nordeste (Faria et al. 2006).

Estudos com morcegos realizados em áreas de Mata Atlântica têm apresentado uma riqueza que varia entre 14-15 espécies (e.g Miretzki & Margarido 1999, Baptista & Mello 2001, Andrade et al. 2010) a mais de 25-40 espécies (e.g. Muller & Reis 1992, Esbérard 2003, Faria & Baumgartem 2007, Silva et al. 2010). Além das diferenças no esforço amostral, essa variação na riqueza pode estar associada ao número de áreas amostradas. Assim, os trabalhos citados acima que apresentaram uma menor riqueza, como o do RVSMJ, tiveram poucos pontos amostrados localmente, não compreendendo uma amostragem que refletisse a totalidade da área estudada.

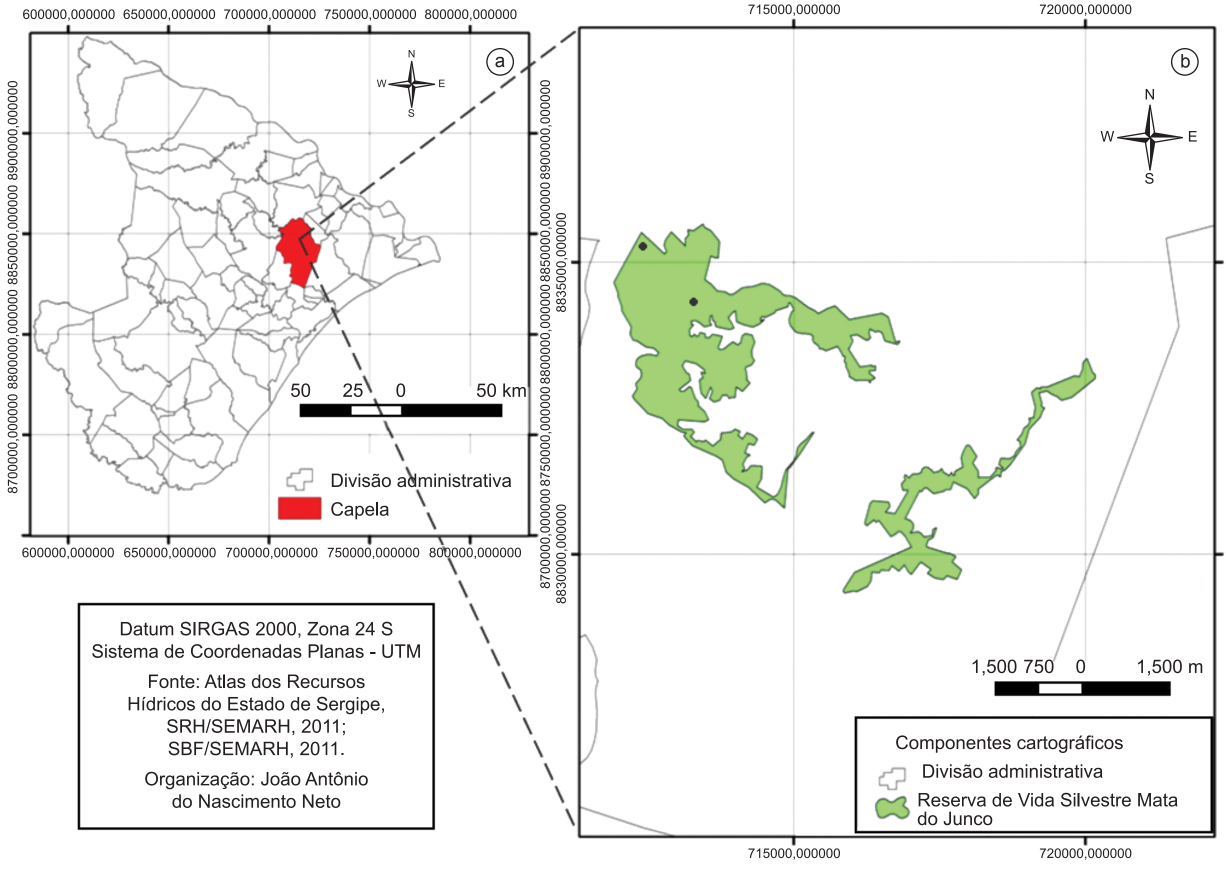

Figura 1. Mapa do estado de Sergipe indicando a localização do município de Capela (a) e a localização do Refúgio de Vida Silvestre Mata do Junco e sítios de coleta (b).

Figure 1. Map of the state of Sergipe indicating the location of the Capela city (a) and location of the Refúgio de Vida Silvestre Mata do Junco and sampling sites (b).

Tabela 1. Relação das espécies de morcegos registradas no Refúgio de Vida Silvestre Mata Junco, estado de Sergipe, e das espécies capturadas no presente estudo, com suas respectivas guildas tróficas.

Table 1. List of bat species recorded in the Refúgio de Vida Silvestre Mata do Junco, state of Sergipe, and species captured in this study with their respective feeding guilds.

Espécies	RVSMJ[1]	Presente estudo	Guilda trófica
Família Phyllostomidae			
Subfamília Desmodontinae			
Desmodus rotundus (É. Geoffroy, 1810)	X		hematófago
Subfamília Phyllostominae			
Phyllostomus discolor (Wagner, 1843)		X	onívoro
Phyllostomus hastatus (Pallas, 1767)	X		onívoro
Tonatia saurophila Koopman e Williams, 1951	X	X	insetívoro
Trachops cirrhosus (Spix, 1823)		X	carnívoro
Trinycteris nicefori Sanborn, 1949 *		X	insetívoro
Subfamília Stenodermatinae			
Artibeus fimbriatus Gray, 1838	X	X	frugívoro
Artibeus lituratus (Olfers, 1818)	X	X	frugívoro
Artibeus planirostris (Spix, 1823)		X	frugívoro
Chiroderma doriae Thomas, 1891		X	frugívoro
Dermanura cinerea Gervais, 1856	X	X	frugívoro
Platyrrhinus lineatus (É. Geoffroy, 1810)	X	X	frugívoro
Sturnira lilium (É. Geoffroy, 1810)	X	X	frugívoro
Subfamília Carolliinae			
Carollia perspicillata (Linnaeus, 1758)	X	X	frugívoro
Subfamília Glossophaginae			
Glossophaga soricina (Pallas, 1766)	X	X	nectarívoro
Família Vespertilionidae			
Myotis nigricans (Schinz, 1821)		X	insetívoro
Rhogeessa hussoni Genoways e Baker, 1996	X		insetívoro

*Novo registro para Sergipe. [1] Rocha et al. (2007) e Mikalauskas et al. (2011).

*New record for Sergipe. [1] Rocha et al. (2007) and Mikalauskas et al. (2011).

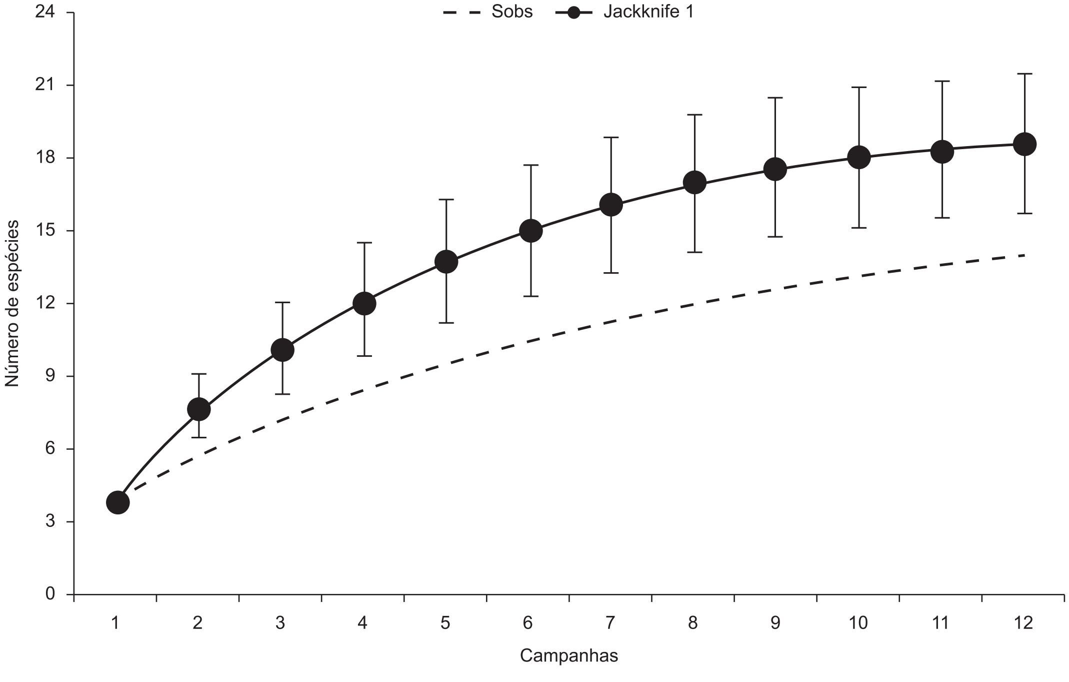

Figura 2. Curvas de acumulação de espécies de morcegos observada (- - - -) e estimada (—●—) pelo estimador não paramétrico Jackknife 1 em campanhas realizadas entre fevereiro de 2011 a fevereiro de 2012 no Refúgio de Vida Silvestre Mata do Junco/Sergipe. As linhas verticais representam o desvio padrão.

Figure 2. Accumulation curves of bats species observed (- - - -) and estimated (—●—) by nonparametric Jackknife 1 estimator in a campaign realized between February 2011 and February 2012 in Refúgio de Vida Silvestre Mata do Junco/Sergipe. Vertical lines represents the standard deviation

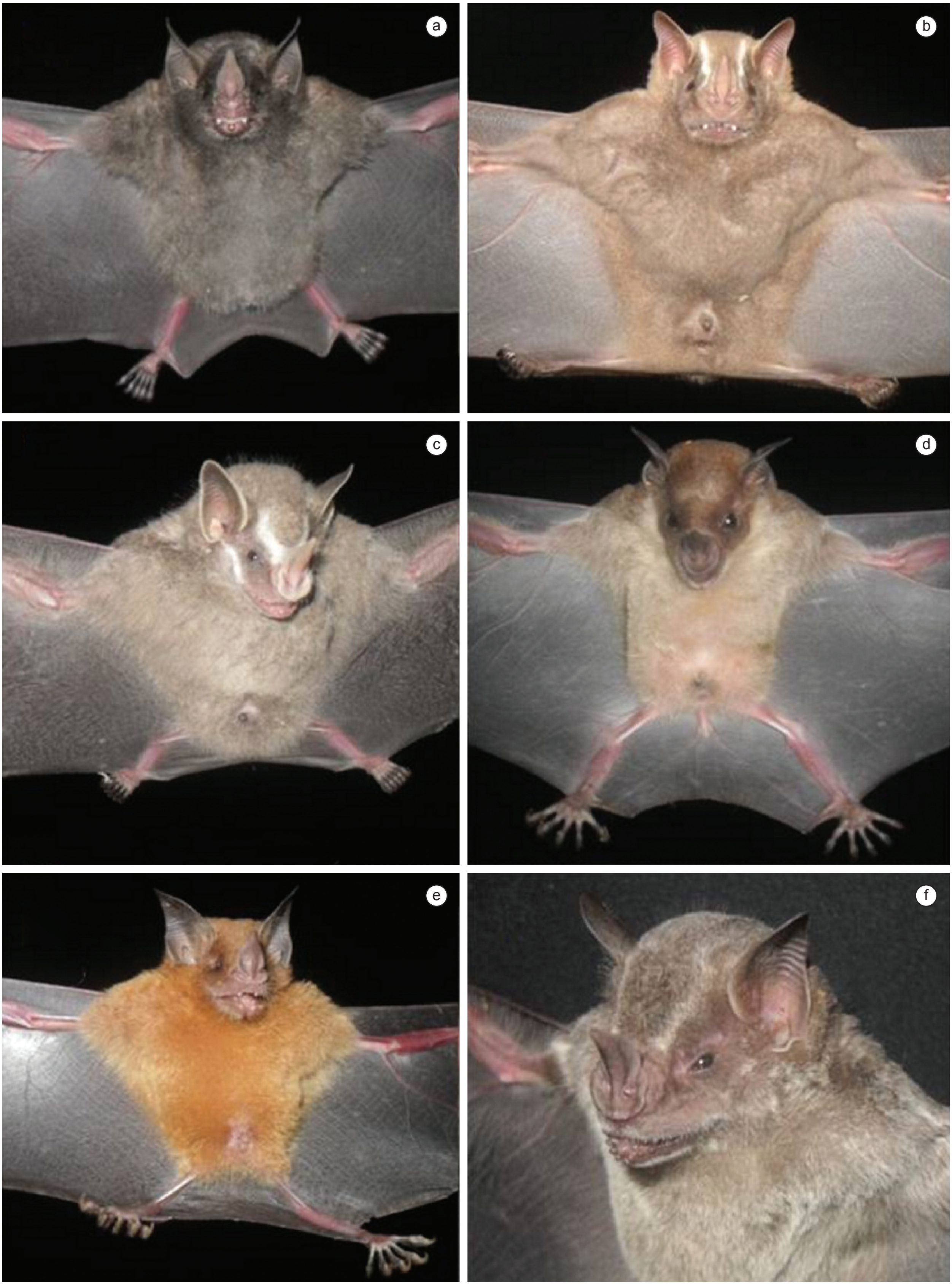

Figura 3. Representantes de morcegos da família Phyllostomidae capturados no Refúgio de Vida Silvestre Mata do Junco/Sergipe. a) *Carollia perspicillata*; b) *Artibeus lituratus*; c) *Dermanura cinerea*; d) *Phyllostomus discolor*; e) *Trinycteris nicefori* e f) *Artibeus planirostris*.

Figure 3. Representatives of the family Phyllostomidae bats captured in Refúgio de Vida Silvestre Mata do Junco/Sergipe. a) *Carollia perspicillata*; b) *Artibeus lituratus*; c) *Dermanura cinerea*; d) *Phyllostomus discolor*; e) *Trinycteris nicefori* and f) *Artibeus planirostris*.

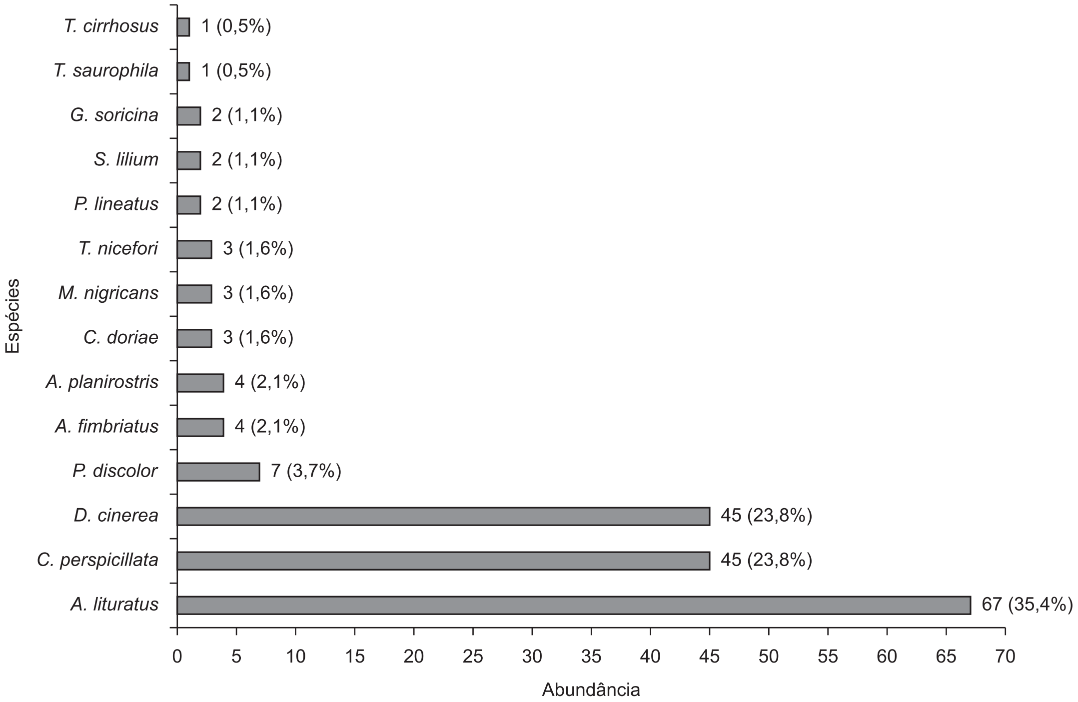

Figura 4. Abundância absoluta e relativa (em %) das espécies de morcegos registradas no Refúgio de Vida Silvestre Mata do Junco/Sergipe entre fevereiro de 2011 a fevereiro de 2012.

Figure 4. Absolute and relative abundance (in %) of bats species recorded in Refúgio de Vida Silvestre Mata Junco/Sergipe from February 2011 to February 2012.

Outro fator que deve ser considerado na obtenção de um inventário representativo da quiropterofauna local é a limitação metodológica, sendo recomendada a utilização de diferentes métodos de amostragem (Bergallo et al. 2003). No caso do uso de redes de neblina, há uma maior captura de filostomídeos (e.g. Trajano 1984, Pedro & Taddei 1998, Ortêncio-Filho & Reis 2009). Portanto, a elevada representatividade desses morcegos nos parâmetros obtidos no RVSMJ já era esperada, em parte devido o uso de exclusivo desse método de coleta. Também deve ser considerada que essa é a família com maior riqueza no Brasil, com aproximadamente 53% das espécies registradas no país (Peracchi et al. 2011).

A maior riqueza e abundância observada na subfamília Stenodermatinae também é justificada pela metodologia adotada, uma vez que esses animais são caracterizados como frugívoros de dossel e sub-bosque (Rex et al. 2008); sendo que morcegos com voo baixo são mais facilmente capturados pela rede de neblina (Pedro & Taddei 1998). Por outro lado, a pouca representatividade de vespertilionídeos pode ser explicada pela habilidade de alguns quirópteros em evitar as redes (Kunz & Kurta 1988), como é o caso de algumas espécies insetívoras, que conseguem detectá-las com facilidade (Trajano 1984).

Três espécies representaram juntas 83,0% dos indivíduos capturados, sendo este resultado um padrão comum em comunidades neotropicais, onde há um alto número de espécies raras e poucas dominantes (Trajano 1984). A elevada abundância observada para *Artibeus lituratus* e *Carollia perspicillata* provavelmente está relacionada com a estrutura ambiental do RVSMJ, a qual apresenta locais com intensa ação antrópica (Santos et al. 2007). Essas duas espécies são consideradas indicadoras de habitats alterados (Muller & Reis 1992, Reis et al. 2003), visto que se adaptam bem a esses ambientes e são menos exigentes na seleção dos alimentos. De forma semelhante, o número de indivíduos observado para *Dermanura cinerea* na área possivelmente está associado à utilização, por esta espécie, de diversos habitats como florestas primárias, secundárias e remanescentes (Zortéa 2007); ambientes também encontrados no RVSMJ.

Com relação à distribuição das guildas alimentares, os frugívoros foram os que apresentaram maior número de indivíduos, sendo esse resultado reflexo do fato das três espécies mais abundantes obtidas nesse trabalho possuírem esse hábito alimentar. Esse grupo tende a ser bastante amostrado com o uso de redes de neblina (Arita 1993, Bergallo et al. 2003), e a existência de áreas agrícolas inseridas no RVSMJ também pode ter favorecido sua elevada representatividade, pois esses ambientes podem servir de locais de alimentação para muitas espécies (Trajano 1984, Mikalauskas 2005).

O registro de novas espécies para o RVSMJ, juntamente com os parâmetros obtidos de riqueza, abundância e guilda trófica, contribuem para o aumento do conhecimento dos quirópteros em Sergipe, principalmente considerando os poucos trabalhos sobre a caracterização da comunidade desses animais no estado (e. g. Mikalauskas 2005, Rocha et al. 2010). Além disso, observou-se que novas espécies podem ser encontradas na localidade, sendo necessária a ampliação e diversificação dos locais amostrados, utilização de outros métodos de coleta e a realização de um maior esforço amostral na área.

Estudos como o realizado no RVSMJ reforçam a importância das unidades de conservação na manutenção da diversidade local e servem de diagnóstico da qualidade ambiental dessas áreas. Nesse sentido, compreender como as espécies de morcegos estão distribuídas e suas interações com o ambiente e os outros organismos, pode servir de base para estratégias de conservação e manejo da localidade estudada.

Agradecimentos

Ao Laboratório de Mastozoologia da UFS, em especial a Daiany S. Reis, Déborah M. Melo, Lúcia G.F. Mello e Marianna N. Oliveira pela contribuição na coleta dos dados; a Patrício A. Rocha e Jefferson S. Mikalauskas pelas informações e auxílio na identificação dos animais; aos funcionários do Refúgio de Vida Silvestre Mata do Junco e a SEMARH pelo apoio logístico.

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Recebido em 09/04/2012
Versão reformulada recebida em 07/08/2012
Publicado em 17/08/2012

Apêndice

Apêndice 1. Espécimes testemunhos depositados na Coleção de Mamíferos da Universidade Federal de Sergipe (CMUFS), Departamento de Biologia, Universidade Federal de Sergipe: *Artibeus lituratus* CMUFS 0030, 0032 ♀, 0040 ♂; *Artibeus planirostris* CMUFS 0033, 0054 ♀, 0031 ♂; *Carollia perspicillata* CMUFS 0001, 0048 ♀; *Chiroderma doriae* CMUFS 0073 ♀, 0051, 0071 ♂; *Dermanura cinerea* CMUFS 0035 ♀, 0002, 0072 ♂; *Glossophaga soricina* CMUFS 0038, 0068 ♀; *Myotis nigricans* CMUFS 0036, 0037, 0039 ♀; *Phyllostomus discolor* CMUFS 0029, 0049, 0050 ♂, *Platyrrhinus lineatus* CMUFS 0034 ♂; *Sturnira lilium* CMUFS 0046 ♀, 0052 ♂; *Tonatia saurophila* CMUFS 0047 ♀; *Trachops cirrhosus* CMUFS 0074 ♂; *Trinycteris nicefori* CMUFS 0055 ♀, 0056, 0063 ♂.

Appendix 1. Vouchers deposited in the Coleção de Mamíferos da Universidade Federal de Sergipe (CMUFS), Departamento de Biologia, Universidade Federal de Sergipe: *Artibeus lituratus* CMUFS 0030, 0032 ♀, 0040 ♂; *Artibeus planirostris* CMUFS 0033, 0054 ♀, 0031 ♂; *Carollia perspicillata* CMUFS 0001, 0048 ♀; *Chiroderma doriae* CMUFS 0073 ♀, 0051, 0071 ♂; *Dermanura cinerea* CMUFS 0035 ♀, 0002, 0072 ♂; *Glossophaga soricina* CMUFS 0038, 0068 ♀; *Myotis nigricans* CMUFS 0036, 0037, 0039 ♀; *Phyllostomus discolor* CMUFS 0029, 0049, 0050 ♂, *Platyrrhinus lineatus* CMUFS 0034 ♂; *Sturnira lilium* CMUFS 0046 ♀, 0052 ♂; *Tonatia saurophila* CMUFS 0047 ♀; *Trachops cirrhosus* CMUFS 0074 ♂; *Trinycteris nicefori* CMUFS 0055 ♀, 0056, 0063 ♂.

Survey of edaphic fauna in forest fragment in the municipality of Anchieta (SC, Brazil)

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BRANCHER, D. & ROZA-GOMES, M.F. **Survey of edaphic fauna in forest fragment in the municipality of Anchieta (SC, Brazil)**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02212032012

Abstract: Among the edaphic Hexapods, the insects are more abundant and important in that they act as environmental indicators. This study aimed to conduct a survey of the edaphic fauna in a forest fragment of transition from ombrophilous forest to mixed seasonal deciduous forest in the municipality of Anchieta, SC, Brazil. Samples were collected every fortnight from May to August 2010 by using the method of pitfall traps. Were collected 6598 individuals. The groups more abundant was Hymenoptera with 3398 individuals (51%), Collembola with a total of 1370 individuals (21%) and Diptera represented by 910 individuals (14%). The Simpson Index was found 0.60 and the Shannon Diversity Index was 3.00. The results obtained show that the place studied by provide conditions of survival to susceptible species such as Collembola, indicated a good quality of the soil study.
Keywords: *insects, pitfall traps, seasonal fluctuation, soil fauna.*

BRANCHER, D. & ROZA-GOMES, M.F. **Levantamento da fauna edáfica em fragmento florestal no Município de Anchieta (SC, Brasil)**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02212032012

Resumo: Dentre os Hexapoda edáficos, os insetos são os mais abundantes e de grande importância por atuarem como indicadores ambientais. Esse estudo teve como objetivo realizar um levantamento da fauna edáfica em um fragmento florestal de transição de floresta ombrófila mista para floresta estacional decidual, no Município de Anchieta, SC, Brasil. As coletas foram realizadas quinzenalmente no período de maio a agosto de 2010 utilizando o método das armadilhas de queda tipo pitfall traps. Foram coletados 6598 indivíduos. Os grupos mais abundantes foram Hymenoptera com 3398 indivíduos (51%), Collembola com um total de 1370 indivíduos (21%) e Diptera representada por 910 indivíduos (14%). O valor do Índice de Simpson encontrado foi de 0,60 e o Índice de Diversidade de Shannon de 3,00. Os resultados obtidos mostram que o local estudado por apresentar condições de sobrevivência para espécies sensíveis como os Collembola, indicam uma boa qualidade do solo da área estudada.
Palavras-chave: *insetos, armadilhas de queda, levantamento populacional, fauna de solo.*

Introduction

The phylum Arthropoda corresponds of the most successful to the evolution Earth (Brusca & Brusca 2002) with approximately 1.000.000 species (Costa Ribeiro & Rocha 2002, Storer 2003), representing 85% of all animal species described (Brusca & Brusca 2007).

Represents at phylum the most important ecological, because most of the energy flow of ecosystems passing through the bodies of these animals (Mota et al. 2009) and dominate all terrestrial and aquatic ecosystems in number of species or individuals or both (Storer 2003). The litter arthropod fauna stands out in forest ecosystems because of their importance in nutrient cycling and degradation of organic matter, as long as these organisms are primarily responsible for fragmenting the accumulated litter from the surrounding greenery (Ferreira & Marques 1998).

According to Storer (2003), the class Insecta comprises over 900.000 species, are the only invertebrates that can live in dry environments and only able to fly. Represent about 70% of animal species known, therefore, represent the most numerous group existent today (Almeida 1998).

The edaphic insects are living in the soil or at least seek their resources in the ground. Are extremely important for preserving biological, chemical and physical ecosystems (Dindal 1990) and are the most sensitive to environmental impacts (Dambroz et al. 2007) and can be used as environmental indicators, revealing the conditions of the area where they are.

The edaphic invertebrates are important processes in the terrestrial ecosystems, breaking down organic matter, cycling nutrients and indirectly regulate the biological processes of soil at different levels and establishing relations with the microorganisms, which are essential for fertility and ecosystem productivity (Nunes et al. 2009).

Tropical forests provide diverse composition of litter and nutrient cycling by establishing a more stable community of diversified decomposers, This fact occurs because these forests are situated in a region where the climate is defined by one wet and one dry season (Sanches et al. 2009). The litter is composed of organic matter of animal and vegetable on the soil, at the different stages of decomposition. Thus representing a form of entry and subsequent increased soil organic matter (Barbosa & Faria 2006).

Studies on insects may provide a rich base of information about the level of integrity of environments in which they are, as well as being the more numerous group of animals of the planet a great diversity in terms of species and habitats (Thomazini & Thomazini 2000). Some groups of insects are especially useful in environmental monitoring, it happens because they are so diversified, easily sampled and identified, common throughout the year and responding quickly to environmental alterations (Cullen Junior et al. 2006). The main characteristic is a good indicator of sensitivity to significant changes between 01 and 03 years and 05 years as a margin limit (Lopes 2008).

To study the ecosystem is a way of knowing how the situation of the site. For this reason, many studies have been and are being performed in order to to evaluate the environmental quality, in particular the soil, which houses a large variety of animals that need it to survive is for food or shelter.

Given this, it is of fundamental importance in this survey of edaphic fauna forests. In the forest fragment studied, this type of survey was never done, so do not have information for diversity edaphic fauna and soil quality, and these data are very importance to the local community and also at regional level. In this sense, the objective of this study was to survey the edaphic fauna in the forest fragment at the transition from rain forest to mixed deciduous forest in the municipality of Anchieta, SC, Brazil.

Materials and Methods

1. *The study area*

It is a forest fragment located in the municipality of Anchieta, Santa Catarina, Brazil (26° 29’ 48,14” S and 53° 20’ 40,37” W), altitude 627 m (Figure 1). The study area (45 ha) is defined by areas of agricultural production and animal husbandry. The vegetation typical of municipality is characterized by the deciduous seasonal Forest (approximately 85% of the city) and the Mixed Ombrophylous Forest (approximately 15% of the city) being considered as a transition area between the two forest types forest of the Atlantic Forest biome (Canci & Brassiani 2004).

The Ombrophylous Forest is characterized by mixed forest of Araucaria, is one type of vegetation of the Southern Plateau (Instituto... 1992). The Araucaria Forest is a typical vegetation of the highlands and subtropical regions above 500m altitude, which has suffered very serious aggression over the ages (Leivas & Fischer 2008).

The deciduous forest or tropical deciduous forest vegetation is characterized by two well-defined seasons, a rainy period followed by long dry biologically (Instituto... 1992). Occurs in the form disjunctions presenting forest stratum and dominant macro mesofanerófito predominantly deciduous with more than 50% of individuals devoid of foliage in the unfavorable period (Instituto... 1992).

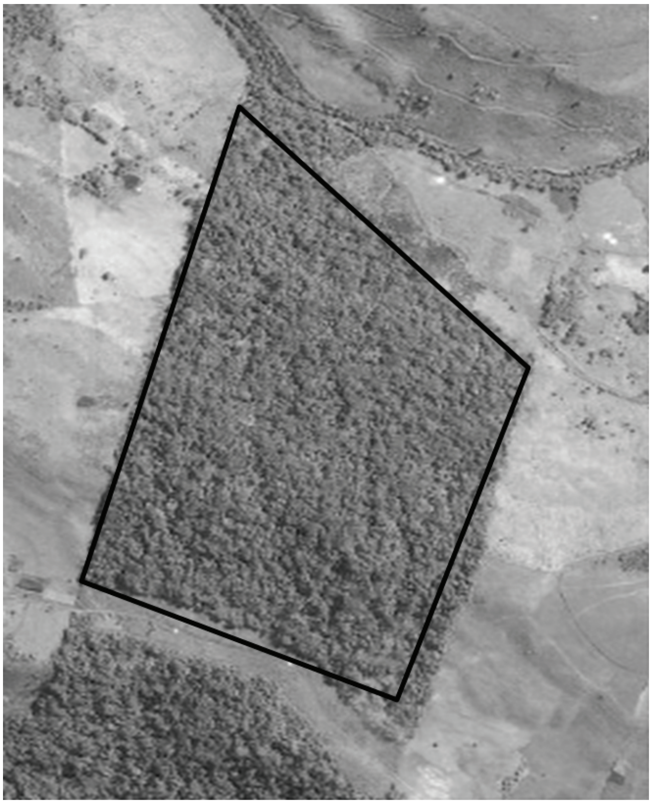

Figure 1. Area (highlighted in black) for waiver of the edaphic entomofauna (26° 29’ 48,14” S and 53° 20’ 40,37” W), altitude 627 m, Anchieta, SC Brazil. Source: Google Earth (2010).

Figura 1. Área (destacada em preto) de levantamento da entomofauna edáfica (26° 29’ 48,14” S e 53° 20’ 40,37” O), altitude 627 m, Anchieta, SC Brasil. Fonte: Google Earth (2010).

The city is inserted in the Uruguay River Basin and the climate following the classification Koeppen, is mesothermal Cfa, with defined seasons and frost in winter. The annual average temperature is 18 °C and average annual rainfall is 1.900 to 2.000 mm (Instituto... 1996).

An estimated the area covered by the municipality of Anchieta, is composed of 10% of flat terrain, 15% of wavy relief and 75% mountainous, with altitudes ranging from 500 to 950 meters (Canci & Brassiani 2004).

1.1. Data collection

Have been distributed 30 pitfall traps (Figure 2) arranged in three transects (A, B and C) 50 m the inside rim the forest and 100 m distant from one transect to another. Each consisting of 10 traps 10 meters distant from each other.

Traps were placed in a straight line, with the help of measuring tape and compass, and demarcated with stakes, using a wire between a pole and another to identify where the trap was set.

Samples were collected from May to August 2010, every 15 days, with two collections per month, totaling eight collections. The traps used are pitfall traps, consisting of disposable bottles of 10 cm in diameter and 15 cm high, with a capacity of 500 mL, according to work by Aquino et al. (2006), containing 70% alcohol, water and a few drops of detergent to break the surface tension of the same. These bottles were buried in the ground level of the litter, remaining active for 24 hours. The pitfall trap is characterized by a data collection instrument to be very simple, easily confectioned, inexpensive and easy to be transported and installed, performing efficiently and effectively. It is used to capture different groups of animals, from microinvertebrados, which make up the soil fauna, even small mammals, allowing to collect species of nocturnal and diurnal (Lopes 2007, Santos et al. 2007).

In this study, after collection, samples were stored in stoppered vials being used pet bottles of 500 mL, containing 70% ethanol, labeled with the same number of field sample and taken to the laboratory of Zoology and Botany of University of Western Santa Catarina (UNOESC) Campus Sao Miguel do Oeste, SC, Brazil, where the collected material has undergone a process of removing of the content contained in the trap (mostly water) using a fine mesh.

Subsequently were observed using a stereoscopic microscope, quantified and identified by order level using dichotomic key (Da Costa Lima 1938). The diversity index was calculated by Simpson's Diversity Index and Shannon Index. Also, it were calculated the analysis of variance (ANOVA) for the months of samples.

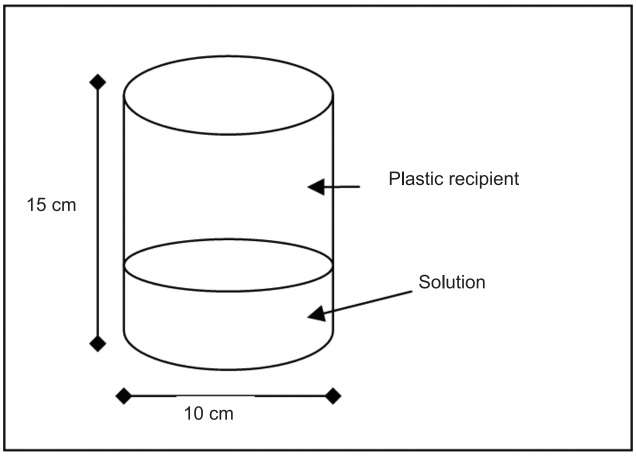

Figure 2. Schematic design of *pitfall trap*.

Figura 2. Desenho esquemático de armadilha tipo *pitfall trap*.

Results and Discussion

During the sample period, were captured 6598 individuals distributed in eight orders (Table 1). The order Hymenoptera predominated in the environment studied, with 51% of all animals captured. The Collembola are next with 21% and 14% with Order Diptera. Orthoptera and Coleoptera had the same percent (5%). Plecoptera showed 2% and Blattaria and Hemiptera with 1% of total edaphic fauna captured.

The results of this study were similar to those of Mota et al. (2009) and Rovedder et al. (2009) in relation to the prevalence of Hymenoptera in the total number of individuals collected.

According Rovedder et al. (2009) the prevalence of Hymenoptera in the samples taken by them, indicated a tendency to low levels of diversity in the ecosystem, which may be related to low natural fertility of the soil under study.

Table 1. Total individuals captured in pitfall traps in forest fragment in the municipality of Anchieta, SC, Brazil, from May-August, 2010.

Tabela 1. Total de indivíduos capturados em armadilhas *pitfall traps* em fragmento florestal no município de Anchieta, SC, Brasil, no período de maio-agosto, 2010.

Groups collected	Number of individuals	Percentage of individuals
Hymenoptera	3398	51%
Collembola	1370	21%
Diptera	910	14%
Coleoptera	327	5%
Orthoptera	316	5%
Plecoptera	166	2%
Hemiptera	58	1%
Blattaria	53	1%
Simpson index	0.60	-
Shannon Diversity Index	3.00	-
Total	6598	100%

Table 2. Number of edaphic animals collected in forest fragment in the municipality of Anchieta, SC, Brazil, emphasizing the abundance of orders collection in each month.

Tabela 2. Número de animais edáficos coletados em fragmento florestal no município de Anchieta, SC, Brasil, destacando a abundância das Ordens em cada mês de coleta.

Order	Number of individuals			
	May	June	July	August
Hymenoptera	132	2333	699	234
Collembola	283	386	254	447
Diptera	296	237	172	205
Coleoptera	35	127	95	70
Orthoptera	99	81	87	51
Plecoptera	31	39	45	49
Hemiptera	15	10	15	18
Blattaria	20	16	11	6
Mean	113,88 ^{ns}	403,63 ^{ns}	172,25 ^{ns}	135,00 ^{ns}
TOTAL	911	3229	1378	1080

^{ns} no significant difference.

For this study, the Hymenoptera were not predominant on all collections. That is, were the most abundant only in June and July (two samples), as can be seen in Table 2.

The results obtained by Cunha (2004) suggest occurrence of an great accumulation the leaflitter which allows the coexistence of many species of macroinvertebrates, and after that accumulation, the ants (Hymenoptera) dominate the leaflitter, predating or expelling the others arthropods.

According Pereira & Silva (2009) the ants indicate the biodiversity from areas with environmental disturbance. Complementing, Lopes (2008) argues that the presence of the order Hymenoptera, indicated environment degradation. However, to use the ants as bioindicators is required a detailed analysis, not being possible to examine the environmental impacts or a regeneration effect on a simple count of their number (Neves et al. 2008).

According Santos et al. (2007), alcohol can be an attractive for the orders Coleoptera and Hymenoptera. This can also explain the appearance of large number of ants in this study because been used alcohol in the interior of pitfall traps.

The Order Collembola, which was the second most abundant in number of individuals and remained practically stable in all collections of the study, the functional role in processes involving the dynamic of the organic matter and the sensitivity to disturbances can be considered effective for a good indicator of soil quality (Assad 1997).

Thus, the number of Collembola collected in the study area, although for a short period of time, can say that the forest fragment provides conditions for survival for these individuals and, consequently, it is a place with good soil.

The Diptera represented the third order most commonly found (Table 1), confirming that the study site gives conditions for the development of these insects, indicating low or absence of of contamination in the soil.

According to Correia (2002) and Leivas & Fischer (2008), the Diptera show great importance on the restoration of areas, playing a major role in the colonization of environments and in nutrient cycling across its larvae phytophagous, saprophagous, microphagous and micetophagous just colonized environments which support the development of their larvae.

In terms the Order Coleoptera, was the most abundant just in June (Table 2). Zardo et al. (2009) in his study on Arthropods communities associated with leaflitter forest stands that the abundance of order Coleoptera is positively related to the depth of the litter. As the collections of the present study were carried out with pitfall traps, it is possible the number of individuals captured of the Order Coleoptera, is not effectively expressed, future studies being needed to other methods of collection for more accurate results. The presence of the Coleoptera could be related to his ownership of animal breeding (cattle raising) next to the fragment, which may be in the Coleoptera that feed on the feces of vertebrates.

The presence of the Order Blattaria, although with small representativeness in the fragment studied, complements the fact that it is an area with good levels of organic matter, because, according to Lopes (2008) the order Blattaria require high organic matter content, in other words, only in places and more balanced variety of foods these animals could be encountered.

Some families of Orthoptera are greatly influenced for the availability of moist environment (Mól et al. 2007). In this forest fragment was verified that the soil is moist enough to allow good state to develop the Orthoptera.

Lopes (2008) argues that the orders Blattaria, Diptera and Coleoptera can be found in preserved environments.

The orders Plecoptera and Hemiptera did not have very significant results. However is believed that the presence of order Plecoptera is related to the small stream running passing through the fragment, because their larvae develop in water (Callisto et al. 2004).

Already members of order Hemiptera, which may be considered agricultural pests and also natural enemies (Brusca & Brusca 2007). Possibly, in this study were present because there agricultural production areas near the study area or because they are of this specific habitat.

The value of Simpson index was found to be 0.60. The Shannon Diversity Index was 3.00

The Simpson and Shannon index indicate that there is encountered a good diversity in the forest fragment studied. This is justified because the Simpson index is a dominance index and reflects the probability that two randomly chosen individuals in the community belong to the same species. Ranges from 0 to 1 and the higher, the more likely individuals are the same species, ie higher dominance and lower diversity (Uramoto et al. 2005). Already the Shannon index measures the level of uncertainty to predict to what species belong to one individual chosen at random from a sample of S species and N individuals. The lower the value of the Shannon index, the lower the degree of uncertainty and therefore the diversity of the sample is low. The diversity tends to be higher the higher the index value (Uramoto et al. 2005).

By analysis of variance was not significant difference among month of observation. However, compared to the months of collection, the month of May had the lowest number of individuals and in June was what had the highest number of samples (Table 2).

The pluviometric precipitation between the months May to August varied greatly, with the month of greater precipitation in May it was the 231.3 mm. And the month of less precipitation in June was 30.2 mm (Empresa... 2010). Whereas the temperatures have already had between 14.9 °C to 16.3 °C (Empresa... 2010). That indicates that the animals were more abundant in the driest months.

Faced with the results obtained, it were observed that the forest fragment studied provide favorable conditions to insects and consequently presented good quality of soil. However there is need of greater surveying related to fauna as bioindicators of soil because this survey was conducted only in autumn and winter season and is known to that the class Insecta is more abundant in the warm season.

Acknowledgements

To God, the great force that drives us. The Program University for All (PROUNI) for granting the scholarship integral study to the first author. To all who in one way or another have contributed to this study.

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Received 26/12/2011
Revised 07/08/2012
Accepted 20/08/2012

Litterfall and leaf decomposition in forest fragments under different successional phases on the Atlantic Plateau of the state of Sao Paulo, Brazil

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VENDRAMI, J.L., JURINITZ, C.F., CASTANHO, C.T., LORENZO, L. & OLIVEIRA, A.A. **Litterfall and leaf decomposition in forest fragments under different successional phases on the Atlantic Plateau of the state of Sao Paulo, Brazil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn03312032012

Abstract: Litterfall and litter decomposition are vital processes in tropical forests because they regulate nutrient cycling. Nutrient cycling can be altered by forest fragmentation. The Atlantic Forest is one of the most threatened biomes in the world due to human occupation over the last 500 years. This scenario has resulted in fragments of different size, age and regeneration phase. To investigate differences in litterfall and leaf decomposition between forest successional phases, we compared six forest fragments at three different successional phases and an area of mature forest on the Atlantic Plateau of Sao Paulo, Brazil. We sampled litter monthly from November 2008 to October 2009. We used litterbags to calculate leaf decomposition rate of an exotic species, *Tipuana tipu* (Fabaceae), over the same period litter sampling was performed. Litterfall was higher in the earliest successional area. This pattern may be related to the structural properties of the forest fragments, especially the higher abundance of pioneer species, which have higher productivity and are typical of early successional areas. However, we have not found significant differences in the decomposition rates between the studied areas, which may be caused by rapid stabilization of the decomposition environment (combined effect of microclimatic conditions and the decomposers activities). This result indicates that the leaf decomposition process have already been restored to levels observed in mature forests after a few decades of regeneration, although litterfall has not been entirely restored. This study emphasizes the importance of secondary forests for restoration of ecosystem processes on a regional scale.
Keywords: *biomass, nutrient cycling, secondary forest, tropical forest.*

VENDRAMI, J.L., JURINITZ, C.F., CASTANHO, C.T., LORENZO, L. & OLIVEIRA, A.A. **Produção de serrapilheira e decomposição foliar em fragmentos florestais de diferentes fases sucessionais no Planalto Atlântico do estado de São Paulo, Brasil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn03312032012

Resumo: A produção e a decomposição de serrapilheira são processos vitais nas florestas tropicais, uma vez que determinam a ciclagem de nutrientes. O processo de ciclagem de nutrientes pode ser alterado pela fragmentação florestal. A Floresta Atlântica é um dos biomas mais ameaçados mundialmente devido à ocupação humana nos últimos 500 anos. Este cenário resultou em fragmentos de diferentes tamanhos, idades e estádios de regeneração. Para explorar as diferenças na produção de serrapilheira e na decomposição foliar de acordo com o estádio sucessional da floresta, comparamos seis fragmentos florestais em três diferentes estádios sucessionais e uma área de floresta primária no Planalto Atlântico de São Paulo, Brasil. Coletamos a serrapilheira mensalmente de novembro de 2008 a outubro de 2009. Utilizamos bolsas de confinamento de serrapilheira para calcular a taxa de decomposição foliar de uma espécie exótica, *Tipuana tipu* (Fabaceae), durante o mesmo período de coleta da serrapilheira. A deposição de serrapilheira foi maior na área de estádio sucessional mais inicial. Esse padrão pode estar relacionado com as características estruturais dos fragmentos florestais, especialmente com a maior abundância de espécies pioneiras, que possuem uma maior produtividade e são espécies típicas de fragmentos em estádios iniciais de sucessão. Por outro lado, não encontramos diferenças significativas nas taxas de decomposição entre as áreas estudadas, o que pode ocorrer devido à rápida estabilização do ambiente de decomposição (efeito combinado das condições microclimáticas e das atividades dos decompositores). Estes resultados indicam que o processo de decomposição foliar foi restabelecido aos níveis das florestas maduras após algumas décadas de regeneração, embora a produção de serrapilheira ainda não tenha sido totalmente restaurada. Este estudo destaca a importância das florestas secundárias em um cenário regional de restauração de processos ecossistêmicos.
Palavras-chave: *biomassa, ciclagem de nutrientes, floresta secundária, floresta tropical.*

Introduction

Deforestation and forest fragmentation are major threats to biodiversity in the tropics (Laurance 1999), particularly in South America, where forest land has been continuously converted to agriculture, urbanization (Food... 2011) and industrial uses. An example of this network is the Brazilian Atlantic Rain Forest, whose exploitation dates back to the time of European colonization, 500 years ago, when the trade of forest resources in conjunction with the pressure from economic cycles in the followed centuries (Dean 1996) culminated in a fragmented and threatened biome. This exploitation resulted in isolated forest fragments of different sizes and successional phases (Ribeiro et al. 2009).

Forest fragmentation is known to alter the microclimate, as a result of a higher insolation and wind penetration, which increases temperature and decreases humidity along forest edges (Kapos et al. 1997). Moreover, fragmentation elevates the rates of tree mortality (Laurance et al. 1998), which influence forest diversity and species composition (Laurance et al. 1998). In addition to altering the ecosystem structure, forest fragmentation can lead to changes in ecological processes such as litter production (Werneck et al. 2001) and nutrient cycling (Laurance 2008).

In forests fragments, aboveground live biomass increases with succession (Vitousek & Reiners 1975) as a result of the recruitment of old growth species (characterized by a larger diameter and height (Clark 1996) and canopy development (Clark 1996, Songwe et al. 1988). Thus, litter production is expected to increase with forest development (Vidal et al. 2007). The amount of litter input, in turn, influences the composition of the decomposer community and associated with the drier microclimate conditions, typical of early successional forest fragments, can reduce the activity of decomposers (Bradford et al. 2002), resulting in a less efficient nutrient cycling.

Litterfall and leaf decomposition represent the main pathway for nutrient cycling in forest ecosystems (Montagnini & Jordan 2002). These ecosystem processes are of key importance on tropical forests, where the vegetation is generally sustained by soils with low fertility (Lavelle et al. 1993). Therefore, forest productivity depends on efficient nutrient cycling mechanisms that ensure rapid turnover of litter nutrients (Montagnini & Jordan 2002). In tropical montane forests, nutrient cycling mechanisms are especially relevant, since their leaf litter is composed by lower nutrient concentrations than those from lowland forests (Bruijnzeel & Veneklaas 1998) and the lower temperatures reduces the decomposition rate and nutrient release (Röderstein et al. 2005), making their soils extremely poor in nutrients (Bruijnzeel & Veneklaas 1998).

Although different aspects of forest fragmentation have been studied in the last decades in the tropics (Dixo et al. 2009, Banks-Leite et al. 2010, Bieber et al. 2011, Lira et al. 2012), its consequences on ecosystem processes are still poorly understood (Vasconcelos & Luizão 2004, Vidal et al. 2007, Ostertag et al. 2008). Thereby, this study aimed to evaluate how litterfall and nutrient cycling are affected by the structure of forest fragments at different successional phases under similar climatic conditions on the Atlantic Plateau of the state of Sao Paulo, Brazil. We hypothesized that forest fragments of later successional phases would have higher litterfall input and leaf decomposition than early successional fragments under similar climatic conditions, as a result of the major biomass and the more favorable environmental conditions (which represent the combined effects between microclimate and decomposers activities), respectively.

Materials and Methods

1. *Study site*

The study area is located in the municipalities of Ibiúna, Piedade and Tapiraí, state of Sao Paulo, southeastern Brazil at an altitude of 800 to 1100 m a.s.l. (Ponçano et al. 1981). The climate is temperate humid with temperate summer, Cfb (Köppen 1948). The average annual temperature is of 20 °C and an average annual precipitation is of 1808 mm (CIIAGRO/IAC 2012). The three soil classes of the region are Cambisol, Latosol and Argisol (Oliveira et al. 1999) with slopes ranging from 20 to 30% (Ponçano et al. 1981). The original vegetation is dense montane ombrophilous forest (*sensu* Veloso et al. 1991), which is considered a transition forest between the Atlantic coastal forests and the mesophilous semi-deciduous forests from inland Sao Paulo (Aragaki & Mantovani 1998).

In the municipalities of Piedade and Tapiraí, a landscape of 10,000 ha (23° 50’ 00” S and 47° 20’ 00” W) was bounded by the BioCAPSP II project (2000), and consists in forest fragments at different successional phases, surrounded by agricultural fields, cattle pasture and degraded areas. In this landscape, we selected six forest fragments of different land use history, size (26.7 to 167.1 ha) and age (25 to > 65 years) (Table 1). We adopted a classification of the successional phase of these fragments that was based on a combination of structural and floristic variables (basal area, density, basal area of pioneers, number of multiple trunks and maximum canopy height) (Table 1, see Jurinitz 2010 for details), which resulted in three phases: late secondary (1-2), intermediate (1-2) and early (1-2) (Table 1). The numbers after each phase refer to the increasing order of successional phases within each group, and lower figures indicate fragments at an earlier regeneration state. It is important to note, however, that this classification allows forest fragments of different ages to be classified in the same successional phase, e.g. Intermediate Secondary 1 and 2 (Table 1). This occurs because the successional phase of a fragment cannot be interpreted

Table 1. Characteristics of forest fragments on the Atlantic Plateau of the state of Sao Paulo, Brazil. Forest fragments are ordered by decreasing order of successional phase.

Study area	Study area acronym	Area (ha)	Age (yr)[a]	% Basal area of pioneers[b]	% Canopy opening[b]
Control	C	>26,000	-	-	-
Late Secondary 2	LS-2	97.6	≥65	0	3.7
Late Secondary 1	LS-1	26.7	≥65	0	3.7
Intermediate Secondary 2	IS-2	167.1	25	9.6	4.1
Intermediate Secondary 1	IS-1	85.3	≥65	2.2	8.2
Early Secondary 2	ES-2	39.9	25	13.9	6.4
Early Secondary 1	ES-1	41.3	25	36.8	8.2

[a]Lira et al. (2012). [b]Jurinitz (2010).

only as a chronosequence, but also as a consequence of many factors (such as the ones mentioned previously). The control area was located in the Jurupará State Park, municipality of Ibiúna (23° 57' 13" S and 47° 24' 31" W) and contained over 26,000 ha of preserved mature forest (Table 1).

2. *Litterfall*

Nine 0.5 × 0.5 m litter collectors were installed 1.5 m above the surface of the soil in each area. Collectors were arranged along three parallel transects 100 m apart, except for the Late Secondary 1 fragment; due to the small size of this fragment (Table 1), the distance between the transects was 50 m. Three collectors were installed at 40 m intervals along each transect (Figure 1a). We collected the deposited material monthly from November 2008 to October 2009, dried at 60 °C to a constant weight and weighed on a digital scale that was precise to the thousandth of a gram. Branches larger than 0.5 cm in diameter were discarded.

3. *Litter decomposition experiment*

Leaf decomposition rates were estimated using the litter confinement method in decomposition bags (Bocock & Gilbert 1957). Although this method may underestimate actual decomposition rates, it is recommended for comparative purposes (Wieder & Lang 1982). To avoid having any area be favored by the presence of soil microbiota that was locally specialized in decomposition of a particular substrate, as suggested in an earlier study performed in the Cerradão (Castanho & Oliveira 2008), which is a forest-like Brazilian savanna, we standardized the substrates in this experiment using an exotic species (*Tipuana tipu* (Benth.) Kuntze, Fabaceae). Decomposition bags were 0.2 × 0.2 m and made with 0.4 cm^2 nylon mesh filled with approximately 3 g of *T. tipu* leaves dried at 60 °C to a constant weight. In each forest fragment, 60 litterbags were distributed in 10 random blocks within a 50 × 100 m plot located at least 20 m from the forest edge (Figure 1b). We placed the bags on the soil surface with a minimum distance of 20 m between blocks. This experiment was conducted near the areas used for the litterfall. In the control area, we arranged the blocks along two litter sampling transects with five blocks per transect and a distance of 20 m between adjacent blocks. The experiment was set up at the beginning of the rainy season in October 2008. Sampling was performed after 30, 90, 150, 210, 300 and 390 days. In each period, we collected one litter bag per block, totaling 10 bags per study area. In the laboratory, we removed and transferred the material inside each bag to Petri dishes, dried at 60 °C to a constant weight and weighed. Due to trees falling in March and May 2009, three fragments (LS-1, IS-1 and ES-1) lost one decomposition block each.

4. *Data analyses*

We used the Monte Carlo permutation method to test for differences in litterfall between successional phases by calculating the modulus of the sum of the differences between average annual litter production from all areas ($X_{general}$) and the annual average from each area (X_j): $\Sigma \mid X_{general} - X_j \mid$. One thousand permutations were generated from monthly data, which was blind to the identity of the sampled areas. To check for differences between fragments, we calculated 95% confidence intervals (CI) by bootstrap resampling (1000 permutations of annual data with the identity of each area known). Areas were considered distinct when maximum or minimum values of the confidence interval from one fragment did not overlap the average from another area. In addition, the coefficient of variation (CV) was calculated to determine the variability of the dataset.

In the leaf decomposition experiment, we applied a simple model of exponential decay (Jenny et al. 1949, Olson 1963) to calculate decomposition rates: $-X_t/X_0 = e^{-kt}$, where X_0 is the initial dry mass, X_t is the dry mass at time t and k is the decay constant. The model was fit to the data using linear regression of the natural logarithm of leaf mass remaining in each decomposition block over time. Therefore, the slope coefficient of the linear equation represents the decomposition rate in each block. We used Analysis of variance (ANOVA) to test for effects of successional phase on the decomposition rate. The estimated decomposition rate for each block in each area served as the response variable, and the forest (with seven levels) served as the explanatory variable.

Results

1. *Litterfall*

Litter production was seasonal. All areas studied exhibited a similar pattern (Figure 2), and the highest production was during the

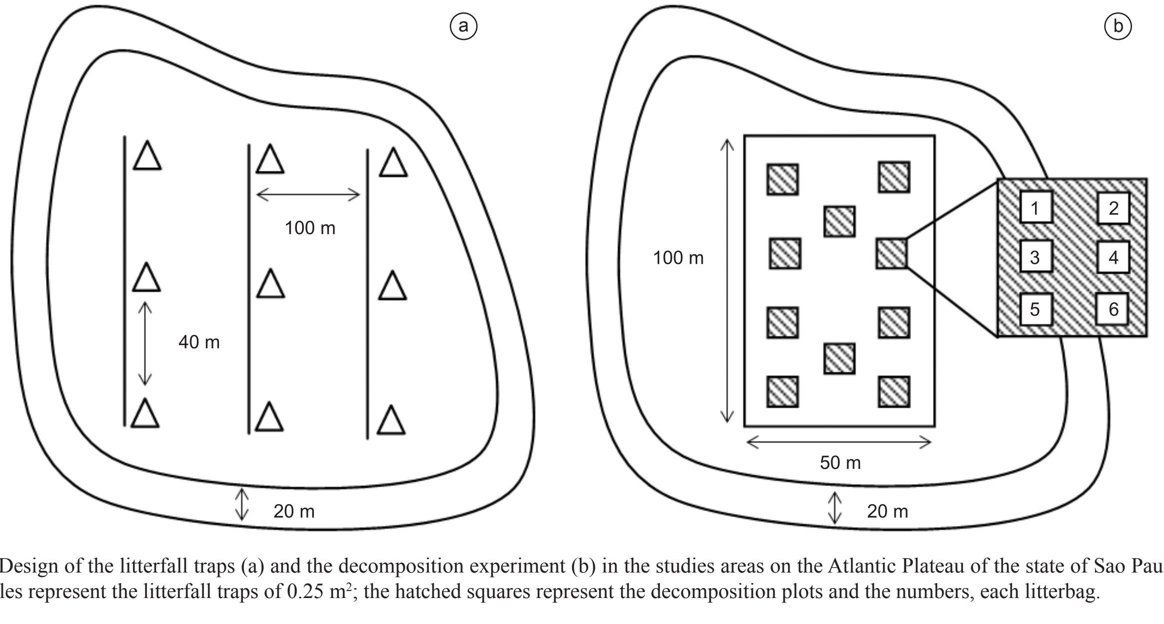

Figure 1. Design of the litterfall traps (a) and the decomposition experiment (b) in the studies areas on the Atlantic Plateau of the state of Sao Paulo, Brazil. The triangles represent the litterfall traps of 0.25 m^2; the hatched squares represent the decomposition plots and the numbers, each litterbag.

rainy season (509.1 ± 112.5 kg/ha from November 2008 to January 2009) and was the lowest during the dry season (178.3 ± 56.5 kg/ha from March to June). The early secondary fragment 1 (ES-1) exhibited two higher litterfall peaks than the other forest fragments, which were in the middle of the rainy season and at the end of the dry season (Figure 2).

The comparison of average litterfall between areas showed that production in fragment ES-1 was significantly higher than other areas studied ($p < 0.05$), except for fragment ES-2 (Table 2). The latter did not show any differences compared to late phase fragments or the control area; however, it did differ from the intermediate secondary fragments (Table 2). The other areas showed no significant differences between them (Table 2). The coefficients of variation indicated a broad range in litter production values for the study areas, which were between 60.3 to 72.3% (Table 2).

2. *Litter decomposition experiment*

Leaf decomposition was rapid, and almost 70% of the initial mass was lost in the first 30 days (Figure 3). The fitted simple exponential model had a p-value that was less than 0.05 in over 70% of the cases (blocks). The coefficient of determination (R^2) ranged from 0.21 to 0.99 and was equal to or greater than 0.70 in 73% of the cases ($n = 67$). Decomposition blocks showed high variation in decomposition rates over time in each study area. However, the average decomposition rates did not differ between areas ($p = 0.238$, Figure 4).

Discussion

1. *Litterfall*

Studies in tropical forests have identified a seasonal pattern in litter production. Litterfall may peak in dry periods in forests with higher water restriction (Dantas & Phillipson 1989, Sanchez & Alvarez-Sanchez 1995, Barlow et al. 2007) or alternatively in wetter period in forests with lower water restriction as in the Atlantic Forest (Leitão-Filho et al. 1993, Pinto & Marques 2003, Vidal et al. 2007). The pattern of higher deposition of litter in the rainy season may be related to more favorable environmental conditions for leaf renewal in the rainy season, such as greater day length, relative humidity and precipitation (Jackson 1978). In the early secondary fragment 1 (ES-1), the second peak of litterfall coincided with the dry season (September 2009) and may be due to high precipitation, which was atypical for the period when compared with the 12 previous years (Figure 5, CIIAGRO/IAC). The mechanical action of the rain associated with wind may have contributed to an increase in plant material falling to the ground (Xiong & Nilsson 1997, Moraes 2002). In fact, significant amounts of green leaves and branches were found in collectors from this fragment for this period. In other areas, the increase in litter production in the drier period was not as significant, which was possibly due to the presence of a more closed canopy (Table 1) than the fragment ES-1 (Table 1), that can reduce the impact of rainfall on lower strata. Moreover, it could also be related to terrain slope; however, our samples were conducted on areas with less than 20 degrees of topographic inclination which reduces the impact of this factor.

Table 2. Average annual litterfall (kg/ha) in forest fragments on the Atlantic Plateau of the state of Sao Paulo, Brazil.

Study area	Average annual litterfall (kg/ha)	95% CI		% CV
		Min.	Max.	
Control	344.5^{ac}	301.2	393.5	70.1
Late Secondary 2	346.1^{ac}	301.7	392.9	71.6
Late Secondary 1	362.3^{ac}	322.7	404.6	60.6
Intermediate Secondary 2	323.1^{ab}	279.6	368.3	72.3
Intermediate Secondary 1	324.5^{ab}	286.6	364.7	64.5
Early Secondary 2	371.0^{cd}	329.4	415.5	63.0
Early Secondary 1	405.2^{d}	352.4	462.4	72.1

Minimum and maximum values of the 95% confidence interval (CI) and coefficient of variation (CV) are shown as percentages. Different letters represent significant differences based on the bootstrap test (α = 0.05). Forest fragments are ordered by decreasing order of successional phase.

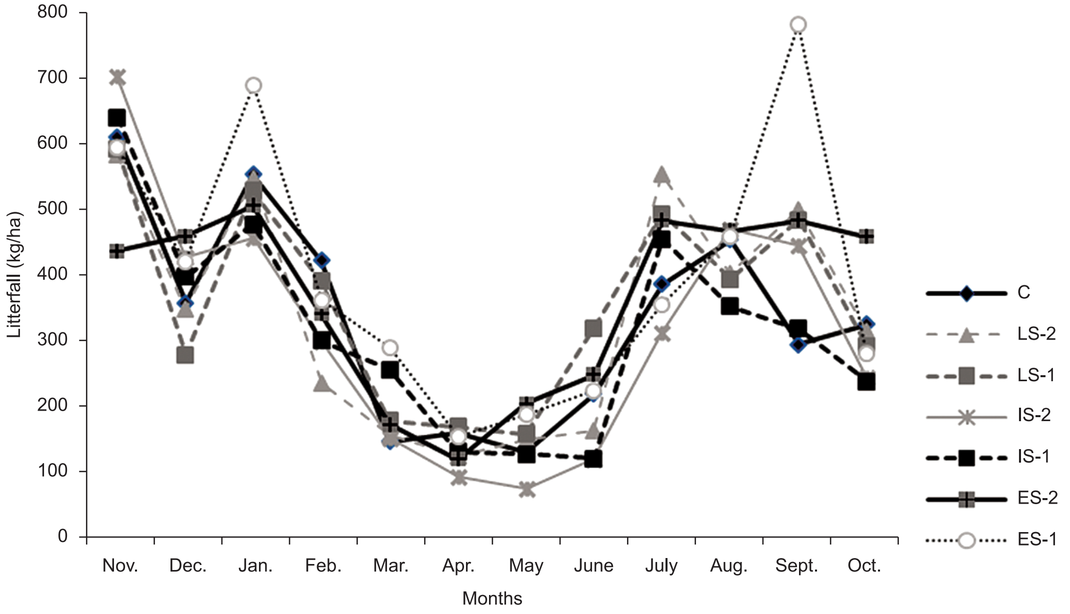

Figure 2. Monthly average litterfall biomass (kg/ha) over 12 sampling months (sampling started in 2008) in forest fragments on the Atlantic Plateau of the state of Sao Paulo, Brazil. Control (C), Late Secondary 2 (LS-2), Late Secondary 1 (LS-1), Intermediate Secondary 2 (IS-2), Intermediate Secondary 1 (IS-1), Early Secondary 2 (ES-2) and Early Secondary 1(ES-1).

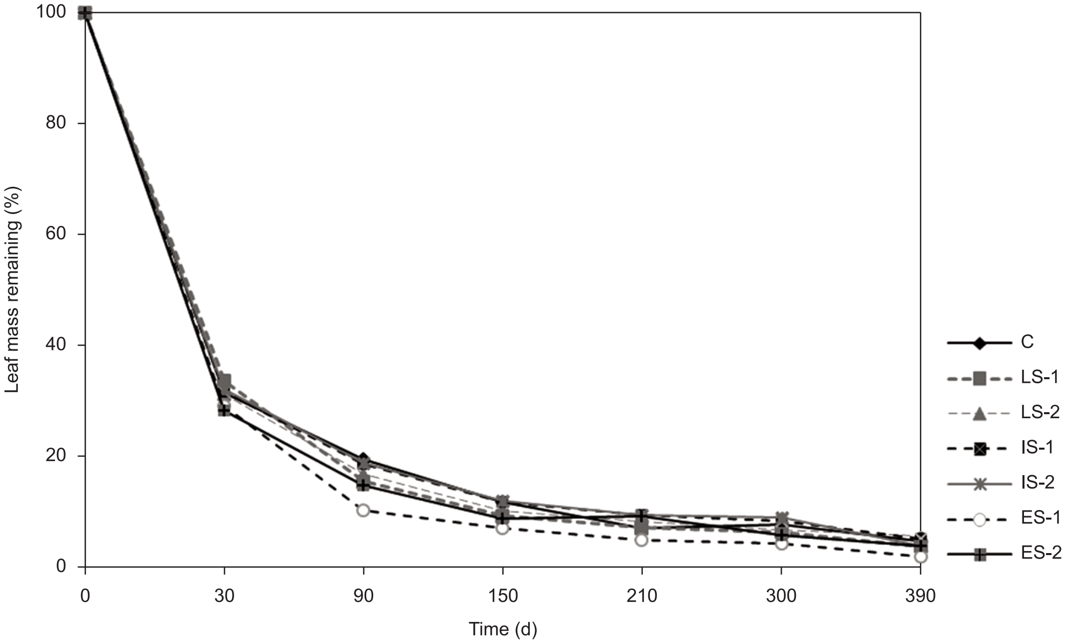

Figure 3. Leaf mass percentage remaining over 390 days in forest fragments on the Atlantic Plateau of the state of Sao Paulo, Brazil. Control (C), Late Secondary 2 (LS-2), Late Secondary 1 (LS-1), Intermediate Secondary 2 (IS-2), Intermediate Secondary 1 (IS-1), Early Secondary 2 (ES-2) and Early Secondary 1(ES-1).

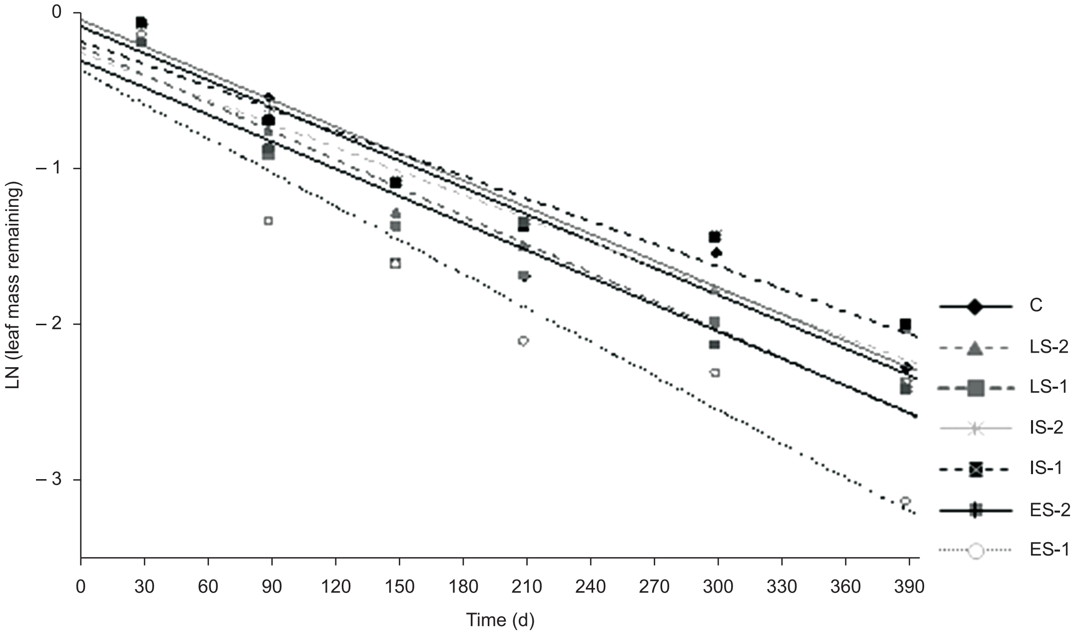

Figure 4. Natural logarithm of leaf mass remaining over time in forest fragments on the Atlantic Plateau of the state of Sao Paulo, Brazil. Mean decomposition blocks over time with fitted lines for each study area. Late Secondary 2 (LS-2), Late Secondary 1 (LS-1), Intermediate Secondary 2 (IS-2), Intermediate Secondary 1 (IS-1), Early Secondary 2 (ES-2) and Early Secondary 1(ES-1).

The high spatial heterogeneity in litterfall suggests there was considerable variation in the biotic and abiotic conditions within each area, and the highest coefficients of variation were in areas that were larger than 80 ha. In this context, smaller fragments were less heterogeneous, which was likely due to edge effects, such as wind and temperature, in a relatively higher proportion of the fragment when compared with larger fragments, once edge effects can propagate hundred meters into the forest (Laurance 2000). The exception to this pattern was fragment ES-1, which had a high coefficient of variation despite its small area (41.3 ha), likely due to the presence of two bodies of water. This factor likely altered the local microclimate, which increased spatial variability. However, this effect could have been also overestimated due to the small sample size.

The higher litterfall in the early successional fragment 1 (ES-1) when compared with the fragments of later successional phases revealed a pattern contrary to our prediction that higher litterfall

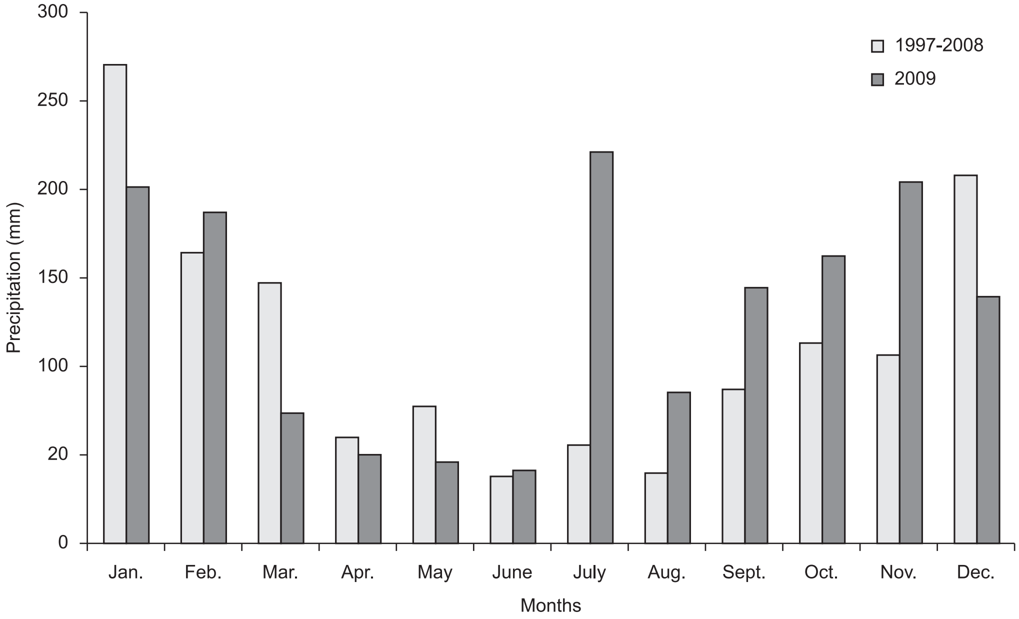

Figure 5. Average rainfall of the years 1997-2008 and 2009 of the municipality of Piedade, state of Sao Paulo, Brazil (CIAGRO/IAC).

would be observed in forests at an advanced successional phase due to their greater biomass and a more closed canopy (Werneck et al. 2001, Nascimento & Villela 2003, Vidal et al. 2007). The greater biomass produced in ES-1 may be associated to a high biomass of pioneer species, given the fact that in this fragment 36.8% of the total basal area corresponded to pioneer species, when compared with the others fragments where this proportion were quite smaller (Table 1). Pioneer species are characterized by rapid growth (Martins & Rodrigues 1999), have a higher investment in production of leaves and roots rather than timber (Leitão-Filho et al. 1993, Guariguata & Ostertag 2001) and higher leaf turnover than late successional trees (Coley 1983). Data from forests at early successional phases suggest that once the forest canopy is closed, which may be around 20 years, litter input, especially leaf production, stabilizes to the levels of mature forest (Barlow et al. 2007). Although fragment ES-1 is 25 years old, it has a high canopy openness percentage compared with late successional forests (Table 1), which implies in a higher litter production. Therefore, fragment age is not always a good indicator of litterfall or successional phase because during ecological succession, features of the landscape where the fragment is located influence its temporal dynamics. For example, proximity to preserved forest areas may speed up the successional process because the preserved forests may serve as a source of propagules for the fragment (Brown & Lugo 1990). In this context, the controversial pattern of litterfall in Atlantic forests (higher amounts of litter production in later successional phases (Vidal et al. 2007, Scheer et al. 2009), or alternatively higher litterfall in early succession phases (Leitão-Filho et al. 1993) or even the absence of differences in litterfall between fragments of different successional phases (Barlow et al. 2007, Dickow et al. 2012), may be related to the divergent structures and historical disturbance of the forest fragments studied. Fragments ES-1 and ES-2 showed no differences in litter production, which was likely due to their similar structure (Jurinitz (2010)).

2. *Litter decomposition experiment*

The selected litter for the decomposition experiment presented a rapid decay, being faster than the decomposition of a species from the Atlantic Forest (*Guapira opposita* (Vell.) Reitz, Nyctaginaceae), which had lower C:N ratio (Castanho & Oliveira 2008). It is established that litter with low C:N ratios decompose faster than those with higher C:N ratio (Xuluc-Tolosa et al. 2003). Besides the composition of the material, the rapid mass loss in the study areas (70% after the first 30 days) may also be attributed to favorable climatic conditions of the tropics (high temperature and humidity) for decomposition activity (Brown & Lugo 1990). In general, weight loss during leaf decomposition can be divided into two phases: an initial rapid loss, which is attributed to the leaching of soluble components in the litter, such as sugars and proteins, and a period of slower mass loss, which is attributed to the breakdown of more recalcitrant components such as cellulose and lignin (Xu et al. 2004).

The hypothesis that decomposition rates would differ between forest fragments was not supported by the results of this study. Differences in the decomposition rate between the forests fragments studied would be expected to be lower in fragments of early successional phase, since those forests have a more open canopy which influences the microclimate conditions and consequently reduces the decomposers activity (Aerts 1997). Studies on tropical forest succession have showed that environmental conditions for litter decomposition on forests at early successional phase were as favorable as those on forests at late successional phase (Ewel 1976, Xuluc-Tolosa et al. 2003, Vasconcelos & Laurance 2005). Besides, Höfer et al. (2001) have found similarities in nutrient cycling efficiency by macrofauna communities between disturbed areas (agricultural fields and secondary forests) and mature forests in the central Amazon even though each area had different species. Additionally, studies of decomposition rates with natural litter comparing chronosequences have found a pattern similar to this study (Ostertag et al. 2008, Gießelmann et al. 2011). According to Gießelmann et al. (2011), the absence of difference in the decomposition rates between forests at different successional phases may be related to the ability of the microorganisms to quickly adjust their community structure to environmental variations through rapid population growth or growth of hyphae. Therefore, macrofauna activity and environmental conditions in the fragments may have been restored to similar levels observed in mature forest, which may explain the lack of differences in decomposition rates in this study.

Alternatively, the lack of significant differences in leaf decomposition among the areas may be attributed to the great spatial heterogeneity observed in each area. According to Lavelle et al. (1993), intra-area variation may be greater than inter-area variation, which emphasizes the importance of local soil and biological factors for decomposition on rain forests. Only severe changes in forest structure, such as total removal of vegetation, could affect decomposition as it was evaluated in this study (Ewel 1976).

In conclusion, the results indicate that an abundance of pioneer species in forest fragments is a determining factor for high litterfall in forest areas of the Atlantic Plateau of Sao Paulo. Nevertheless, the decomposition process of the standardized material was not affected by environmental changes after a few decades of secondary succession caused by forest fragmentation, which was likely due to rapid stabilization of the combined effect of microclimatic conditions and decomposers activities. However, it should be noted that actual decomposition rates from study areas may also be influenced by the local substrate and therefore may differ from the rates determined in this study. This study indicates that the decomposition environment in forest fragments may have been restored to similar levels observed in mature forests approximately two decades after fragmentation. Thus, the conservation of secondary forests is essential for restoration of ecological functions even though the local biodiversity is lower compared to mature forests.

Acknowledgements

We thank the Institute of Biosciences at the University of São Paulo for their support; the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for the scholarship granted (process number 2008/58357-3) and financial support (process number 2006/56054-8); the German Department of Education and Research (German BMBF project ID 01LB 0202) for logistical support to project BioCAPSP (Biodiversity Conservation at the Atlantic Plateau of Sao Paulo); the Forestry Institute of Sao Paulo for support; the owners of the forest fragments for the work permit; and all the friends who helped in field collection and provided advice, specially Claudia Guimarães, Flávio Bonatti and Marcel Vaz.

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Received 12/02/2012
Revised 20/09/2012
Accepted 24/09/2012

Mitochondrial pseudogenes in insect DNA barcoding: differing points of view on the same issue

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LEITE, L.A.R. **Mitochondrial pseudogenes in insect DNA barcoding: differing points of view on the same issue**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?thematic-review+bn02412032012

Abstract: Molecular tools have been used in taxonomy for the purpose of identification and classification of living organisms. Among these, a short sequence of the mitochondrial DNA, popularly known as DNA barcoding, has become very popular. However, the usefulness and dependability of DNA barcodes have been recently questioned because mitochondrial pseudogenes, non-functional copies of the mitochondrial DNA incorporated into the nuclear genome, have been found in various taxa. When these paralogous sequences are amplified together with the mitochondrial DNA, they may go unnoticed and end up being analyzed as if they were orthologous sequences. In this contribution the different points of view regarding the implications of mitochondrial pseudogenes for entomology are reviewed and discussed. A discussion of the problem from a historical and conceptual perspective is presented as well as a discussion of strategies to keep these nuclear mtDNA copies out of sequence analyzes.
Keywords: *COI, molecular, NUMTs.*

LEITE, L.A.R. **Pseudogenes mitocondriais no DNA barcoding em insetos: diferentes pontos de vista sobre a mesma questão**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?thematic-review+bn02412032012

Resumo: Ferramentas moleculares têm sido utilizadas para os estudos referentes à identificação e classificação dos organismos vivos. Entre estes, uma curta sequência do DNA mitocondrial, popularmente conhecida como DNA barcoding, tornou-se muito popular. No entanto, a utilidade e confiabilidade dos códigos de barras de DNA têm sido recentemente questionadas porque pseudogenes mitocondriais, cópias não-funcionais do DNA mitocondrial incorporados ao genoma nuclear, foram encontrados em vários táxons. Quando estas sequências parálogas são amplificadas juntamente com o DNA mitocondrial, podem passar despercebidas e acabam sendo analisadas como se fossem seqüências ortólogas. Nesta contribuição objetivou-se revisar e discutir os diferentes pontos de vista sobre as implicações de pseudogenes mitocondriais para entomologia. Discutimos também o problema através de uma perspectiva histórica e conceitual, abordando estratégias para eliminar ou evitar a presença dessas cópias nucleares em meio às sequências funcionais de DNA.
Palavras-chave: *COI, molecular, NUMTs.*

Introduction

The classification and identification of living organisms, conducted by amateurs and professionals alike, has been classically based on the description and analysis of morphological features. While the general interest in documenting species diversity has grown exponentially over the years, the number of taxonomists and other professionals trained in species identification, such as parataxonomists (Jinbo et al. 2011), has steadily declined. Taking this scenario into account, several researchers have attempted to find different ways to accelerate and facilitate the process of species identification making it accessible to non-specialists.

Much of the recent taxonomic research has focused on the use of molecular tools in the classification and identification of living organisms. Among these efforts, the use of a short stretch of the mitochondrial cytochrome c oxidase subunit I, popularly known as DNA barcode, has received much attention (Hebert et al. 2003a, b, 2004, Janzen et al. 2005, Hajibabaei et al. 2006, 2007, Decaëns & Rougerie 2008, Janzen et al. 2009, Strutzenberger et al. 2010). Some authors are so partial to this technique that they have implied, or suggested, that DNA barcoding is superior to the classical, morphologically-based taxonomy, and that it should substitute morphology in species descriptions and identification as well as in studies trying to ascertain the relationships between them (Packer et al. 2009).

Researchers who question the idea that DNA barcoding is a panacea that will solve all taxonomic problems have argued, among other things, that mitochondrial pseudogenes may lead to an overestimation of the actual species diversity, as well as to unreliable or misleading identifications based on barcoding sequences (Song et al. 2008, Buhay 2009, Hlaing et al. 2009, Hazkani-Covo et al. 2010).

In this contribution different views are compared and some of the problems mitochondrial pseudogenes may cause to insect DNA barcoding are discussed.

DNA Barcoding in Entomology

DNA barcoding, a taxonomic method that uses a short, standardized DNA sequence to identify species, has gained increased attention and acceptance from members of the scientific community interested in documenting the Earths' biodiversity (Hebert et al. 2003a, b, Savolainen et al. 2005, Hajibabaei et al. 2007, Borisenko et al. 2009, Ivanova et al. 2009, Janzen et al. 2009). Since its inauguration in 2004, the *Consortium for the Barcode of Life* – CBOL, managed primarily by the *Canadian Centre for DNA Barcoding* at the *Biodiversity Institute of Ontario*, University of Guelph, Ontario, Canada, has gathered partners from all over the world. Their objective is to build, in less than twenty years, a comprehensive database that will include barcode sequences of all extant eukaryotes (Hajibabaei et al. 2005, Ratnasingham & Hebert 2007, Jinbo et al. 2011).

One of the advantages of DNA barcoding with respect to traditional taxonomy is the speed and low costs involved in gathering and analyzing data (Borisenko et al. 2009, Strutzenberger et al. 2010). The creation of the CBOL's online database (*The Barcode of Life Data System* – BOLD: www.barcodinglife.org) has provided an incentive for numerous researchers to join the barcode initiative. The database is easy to access and provides free storage and retrieval of molecular, morphological and geographical data, besides built-in, integrated analysis tools such as tree reconstructions on the basis of genetic similarity (Ratnasingham & Hebert 2007, Frézal & Leblois 2008).

One of the premises on which DNA barcoding relies on is that the genetic variation among species is greater than the variation within species (Hajibabaei et al. 2007). A single, 648bp long sequence, corresponding to the 5' end o of the mitochondrial cytochrome c oxidase subunit I, is used as a standard, universal marker for all living organisms (Hebert et al. 2003a, b, Ratnasingham & Hebert 2007, Strutzenberger et al. 2010).

The choice of a mitochondrial gene as a universal marker was mostly driven by the fact that the mitochondria is maternally inherited, avoiding problems with recombination. Also, the mitochondrial genome has a high mutation rate when compared with the nuclear genome, which results in high degrees of intra-specific polymorphism and divergence, important in evolutionary studies (Williams & Knowlton 2001, Wheat & Watt 2008, Hlaing et al. 2009).

Several contributions have been made to the taxonomy and systematics of insects using DNA barcoding, particularly in the following orders: Hemiptera (Foottit et al. 2009, Lee et al. 2010, Shufran & Puterka 2011), Diptera (Smith et al. 2006, Ekrem et al. 2007, Rivera & Currie 2009), Hymenoptera (Smith et al. 2005, Sheffield et al. 2009, Smith et al. 2009), Coleoptera (Yoshitake et al. 2008, Raupach et al. 2010, Greenstone et al. 2011), and Trichoptera (Salokannel et al. 2010, Geraci et al. 2011, Zhou et al. 2011). Additionally, a considerable number of articles on lepidopteran DNA barcoding have been produced since the beginning of this century (Hebert et al. 2004, Janzen et al. 2005, Hajibabaei et al. 2006, Hulcr et al. 2007, Bravo et al. 2008, Emery et al. 2009, Wilson 2010, Hausmann et al. 2011). The first animals to be used in the DNA barcoding campaign, and to have their sequences incorporated into the CBOL's database, were insects (Lepidoptera), fish and birds (Ratnasingham & Hebert 2007). The *Consortium for the Barcode of Life* – CBOL: (www.barcodeoflife.org) currently has other campaigns that contribute with DNA barcode data for insects such as bees, mosquitoes, fruit flies (Tephritidae: Diptera), Trichoptera and Lepidoptera.

Several characteristics intrinsic to insects, such as their diversity and the economic and epidemiological relevance of some groups, have made them the main target of DNA barcoding studies. The BOLD system currently stores molecular data on approximately one million exemplars (Table 1). This standard database can be used in studies on the taxonomy, phylogeny, ecology, agriculture and conservation of various groups of organisms (Jinbo et al. 2011).

Several contributions focusing on identification using the mtCOI have proved useful in the detection of cryptic insect species. Some of those cryptic species which were initially almost impossible to separate using morphological characters alone, have had their identities corroborated by other characters in their natural history and even characters in their morphology (Hebert et al. 2004, Janzen et al. 2005, Smith et al. 2006, Pfenninger et al. 2007, Decaëns & Rougerie 2008, Vaglia et al. 2008, Wheat & Watt 2008, Dasmahapatra et al. 2010, Hausmann et al. 2011).

Recent studies have suggested that the barcode sequence may be useful when morphological differences are present in the same species, including cases of sexual dimorphism, different castes, or different stages of development (Miller et al. 2005, Geraci et al. 2011, Jinbo et al. 2011). Other applications of DNA barcoding are: identification of host plants by sequencing the stomach contents or plant tissues left on the outside of an insect's body (Jurado-Rivera et al. 2009); identification of the stomach contents of predators in biological control studies (Greenstone et al. 2005, Greenstone 2006); additional data uncovering trophic relationships (Clare et al. 2009, Hrcek et al. 2011); and finally, population genetics, community ecology and biodiversity inventories (Janzen et al. 2005, Hajibabaei et al. 2006, Lukhtanov et al. 2009, Craft et al. 2010).

According to Jinbo et al. (2011), DNA barcoding may be used in the future in official protocols for the identification of insects and other groups, not as a competitor against traditional taxonomy, but as a strong tool to assist in the discovery and description of new taxa. The projected growth of databases such as the BOLD system, which are capable to integrate morphological, physiological and ecological data, strengthen and give respectability to the method.

Mitochondrial Pseudogenes

Pseudogenes, also known as nuclear mitochondrial DNA (*NUMTs*), are non-functional copies of mitochondrial sequences that have become incorporated into the nuclear genome. The transfer of mitochondrial genes to the nuclear DNA may happen through direct transfer, or may be mediated by RNAs, in which case viral elements are believed to participate (Williams & Knowlton 2001, D'Errico et al. 2004, Frézal & Leblois 2008, Song et al. 2008). According to Strugnell & Lindgren (2007), when transferred to the nucleus, the mitochondrial gene loses its original function, and is free to accumulate mutations, even though the mutation rate of the nuclear DNA is slower than that of the mitochondrial genome.

Pseudogenes have been long known to occur in prokaryotes, where they usually originate when errors in the transcription process cause a gene to "die". A pseudogene is structurally similar to the stretch of DNA it originates from, but may lack a start codon, have duplicated termination codons, and/or abnormal regulatory sequences on either end. For this reason, unlike functional genes, pseudogenes cannot be translated into functional proteins (D'Errico et al. 2004, Gerstein & Zheng 2006).

Table 1. Data obtained from the (*The Barcode of Life Data System* – BOLD: www.barcodinglife.org) relating to the numbers of specimens and species with data in the DNA Barcoding in the database. Date of access: October 26, 2011.

Order	Specimens with DNA Barcodes on BOLD system	Species with DNA Barcodes on BOLD system
Lepidoptera	561.713	64.197
Hymenoptera	134.151	17.099
Diptera	108.679	9.377
Coleoptera	33.344	8.304
Trichoptera	27.731	3.779
Hemiptera	23.285	3.745
Ephemeroptera	9.235	614
Orthoptera	5.218	840
Odonata	4.669	367
Plecoptera	3.863	464
Thysanoptera	1.857	137
Neuroptera	1.714	147
Megaloptera	1.152	112
Isoptera	826	197
Blattaria	684	125
Phthiraptera	624	85
Psocoptera	395	3
Mantodea	374	150
Dermaptera	140	11
Phasmatodea	101	25
Archaeognatha	81	4
Siphonaptera	158	12
Mecoptera	49	27
Embioptera	20	11
Raphidioptera	15	5
Thysanura	14	3
Diplura	10	4
Strepsiptera	9	7
Mantophasmatodea	2	1
Grylloblattodea	1	1
Total	920.114	109.853

Pseudogenes have been detected in several eukaryotes; they vary in number, size and abundance (Bensasson et al. 2001a, Richly & Leister 2004, Timmis et al. 2004, Arthofer et al. 2010). In humans, for instance, *NUMTs* are very common, and five of them are known to cause diseases (Hazkani-Covo et al. 2010).

Besides mitochondrial pseudogenes, two other types of pseudogenes exist: processed and unprocessed. The former are copied from RNA and are not found in the same chromosome they originated from. They lack introns and regulatory sequences. Unprocessed pseudogenes, by contrast, can be found in the same chromosome where they originated, and may have introns and regulatory sequences, just as a functional gene (D'Errico et al. 2004).

NUMTs may originate anywhere in the mitochondrial DNA, and may occur as a unique copy in different parts of the genome. These fragments are usually less than 1kb long, but longer fragments seem to be common in mammals (Bensasson et al. 2001a, Richly & Leister 2004, Arthofer et al. 2010).

According to Sorenson & Quinn (1998), even though *NUMTs* are very similar to their source DNA sequences, they have various degrees of functionality; because they are located in different parts of the cell and away from their origin, they are subject to different evolutionary pressures. This is why misleading conclusions can be reached when pseudogenes are unknowingly included in analyzes of mitochondrial sequences. According to Hazkani-Covo et al. (2010), the generation of *NUMTs* is an important evolutionary process in continuous development.

History of the Relationship Between *NUMTs* and Insects

The first record of a mitochondrial pseudogene in Metazoa was for *Locusta migratoria* (Linnaeus, 1758) (Orthoptera : Acrididae) (Gellissen et al. 1983), when sequences homologous to stretches of the mitochondrial DNA were found in the nuclear genome.

After the first discovery of *NUMTs* in Orthoptera, thirteen years passed until an important contribution involving pseudogenes was published in insect molecular research. In 1996, Sunnucks & Hales reported on numerous transpositions of mitochondrial sequences similar to the cytochrome oxidase I and II in *Sitobion* Mordvilko, 1914 (Hemiptera : Aphididae). According to the authors, the non-mitochondrial copies of at least three species seemed to have originated even before transposition. In the same year, Zhang & Hewitt (1996) detected highly conserved pseudogenes in the nucleus of *Schistocerca gregaria* (Forskal, 1775) (Orthoptera : Acrididae) that had been amplified along with authentic mitochondrial sequences. They observed that pseudogene amplification seemed more common when the source specimen had been preserved dry for longer periods of time, and without drawing further conclusions on that comment, suggested that researchers should seek for *NUMTs* when conducting population biology research using the mitochondrial DNA as a marker in order to avoid potentially misleading evidence.

Five years after the works mentioned above, Bensasson et al. (2001a) found pseudogenes in all 10 species of Acrididae (Orthoptera) studied, distributed in four subfamilies (Podisminae, Calliptaminae, Cyrtacanthacridinae and Gomphocerinae). Until then, grasshoppers were among the groups believed to harbor a great number of pseudogenes. According to Bensasson et al. (2001a), at least in

Orthoptera, the evolution of *NUMTs* seems to involve two steps. First, horizontal transfer, which is the simple transposition of mitochondrial DNA to the nucleus; second, post-transfer replication in the nucleus, which allows for the continuation of the pseudogene. According to the summary compiled by Bensasson et al. (2001b), pseudogenes have been found in a total of 82 species of eukaryotes, corresponding to approximately 21 species of insects, particularly in Orhtoptera and Hemiptera. The great majority of reports on *NUMTs* in animals have been for vertebrates (Blanchard & Schmidt 1996, Sorenson & Quinn 1998, Bensasson et al. 2001b). Other important publications on insect molecular studies appeared in the beginning of the twenty-first century, reporting on the discovery of mitochondrial pseudogenes. For instance, Harrison et al. (2003) located about 100 pseudogenes in *Drosophila melanogaster* Meigen, 1830 (Diptera: Drosophilidae). Richly & Leister (2004) found pseudogenes in 13 eukaryote species, including *Drosophila melanogaster*, but failed to find any in *Anopheles gambiae* Giles, 1926 (Diptera : Culicidae). The variation in the abundance of *NUMTs* in closely related species in that study, when compared with the variation found for other eukaryotes, was explained as a function of two factors. First, among-species differences in the rate of sequence transfer from the mitochondrial to the nuclear DNA; and second, among-species differences in the rate of loss of *NUMTs* in the nucleus. These conclusions were corroborated by a similar study by D'Errico et al. (2004), who utilized only *D. melanogaster* as a representative of Hexapoda.

In 2006, Brower re-evaluated data on *Astraptes fulgerator* (Walch, 1775) (Lepidoptera: Hesperiidae) and found *NUMTs* among the barcode sequences published by Hebert et al. (2004). Later, Pamilo et al. (2007) searched for pseudogenes in four insect species, *D. melanogaster*; *A. gambiae*; *Apis mellifera* Linnaeus, 1758 (Hymenoptera : Apidae) and *Tribolium castaneum* (Herbst, 1797) (Coleoptera : Tenebrionidae), and suggested that the rate of transfer of mitochondrial genes to the nuclear DNA in *Apis mellifera* and *Tribolium castaneum* is high with respect to the dipterans sampled. After analyzing the number of *NUMTs* (>2000) and the relationship between the number of base-pairs transferred per 1 Kb of nuclear sequence (>1.0) in their samples, they also concluded that *A. mellifera* has the greatest number of *NUMTs* in the animal kingdom. Hlaing et al. (2009) searched for *NUMTs* in the genome of *Aedes aegypti* (Linnaeus, 1762) (Diptera: Culicidae), *D. melanogaster* and *A. gambiae*, concluding that the first species has more *NUMTs* than the other two. They also concluded that many of the *NUMTs* detected had originated more recently and for that reason they were difficult to distinguish from their functional counterparts. The authors suggested that similar cases might pose a great problem for DNA barcoding.

Hazkani-Covo et al. (2010) studied sequences of 85 eukaryotes in search for pseudogenes, which they referred to as "molecular Poltergeists". They found *NUMTs* in 72 species, absent from the study of Richly & Leister (2004). One of their new records was *Bombyx mori* (Linnaeus, 1758) (Lepidoptera: Bombycidae) with 0.0016% of the nuclear genome composed of *NUMTs* (the record for Metazoa, *Apis mellifera*, is 0.081%). Magnacca & Brown (2010) found barcode-like pseudogenes in *Hylaeus* Fabricius, 1793 (Hymenoptera : Colletidae), which were easily distinguished from their functional counterparts in their nucleotide sequences and translated amino-acids.

Implications of *NUMTs* for Entomological Studies using DNA Barcoding

Using the subunit I of the cytochrome c oxidase, Hebert et al. (2004) divided *Astraptes fulgerator* (Lepidoptera : Hesperiidae) into ten different species, most of which (six to seven species) were corroborated by morphological, ethological and ecological evidence. The remaining (cryptic) species were defined based solely on their barcode sequences. Even though the authors did not rule out the possibility that pseudogenes were a problem, they stressed that only 2.8% of their sequences were likely to have been amplified from *NUMTs*.

The contribution by Hebert et al. (2004) was criticized by Brower (2006) and Song et al. (2008), who suggested that the number of cryptic species had been overestimated because mitochondrial pseudogenes of *Astraptes fulgerator* had been amplified by the universal primers used by Herbert and collaborators. The critique is based on the fact that when paralogous genes are used in the place of orthologous ones, the assumptions of phylogenetic reconstructions are violated, leading to erroneous reconstructions.

In a study involving DNA barcode sequences as well as pseudogenes of various orthopterans, Song et al. (2008) concluded that the presence of *NUMTs* in their analysis led to an overestimation of the number of species. Even though they expressed some pessimism that *NUMTs* can be completely eliminated, they suggested some strategies to help identify these alien sequences: search for ambiguity among sequences, noise, or double peaks in the electropherogram or chromatogram (Figure 1); sequence translation in search for additional termination codons and the comparison of the amplified sequences with other, published sequences from closely related species.

Hebert et al. (2004) suggested sequencing freshly collected specimens (preserved for less than 10 years) and using reverse transcriptase followed by PCR (RT-PCR) to prevent pseudogene amplification, particularly for taxa known to carry *NUMTs*. Even though they excluded 13 sequences from their analysis because their electropherogram revealed double peaks, they failed to mention other strategies they might have used to look for *NUMTs*, for instance, searching for additional termination codons. Later, Ratnasingham & Hebert (2007) declared that all sequences submitted to the BOLD system are scrutinized with various tools in search for abnormalities typical of pseudogenes, including the search for termination codons and translation into protein for comparison with the cytochrome c oxidase I product.

Zhang & Hewitt (1996) compared the nuclear copies of the mtDNA to mitochondrial heteroplasmy (the presence of more than one type of mtDNA within cells). The latter, a common cause of degenerative diseases, also causes trouble in sequence analysis. The authors mentioned some strategies that can be used to avoid pseudogene contamination in molecular data, such as the use of specific primers, search for well delimited peaks in the chromatograms and termination codons, comparison with other sequences, and re-sampling when radically divergent sequences are found, or contradictory topologies are recovered in an analysis. An additional strategy, mentioned by Calvignac et al. (2011) to avoid *NUMTs* is to evaluate the rate of evolution of potential pseudogenes as they tend to evolve faster with respect to their paralogous counterparts.

Moulton et al. (2010) tested the strategy of using specifically designed primers to amplify the barcode region as a means to avoid co-amplification of *NUMTs* in 11 species of Orthoptera. Their results casted more doubts on the barcode method, because the use of specific primers only eliminated *NUMTs* from sequences of one species, and merely reduced the amount of amplified pseudogenes from the others. Several of the pseudogenes found lacked termination codons, a determining factor that makes their identification difficult. Moulton and collaborators regarded the presence of *NUMTs* as a challenge to insect DNA barcoding, and suggested that a lot more control on sequence quality needs to be exerted, and further studies

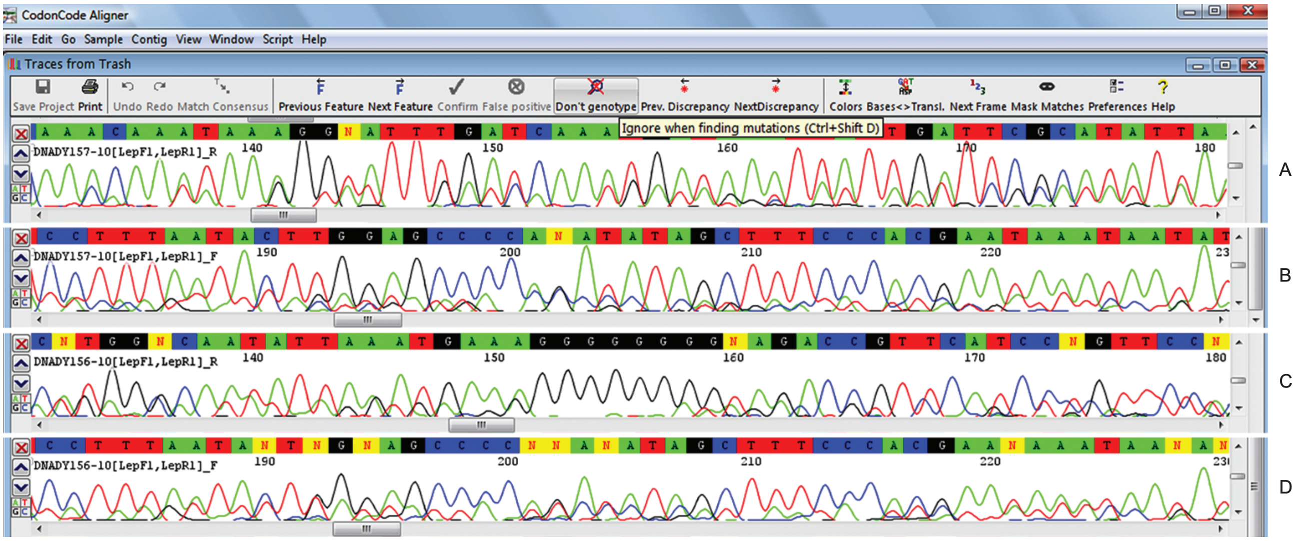

Figure 1. Modified chromatogram from (**CodonCode Aligner v.3.0.1 copyright© 2002-2009**) related to the COI project with the genus *Dynamine* Hübner, [1819] (Lepidoptera : Nymphalidae). A-D. Sequences of *Dynamine myrrhina* (Doubleday, 1849). A, C. 3'--- 5'. B, D. 5'--- 3'.

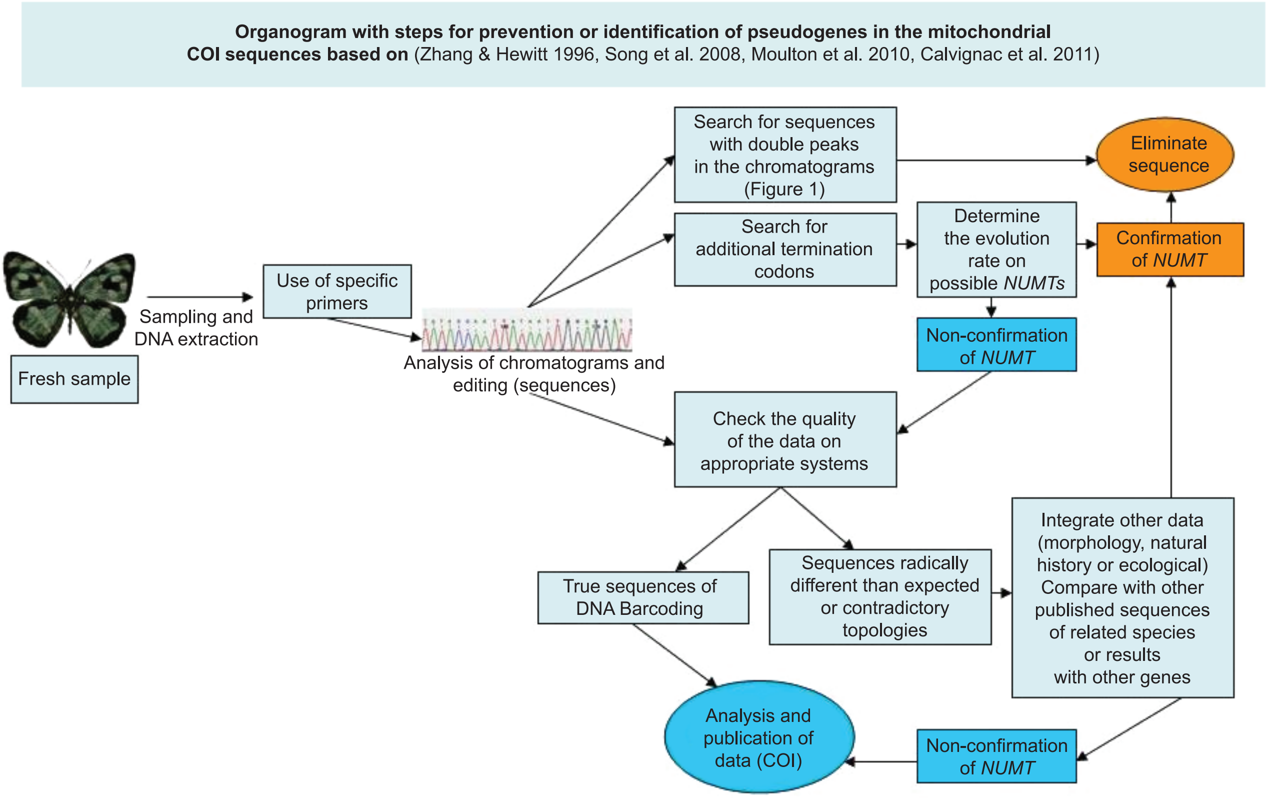

Figure 2. Suggested steps for the future studies with DNA Barcoding in insects seeking the elimination or reduction of the presence of NUMTs in sequences.

on the ubiquity of *NUMTs* need to be conducted, if the COI is to be used as a universal marker.

Conclusions

Based on all previously published data and discussions about mitochondrial pseudogenes in DNA barcoding, we conclude that, if ignored, *NUMTs* pose a major problem for taxonomic and phylogenetic studies based exclusively on barcode sequences. Increased control on submission sequences, amplification from fresh material, use of specific primers, careful analysis of chromatograms, and comparison with other sequences should be mandatory to reduce the risk of contamination with *NUMTs*. In other words, the barcode protocol needs to be adjusted to accommodate for the new information regarding the prevalence of pseudogenes.

Different steps must be prioritized in future studies using DNA barcoding (Figure 2), as previously suggested by others (Zhang & Hewitt 1996, Song et al. 2008, Calvignac et al. 2011), and methodologies must be specified in such a manner as to allow other researchers to make inferences on the reliability of each dataset. Sequences that resemble a pseudogene should be removed as early as possible, beginning with chromatogram analysis in search for suspicious peaks.

Since the barcode sequence was proposed as a universal marker by Hebert et al. (2003a, b), the number of entomological studies using it have grown exponentially. However, despite the problems discussed in the present study, the majority of them fail to mention the possibility of contamination with pseudogenes in their data, or have neglected to use methodologies aimed to mitigate the problem (Janzen et al. 2005, Hajibabaei et al. 2006, Craft et al. 2010, Dasmahapatra et al. 2010). There are two possible explanations for this behavior: ignorance regarding the prevalence of pseudogenes and/or hurry to publish. Fewer studies using COI in insect taxonomy, however, are more reliable despite the fact that they fail to mention *NUMTs*, because they also use morphological and/or ecological information (Burns et al. 2007, Decaëns & Rougerie 2008) as corroborating evidence.

The DNA Barcoding revolution has introduced a strong tool to aid in the taxonomy and phylogenetic systematics, being particularly useful in pairing individuals of different sexes and uncovering cryptic species, which are very important to understand our biodiversity. However, it should not be treated as a substitute for any technique, nor should it be used, along with their programs and system (BOLD), as the only source of evidence in the place of morphological, ecological and natural history evidence, as it has been the case in some studies. The COI is simply a tool that provides additional evidence, and therefore should be treated as such.

More studies should be conducted in order to understand the prevalence of mitochondrial pseudogenes in the various insect orders. Existing data to date are not very informative and only report on the presence and quantity of *NUMTs* in some species within a few orders. The pseudogenes are definitely important contaminants in molecular studies using DNA barcoding, and should be searched for, analyzed, and disposed of when detected.

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Received 26/10/2011
Revised 19/06/2012
Accepted 23/08/2012

Upstream guppies (*Poecilia reticulata*, Peters, 1859) go against the flow

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MOHAMMED, R.S., VAN OOSTERHOUT, C., SCHELKLE, B., CABLE, J. & MCMULLAN, M. **Upstream guppies (*Poecilia reticulata*, Peters, 1859) go against the flow**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn01512032012

Abstract: Guppies (*Poecilia reticulata* Peters 1859) in lakes and from captive-bred populations are predicted to show little rheotaxis compared to conspecifics in a stream environment that are regularly exposed to flash floods associated with involuntary downstream migration. Here we test this hypothesis using an artificial stream, examining guppies of two wild riverine populations, one lake population, and one ornamental strain. Guppies from the most upstream riverine habitat show the most pronounced rheotaxis and are less likely to be swept downstream during flooding events. However, there is no significant difference between guppies from the lowland riverine habitat, the Pitch Lake and ornamental strain. We propose that station-keeping behaviours are most strongly selected in the upstream population because large spatial differences exist in ecology and environment between up- and downstream habitats. Given that these sites are separated by barrier waterfalls that prevent compensatory upstream migration, natural selection operates particularly strong against upstream guppies that have been displaced downstream during flooding events.
Keywords: *Guppy (Poecilia reticulata), rheotaxis, swimming behaviour, migration, natural selection.*

MOHAMMED, R.S., VAN OOSTERHOUT, C., SCHELKLE, B., CABLE, J. & MCMULLAN, M. **Gupies (*Poecilia reticulata*, Peters, 1859) de áreas de cabeceira se posicionam contra a corrente**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn01512032012

Resumo: Populações de guppies (*Poecilia reticulata* Peters) que vivem em lagos e em cativeiro podem demonstrar menos reotaxia em comparação com populações que habitam rios e que estão frequentemente expostas a enchentes e que provocam a migração involuntária para jusante. Neste trabalho, vamos testar esta hipótese num rio artificial utilizando guppies de duas populações selvagens que habitam em rios, uma população que habita em lagos, e uma linhagem ornamental. Os resultados demonstram que os guppies de rios que provêm de localidades a montante demonstram maior reotaxia, diminuindo assim probabilidade de serem arrastados para jusante em períodos de enchentes. No entanto, não foram encontradas diferenças significativas entre guppies de localidades a jusante, do lago Pitch ou ornamentais. Este resultado pode dever-se ao facto de existirem grandes diferenças ecológicas entre os habitats localizados a jusante e a montante dos rios. Devido ao facto de estas localidades estarem separadas por cachoeiras, impossibilitando a migração rio-acima, a seleção natural poderá estar a actuar contra guppies que sejam arrastados rio abaixo durantes os períodos de cheias
Palavras-chave: *Guppy (Poeciliareticulata), reotaxia, piscina comportamento, migração, seleção natural.*

Introduction

Many freshwater fish species have an innate response to orientate their bodies in water currents, a phenomenon known as positive rheotaxis (Northcutt 1997). Unlike species without active swimming abilities or other station-keeping adaptations (e.g. Blake et al. 2007), this innate swimming response prevents the inevitable extinction of closed populations subject to dominant downstream migration (cf. Müller 1954 'drift paradox'). Rheotaxis also maximizes perception of chemical cues, interception of prey, and minimizes energy expenditure (Montgomery et al. 1999). From an evolutionary perspective, rheotaxis allows animals to maintain a position within a stream (station-keeping) which avoids potential fitness costs involved with emigration (McCormick et al.1998).

Guppies (*Poecilia reticulata* Peters, 1859) can be found in a wide range of habitats, from riverine environments to lakes (Deacon et al. 2011).This species is also common in the aquarium trade; they have been bred and kept in captivity since the 1920s (Deacon et al. 2011). The hydrodynamic environment the fish in wild populations encounter is dramatically different. In the mountainous region of the Caroni Drainage in Trinidad, the fish are exposed to seasonal flash-flooding events, coinciding with the wet-season rains (van Oosterhout et al. 2007a). In contrast, the guppies from ornamental strains in aquaculture and those occurring in natural lakes never encounter high water velocities or flash-flooding. For example, the Pitch Lake in Trinidad is a flat crater with pitch and asphalt folds that create several freshwater pools. It is approximately 0.8 km^2 and guppies in this habitat experience little or no water currents. Here we hypothesize that guppies have adapted to the hydrodynamic conditions typical for their habitat. In particular, we predict that the guppies in the Pitch Lake may have lost their innate rheotaxic behaviours. Similarly, we predict that due to relaxed natural selection in captivity (van Oosterhout et al. 2007b) ornamental strain guppies will show little station-keeping behaviour. In contrast, guppies from a riverine habitat are predicted to show more pronounced rheotaxis and station-keeping.

Materials and Methods

1. Experimental animals and procedure

The behaviour of 60 adult guppies from three populations in Trinidad were studied: the Upper Naranjo (UN: Grid Ref. UTM 20P 693443, 1183935), the Lower Aripo (LA: 694432, 1178141) and the Pitch Lake (PL: 650459, 1131727). Additionally, ornamental strain guppies (OS, n = 20) belonging to the Istanbul strain were tested for their rheotactic or station-keeping behaviours. The UN is a small upstream tributary of the Aripo River. The mean water flow rate of upstream sites is significantly higher than in the downstream sites (upstream ≈8.7 cm.s^{-1}; downstream ≈5.5 cm.s^{-1}, see Reznick et al. 2001). This set of populations was chosen to test the hypothesis that riverine fish populations that experience seasonal floods in the wild (i.e. the UN and LA populations) display stronger station-keeping behaviours than guppies from a natural or captive environment with little or no natural water currents (i.e. the PL and the OS guppies). All fish were collected at the end of the dry season (March-June) in 2009 where the water depth and flow rate was comparable to Reznick et al. (2001) observations.

In total, 20 guppies per population with approximately equal sex ratio and similar size range were used: standard length SL = 12-25 mm, (mean (±SD): SL = 18.3 (±1.2) mm). Guppies were maintained in four 80 L aquaria in groups of 35-60 fish per tank. They were screened for parasites following the protocol described in van Oosterhout et al. (2003) and Schelkle et al. (2009). These screens were conducted because guppies infected with *Gyrodactylus* spp. are more likely to be swept downstream than uninfected counterparts van (van Oosterhout et al. 2007a). Briefly, guppies were anaesthetised with 0.02% MS222 and using a stereo-microscope and fibre optic illumination, gyrodactylids were removed with watchmaker's tweezers. Fish were clean of all ectoparasites and showed no symptoms of disease in the two weeks prior to the experiment.

The behaviour of guppies was recorded in an artificial stream (length × width × depth = 112.2 × 12 × 4.0 cm^3). The water flow rate was 15.4 (±1.2) cm.s^{-1}, comparable to their mean critical swimming speed (Syriatowicz & Brooks 2004). The artificial stream was divided into 11 segments of 10.2 cm each, with a downstream weir which led to a small pool. The focal fish was released into the sixth segment in the middle of the stream. Its position was recorded at 5 seconds intervals over a period of 240 seconds. The experiment was terminated after 240 seconds or when the focal fish went across the weir into the pool (i.e. swept downstream). Post release, all monitoring was done via video to avoid disturbance to the fish.

The incidence of guppies being swept downstream was noted, and the average position of a guppy in the river and its mobility (i.e. average distance swum in 5 seconds intervals) during its time in the stream was calculated. A previous study using an artificial stream showed that guppies were not attracted to conspecific chemosensory cues (Archard et al. 2008). Hence, we used tank water that was recycled throughout the experiment. The water temperature was 27.0 (±1.0) °C and recordings were made between 0700-1700 h under indirect natural daylight in June 2009.

2. Statistical analyses

A binary logistic regression analysis (logit) with a dichotomous dependent variable ("swept downstream" or "kept station") was used to test whether the incidence that a guppy was swept downstream was explained by the origin of population, sex and SL. The model had three predictors: 'Population' and 'Sex' as fixed factors, and 'SL' as covariate. The model was fitted using an iterative re-weighted least squares algorithm to obtain maximum-likelihood estimates of all parameters. The log-likelihood was used to test whether the coefficients of the predictors were significantly different from zero. A logit link function was used to calculate the odds ratio and its 95% confidence interval (CI). Differences in the mean position of guppies in the stream between populations, sexes and SL were tested using a General Linear Model (GLM). We also used a GLM to compare the mobility of guppies among populations, sexes and SL. In these models, Population and Sex were fixed factors, and SL was the covariate. We checked whether the data were appropriate for parametric analysis and confirmed homogeneity of variances and normal distributions of residuals. All tests were conducted in Minitab 12.1.

Results

Guppies from the UN were significantly less likely to be swept downstream than their LA counterparts (Binary Logistic Regression: $Z = -2.47$, p = 0.014), mean and 5-95%CI odds ratio = 0.11 (0.02-0.64). However, there was no significant difference in the likelihood of fish being displaced downstream between the other populations (OS guppies: $Z = -1.83$, p = 0.068; PL guppies: $Z = -1.25$, p = 0.212) (Figure 1). The Sex and SL of guppies did not explain variation in the probability being swept downstream ($Z = 0.47$, p = 0.636 and $Z = 0.17$, p = 0.862, respectively).

There was a significant difference in the mean position of fish among populations ($F_{3,74} = 4.32$, p = 0.007), with the UN being on average most upstream, and the OS the furthest downstream (see

Figure 2). Fish size (SL) and Sex did not affect the position of fish within the artificial river ($F_{1,74} = 0.16$, $p = 0.692$, and $F_{1,74} = 1.87$, $p = 0.161$). There were significant differences in mobility between the fish of the four populations (GLM: $F_{3,74} = 3.71$, $p = 0.015$) without the inclusion of Sex and SL data. However, SL did not explain variation in mobility between the fish (GLM: $F_{1,74} = 0.61$, $p = 0.438$), and there was no difference between the Sexes (GLM: $F_{1,74} = 0.89$, $p = 0.414$). The UN fish were significantly less mobile than fish of the other three populations, moving on average 6.0 cm per 5s, compared to 11.4, 9.1 and 9.3 cm per 5s for the LA, PL and OS guppies, respectively.

Discussion

Guppies from the upstream population, the Upper Naranjo (UN) were significantly less likely to be flushed downstream than Lower Aripo (LA), Pitch Lake (PL) and ornamental strain (OS) guppies. We hypothesised that wild fish, experiencing seasonal floods (i.e. the UN and LA populations) should display stronger rheotaxis or station-keeping behaviours than guppies in habitats with little or no natural water currents (i.e. the PL and the OS guppies). The results are inconsistent with our hypothesis, and suggest that the level of rheotaxis of guppies in populations that are not subjected to seasonal flooding is similar to that of guppies occurring in (lowland) rivers which are regularly in spate-conditions.

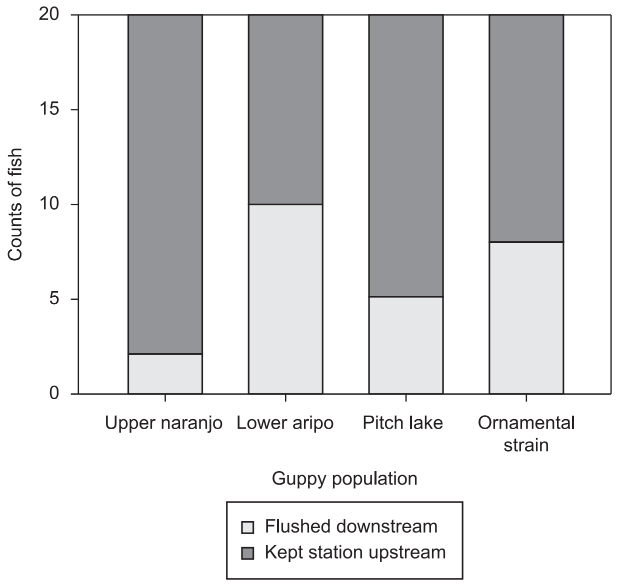

Figure 1. Number of fish that remained stationary and retained their position in the artificial stream (grey bars) and fish swept downstream over the weir into the pool (black bars) in the four populations. UN guppies were significantly less likely to be swept downstream than LA guppies (see text).

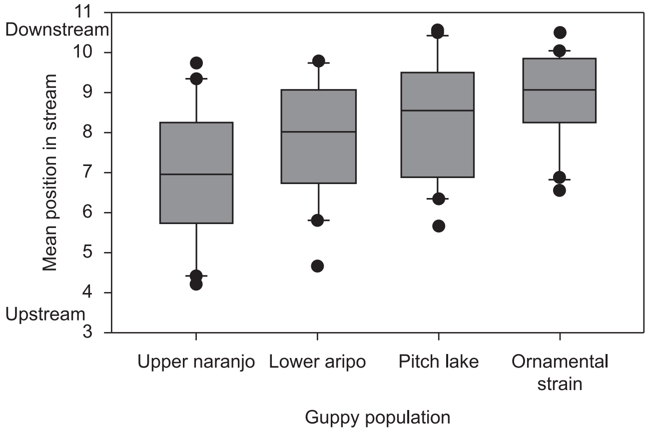

Figure 2. Box plot showing the average position of guppies in the artificial stream. Dots represent outliers, bars show the lower and upper limits and the box represents the first and third quartile value with the median. There was a significant difference between the mean positions of fish among populations (see text).

First, we consider the hypothesis that the relatively reduced level of station-keeping observed in the high-predation LA guppies can be explained by a trade-off between escape-response versus swimming endurance. The UN guppies live a low predation environment, whereas the LA has high predator pressure on the guppies (van Oosterhout et al. 2007). Selection favours enhanced escape-response in high predation sites, a behaviour known as fast-start evasion response or c-start (Ghalambor et al. 2004). Could adaptations favouring the c-start compromise rheotaxis and swimming endurance in the high-predation LA? To answer this question we need to consider the station-keeping behaviour of the Pitch Lake and the ornamental guppies, which originate from habitats with little or no predation. Similar to the low-predation UN guppies, these populations do not experience strong selection for c-start. Nevertheless, Pitch Lake and ornamental guppies are equally prone to being swept downstream as the LA guppies. This suggests that the hypothesised trade-off between escape-response versus swimming endurance in the LA cannot be held responsible for reduced station-keeping performance in all three populations (i.e. LA, PL and OS).

Reduced predator fauna has been shown to increase the number of guppies that occupy the fast flowing regions of the river (Kodric-Brown & Nicoletto 2005). Flow rates in upstream sites are, on average, greater than in downstream sites (Reznick et al. 2001). Furthermore, upstream guppies that are not discouraged (by piscivorous predators) from deeper or faster flowing regions of the river are presumably more likely to develop peduncle muscle in response to exposure to high flow rates (e.g. Nicoletto 1996). Therefore, increased rheotactic behaviour in the UN may be a plastic response to reduced predator fauna in a fast flowing river. Darden & Croft (2008) found that in high predation (lowland) sites, predation risk is greater in the deeper regions of a river. Interestingly, the authors also found that, in response to male presence, females will move into deeper waters, thereby increasing their predation risk (Darden & Croft 2008). The authors argue that this behaviour may increase the risk of female predation, but that this cost is balanced by a reduced level of harassment from males. It is conservable that in low predation (upstream) sites males do not suffer such increased predation risk in high flow regions and therefore only those males able to display and maintain their position in faster flowing regions of the river pass on their genes (e.g. Kodric-Brown & Nicoletto 2005). The findings in the present study and those in previous studies (Kodric-Brown & Nicoletto 2005, Darden & Croft 2008) suggest that a reduction in predator fauna in upstream sites may drive both phenotypic plasticity (in development of peduncle muscle) and selection toward increased rheotactic behaviour in the UN guppies.

Fish that are displaced from the UN during seasonal flood events may be prevented from returning upstream by barriers to gene flow such as waterfalls (Crispo et al. 2006, van Oosterhout et al. 2007a). Compensatory upstream migration in the lowlands may allow the return of displaced fish that have not been swept over such barriers (see Barson et al. 2009, Willing et al. 2010). In addition, distinct differences exist in predator and parasite faunas between upland and lowland habitats (Endler 1980, Reznick et al. 2001, Cable & van Oosterhout 2007). Several translocation experiments have shown that guppies are particularly well-adapted to cope with the local biotic and abiotic environmental conditions (e.g. Gordon et al. 2009). For example, guppies that evolved in a low-predation upland habitat have reduced anti-predator responses such as shoaling behaviour (Huizinga et al. 2009). Furthermore, the males tend to be more colourful, which make them vulnerable to visually-hunting predators that are common in the lowland environment (Endler 1995). Consequently, selection will favour behavioural responses that increase site fidelity (Winker et al. 1995, Aparicio & De Sostoa 1999). It is therefore likely that in the low-predation upland population of the UN, natural selection has promoted flush avoidance behaviour and positive rheotaxis. In contrast, even after downstream displacements during floods, lowland guppies of the LA population will find themselves in a similar, high-predation habitat to which they are adapted. We propose that the combination of a larger flow rate in the upland habitats in combination with the dramatic fitness consequences for upland guppies that are unable to resist flash-flooding has resulted in strong selection for station-keeping in the UN. This could explain why the UN guppies show the highest level of rheotaxis.

Croft et al. (2003) showed sex-biased dispersal in guppies, demonstrating a significant bias for upstream movement by males but not females. In addition, they found a positive correlation between body length and distance moved in females. van Oosterhout et al. (2007a), on the other hand, showed that males with parasite infections were more likely to be swept downstream during wet-season floods than females. The current study did not detect differences in rheotaxic behaviour between the sexes, and the size of fish did not explain differences in this behaviour. Instead, most variation was explained by the population origin of the fish.

Although our data can be explained by differences in selection pressures between populations, we cannot rule out that these results can be explained also by proximate (mechanistic) differences between populations. Future anatomical, behavioural and genetic studies into rheotaxis of guppies seem warranted, as due to the strong gradient in selection pressure the expression of this behaviour should vary predictably across the environment.

Acknowledgements

We thank Mr and Mrs Rasheed Mohammed for their support, Gabrielle Archard and Thomas Breithaupt for comments on the MS and Raquel S. Xavier for Portuguese translations. This work was supported by a Natural Environment Research Council studentship to MM (NER/S/A/2005/13362A), a Biotechnology and Biological Sciences Research Council CASE studentship to BS (BB/D526137/1) and a European Community Framework Programme 6 (MTKD-CT-2005-030018).

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Received 05/04/2012
Revised 02/08/2012
Accepted 06/08/2012

Characterization of galls, insect galls and associated fauna of Ecological Station of Jataí (Luiz Antônio, SP)

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SAITO, V.S. & URSO-GUIMARÃES, M.V. **Characterization of galls, insect galls and associated fauna of Ecological Station of Jataí (Luiz Antônio, SP).** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02312032012

Abstract: This is the first study about galls, gall makers and associated fauna of the Ecological Station of Jataí. Galls are plant structures formed by abnormal growth of cells, tissues or organs induced by several organisms, as fungous, nematoids and insects. Five areas of the conservation unity, two in the phytophysionomy of cerrado in regeneration and three in the cerradão area were studied, totalizing 69 morphotypes of galls on 41 host species from 24 families. This is the first record of Annonaceae as the richest family in morphotypes in Brazil; 34 gall makers and associated fauna were identified, which 23 Diptera (67.4%), eight Hymenoptera (23.5%), two Hemiptera (5.8%) and one Thysanoptera (2.9%). Were described 41 new morphotypes of gall and made the first characterization of gall on *Maprounea guianensis* Aubl., *Acosmium subelegans* (Mohlenbr.) Yakovlev., *Strychnos bicolor* Progel, *Eriotheca gracilipes* K. Schum., *Stryphnodendron obovatum* Benth., *Broyesum gaudichaudii* Trécul, *Psychotria suterella* Müll. Arg., *Psychotria trichophora* Müll. Arg. and *Serjania erecta* Radlk.
Keywords: *Annonaceae, Cecidomyiidae, Cerrado, galling species, geographic distribution, host plant, parasitoid.*

SAITO, V.S. & URSO-GUIMARÃES, M.V. **Caracterização de galhas, insetos galhadores e fauna associada de Estação Ecológica de Jataí (Luiz Antônio, SP).** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02312032012

Resumo: Este é o primeiro estudo sobre galhas, insetos galhadores e fauna associada da Estação Ecológica de Jataí. Galhas são estruturas vegetais formadas por um crescimento anormal de células, tecidos ou órgãos induzido por vários organismos, como fungos, nematóides e insetos. Cinco áreas da unidade de conservação, dois na fitofisionomia de cerrado em regeneração e três na área de cerradão foram estudadas, totalizando 69 morfotipos de galhas em 41 espécies de plantas hospedeiras de 24 famílias. Este é o primeiro registro de Annonaceae como a família mais rica em morfotipos no Brasil; 34 insetos galhadores e fauna associada foram identificados, sendo 23 Diptera (67,4%), oito Hymenoptera (23,5%), dois Hemiptera (5,8%) e um Thysanoptera (2,9%). Foram descritos 41 novos morfotipos de galhas e foi feita a primeira caracterização de galhas em *Xylopia aromatica* (Lam.) Mart., *Connarus suberosus* Planch., *Maprounea guianensis* Aubl., *Acosmium subelegans* (Mohlenbr.) Yakovlev., *Strychnos bicolor* Progel, *Eriotheca gracilipes* K. Schum., *Stryphnodendron obovatum* Benth., *Broyesum gaudichaudii* Trécul, *Psychotria suterella* Müll. Arg., *Psychotria trichophora* Müll. Arg. e *Serjania erecta* Radlk.
Palavras-chave: *Annonaceae, Cecidomyiidae, Cerrado, espécies galhadoras, distribuição geográfica, planta hospedeira, parasitoide.*

Introduction

Galls are plant structures formed by abnormal growth of cells, tissues or organs in response to stimuli caused by other organisms (Carneiro et al. 2009, Rohfritsch & Shorthouse 1982). This abnormal growth is due to increase in cell volume (hypertrophy) and/or cell number (hyperplasia). A rich insect fauna is associated with the galls and includes predators, parasitoids, tenants and successors, so galls represent a true micro habitat where several tri-trophic relations are established (Maia 2001). A recent study estimated the richness of insect galls in about 120,000 species (Espirito Santo & Fernandes 2007), making knowledge of this group essential for ecological studies.

In Neotropic, six orders of insects are cited by having representatives galling species, Diptera, Lepidoptera, Hymenoptera, Coleoptera, Hemiptera and Thysanoptera (Maia et al. 2008). Among these, there is a wide prevalence of galls induced by Diptera, were recorded over a thousand morphotypes, mainly driven by species of family Cecidomyiidae (Maia et al. 2008), which represent the group of predominantly insect galls in all zoogeographical regions of world (Gagné 1994). Julião et al. (2005) discusses the use of such groups as bioindicators because they are easy objects of study, due to the bodies remain locatable for much of their life cycle and are abundant in their hosts, although they are still few studies on the characterization of this fauna (Lara & Fernandes 1996), despite efforts to work on characterization of galls and gall makers in areas of restinga (Maia 2005), Cerrado, rupestrian fields, semidecidual forest in the states of São Paulo and Minas Gerais (Urso-Guimarães & Scarelli-Santos 2006, Urso-Guimaraes et al. 2003, Lara & Fernandes 1996).

The Cerrado is a very devastated domain, especially in São Paulo, where only 5.48% of the original Cerrado is still available. There are few studies about galls in this biome in Sao Paulo, with only one gall characterization in Pé-de-Gigante Reserve (Urso-Guimarães & Scarelli-Santos, 2006). The Ecological Station of Jataí (ESJATAÍ) is the largest conservation area of Cerrado in São Paulo and yet few studies on biodiversity of invertebrate were made, as well in other Brazilian cerrado areas, and most groups and communities have not been studied (Peruquetti 2004).

Material and methods

1. *Study area*

The ES JATAÍ is located in the city of Luiz Antônio, São Paulo, between coordinates 21° 30’ and 21° 40’ S and 47° 40’ and 47° 50’ W (Figure 1), Unit of Water Resources Management nº 9 - Mogi Guaçu in region of Médio Mogi Guaçu (Pires et al. 2000). The climate is Aw of Koppen, or Tropical of central Brazil (Pires et al. 2000, Toppa et al. 2006). Altitude varies from 515 m to 835 m in altitude relative to sea level and located in the Paraná Sedimentary Basin (Toppa et al. 2006). In relation to vegetation types, ES JATAÍ has about 60% of cerradão, 20% of cerrado regeneration, 12% of Semideciduous Forest, 3% of lowland vegetation, 1% of campo sujo, 2% of recovery areas and less than 1% of Cerrado sensu stricto (Toppa et al. 2006, Fundação... et al. in prep).

2. *Experimental procedures*

2.1. Sampling

Five areas were chosen to sampling, three areas of cerradão and two of cerrado regeneration. These areas should have different degrees of conservation, as evidenced by the presence or absence of exotic grasses, palms and bromeliads.

Samples were collected in areas including the border of roads of ES Jataí, because as already described by Price et al. (1998), the border represent an environment with increased solar radiation and desiccation, where there is increased the richness of galls.

The coordinates of starting points of sampling:

1 - 21° 36’ 19.44” S and 47° 47’ 28.86” W (geographical)
2 - 21° 36’ 14.10” S and 47 ° 46’ 34.44” W (geographical)
3 - 21° 36’ 2.81” S and 47 ° 45’ 38.32” W (geographical)
4 - 21° 35’ 33.27” S and 47 ° 45’ 40.86” W (geographical)
5 - 21° 37’ 48.48” S and 47° 42’ 33.15” W (geographical)

The samples were obtained using methods described by Fernandes et al. (1995), Fernandes & Negreiros (2006), Julião et al. (2005), occurred on days 19, 20 and 21 April 2010 and consisted of three random routes of an hour for each area, totaling 15 hours of sampling. According to Fernandes et al. (1995), the sampling during a weather station is sufficient to evaluate the number of galls per habitat, because of the absence of statistical difference in the results obtained, which were conducted in two seasons, dry and rainy seasons. This is due to the galls are sessile and remain attached to host plants, which makes possible accounting of galls even after adult emergence.

The stems of plants with galls were collected and placed in individual plastic bags, tagged and taken to laboratory where were placed in plastic bottles covered with fine mesh to wait for the emergence of gall maker. Exsiccates were made from plants collected for later identification by specialists. The collection of sentinel plants is deposited in the Herbarium of the UFSCar campus Sorocaba.

2.2. Criteria for characterization of the galls

The morphology of gall is considered of great taxonomic value because of high specificity of galling species and host plant. Moreover, their characters are easier to observe than those of adults or immature stages of galling species, given the diminutive size of these (Maia 1995). By morphotype, understood to be the characters used as shape (Figure 2), color (Figure 3), pubescence (Figure 4), grouping (Figure 5) and organ of occurrence of gall on the host plant (Figure 6) (Maia 1995).

The characterization of galls was done using a synthesis of the nomenclatures presented in works in the area as Möhn (1961), Maia (2001), Urso-Guimarães et al. (2003), Urso-Guimarães & Scarelli-Santos (2006) and review of the specificity of galls made by Carneiro et al. (2009). Galls that were not found galling species the identification where made by similarity to several studies (Urso-Guimarães & Scarelli-Santos 2006, Maia & Fernandes 2004, Gonçalves-Alvim & Fernandes 2001, Maia et al. 2008, Carneiro et al. 2009, Urso-Guimarães et al. 2003).

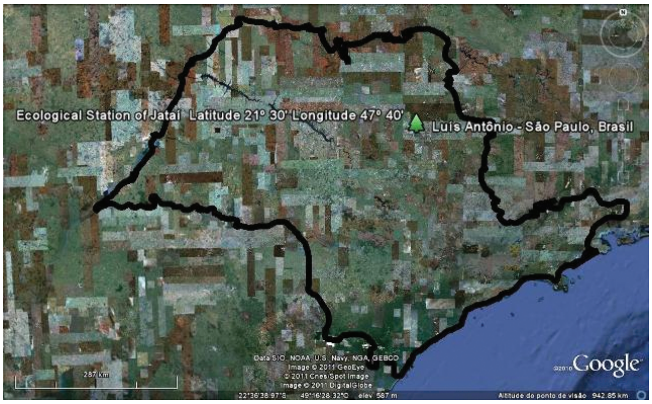

Figure 1. Location of Ecological Station of Jataí, SP (fonte: Google Earth Free).

Were made permanent slides with cecidomyiids according to procedures of Gagné (1989). To identify the cecidomyiids was used identification key of Gagné (1994). The parasitoids were identified to family using identification keys of Kristensen (1991). Specimens of insect galls and their associated fauna sampled are deposited in the Didactic and Scientific Collection of Invertebrates of UFSCar Campus Sorocaba.

Results

Were found 69 morphotypes of galls in 41 plant species from 24 families (Table 1). Of all the insects identified, 23 are Diptera (67.6%), eight are Hymenoptera (23.5%), two are Hemiptera (5.9%) and one Thysanoptera (2.9%) (Figure 7). If we consider only the galling habit (n = 25), the percentage of Cecidomyiidae (single

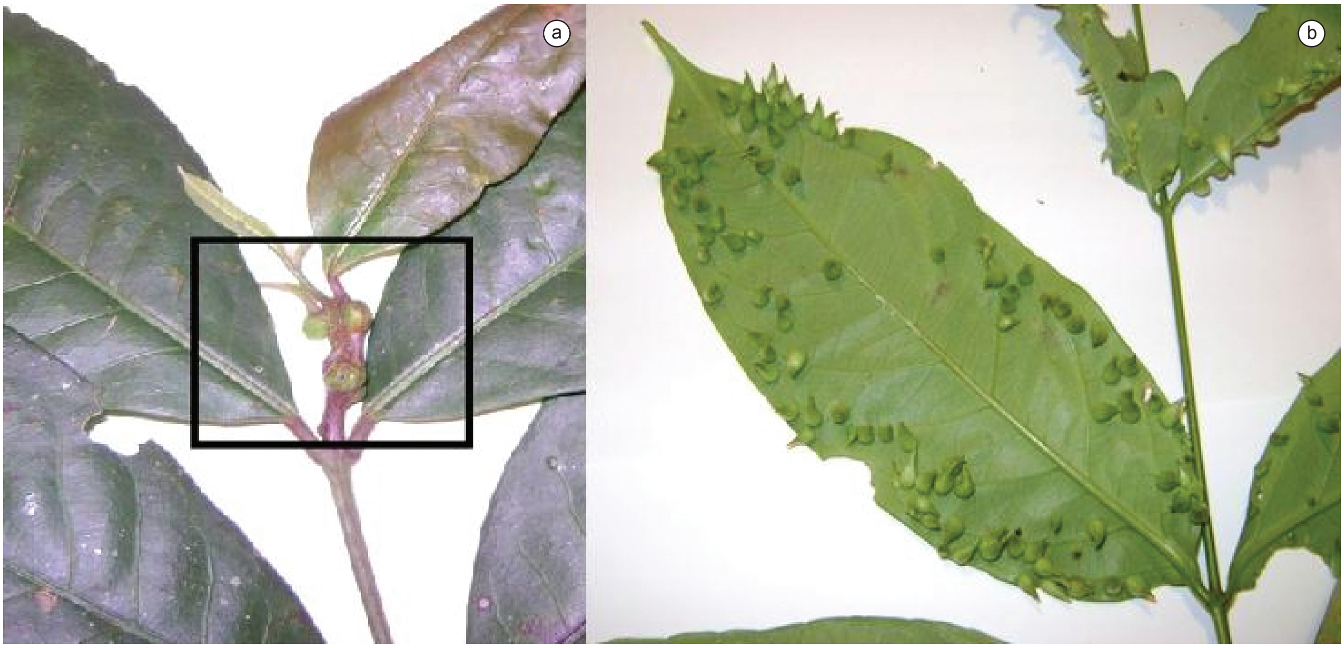

Figure 2. Example of shapes of galls characterized in the Ecological Station of Jataí (SP). a) globoid form (*Siparuna guianensis* Aubl), b) conic form (*Banisteriopsis pubipetala* (A. Juss.) Cuatrec.).

Figure 3. Example of the coloration of galls characterized in the Ecological Station of Jataí (SP). a) green (*Andira* sp.), b) cream (*Miconia albicans* Sw.).

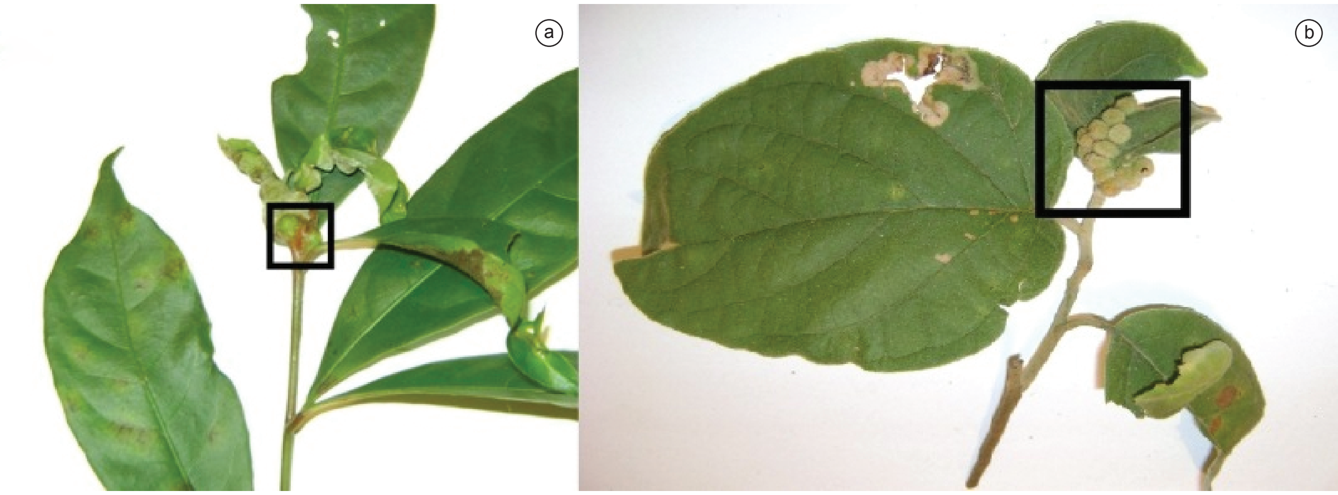

Figure 4. Example of the presence and absence of pubescence in the galls characterized in the Ecological Station of Jataí (SP). a) glabrous (without trichomes) (*Nectandra* sp.), b) pubescent (with trichomes) (*Bauhinia rufa* Graham).

Figure 5. Example of isolated (a) (*Duguetia furfuracea* (A. St.-Hil.) Saff.) and grouped (b) (*Arrabidaea* sp.) galls characterized in the Ecological Station of Jataí (SP).

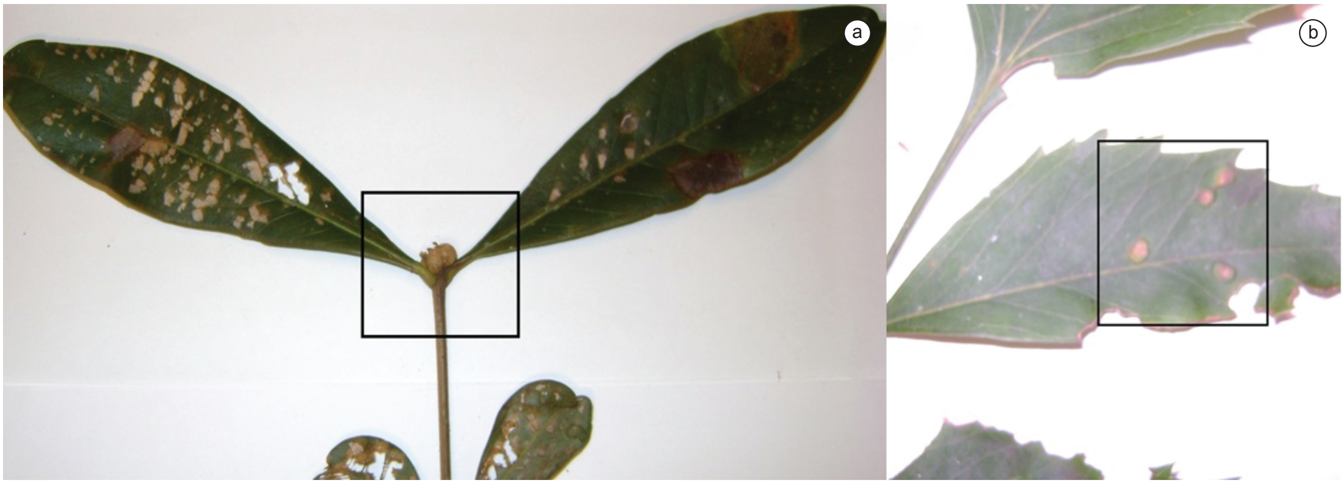

Figure 6. Example of occurence organs of galls characterized in the Ecological Station of Jataí (SP). a) apical gem (*Byrsonima cf intermedia* A. Juss.),b) leaf (*Acosmium cf subelegans* (Mohlenbr.) Yakovlev.).

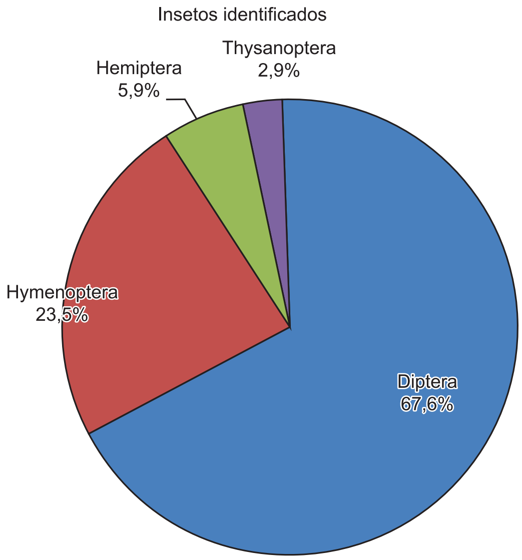

Figure 7. Percentage of the orders of insects found in galls of Ecological Station of Jataí, SP.

Figure 8. Example of gall characterized in the Ecological Station of Jataí (SP) with discoid form and may be a scar from another form.

Table 1. Table of characterization of the morphotypes of galls found in the Ecological Station of Jataí, SP, by species of host plant.

Family	Specie	Organ	Shape	Pubescence	Ocurrence	Color	nº of type
Anacardiaceae	*Tapirira guianensis*Aubl.	leaf	point	no	isolated	Black	1
Annonaceae	*Annona coriacea* Mart.	Leaf	discoid	no	isolated	Green and brown	2
	Annona crassiflora Mart.	Leaf	discoid	no	isolated	Green and brown	3
	Duguetia furfuracea (A. St.-Hil.) Saff.	Leaf	globular	no	isolated	Brown	4
		Leaf	discoid	no	isolated	Brown	5
		Leaf	winding	no	isolated	Green	6
		Leaf	swelling	no	isolated	Green	7
		Leaf	cylindrical	no	isolated	Green	8
	Xylopia aromatica (Lam.) Mart.	Leaf	discoid	no	isolated	Brown	9
		Leaf	globular	no	grouped	Black	10
		Leaf	discoid	yes	isolated	Red	11
Asteraceae	*Gochnatia pulchra* Cabrera	Leaf	globular	yes	isolated	Cream	12
Bignoniaceae	*Arrabidaea* sp.	Leaf bud	globular	yes	grouped	Brown	13
		Leaf	globular	yes	grouped	Brown	14
		Stem	swelling	no	isolated	Brown	15
		Leaf	discoid	no	isolated	Green and brown	16
Chrysobalanaceae	*Couepia grandiflora* Mart. &Zucc.	Leaf	globular	no	isolated	Green	17
		Leaf	swelling	no	isolated	Red	18
Connaraceae	*Connarus suberosus* Planch.	Leaf	discoid	no	isolated	Brown	19
Erythroxylaceae	*Erythroxylum suberosum* A. St. –Hill.	Stem	swelling	no	isolated	Brown	20
		Leaf	discoid	no	isolated	Brown	21
Euphorbiaceae	*Mabea fistulifera* Mart.	Leaf	discoid	no	isolated	Green	22
	Manihot caerulescens Pohl	Leaf	cylindrical	no	isolated	Brown	23
	Maprounea guianensis Aubl.	Stem	swelling	no	isolated	Brown	24
		Leaf	winding	no	isolated	Green	25
Fabaceae	*Acosmium cf subelegans* (Mohlenbr.) Yakovlev.	Leaf	discoid	no	isolated	Red	26
	Andira sp.	Leaf	ravioli	no	isolated	Green	27
	Bauhinia rufa Graham	Leaf	globular	yes	isolated	Brown	28
	Hymenaea sp.	Leaf	discoid	no	isolated	Brown	29
		Leaf	globular	no	isolated	Green	30
	Senna sp.	Leaf	discoid	yes	isolated	Brown	31
Lauraceae	*Nectandra* sp.	Leaf	globular	no	isolated	Brown	32

Table 1. Continued...

Family	Specie	Organ	Shape	Pubes cence	Ocurrence	Color	nº of type
	Ocotea corymbosa (Meisn.) Mez	Leaf	point	no	isolated	Green	33
Loganiaceae	*Strychnos bicolor* Progel	Stem	swelling	no	isolated	Brown	34
Malpighiaceae	*Byrsonima cf intermedia* A. Juss.	Leaf bud	swelling	no	isolated	Brown	35
		Leaf	triangular	no	isolated	Green-brown	36
		Stem	swelling	no	isolated	Brown	37
		Apical bud	globular	no	grouped	Brown	38
		Stem	globular	no	grouped	Brown	39
		Leaf	discoid	no	isolated	Brown	40
	Banisteriopsis pubipetala (A. Juss.) Cuatrec.	Leaf	conical	no	isolated	Green	41
		Leaf	discoid	no	isolated	Brown	42
		Leaf	triangular	no	isolated	Green	43
Malvaceae	*Eriotheca gracilipes* K. Schum.	Leaf	discoid	yes	isolated	Red	44
Melastomataceae	*Miconia albicans* Sw.	Leaf	globular	no	grouped	Brown	45
Minasaceae	*Stryphnodendron obovatum* Benth.	Leaf	discoid	no	isolated	Green and brown	46
Moraceae	*Broyesum gaudichaudii* Trécul	Leaf	discoid	no	isolated	Brown	47
Myrtaceae	*Eugenia aurata* O. Berg	Stem	swelling	no	isolated	Brown	48
		Leaf	discoid	no	isolated	Brown	49
	Eugenia bimarginata DC.	Leaf	discoid	no	isolated	Brown	50
	Eugenia punicifolia Kunth (DC.)	Leaf	triangular	no	isolated	Green and brown	51
		Leaf bud	swelling	no	isolated	Green	52
	Myrcia cf lingua O. Berg (Mattos)	Leaf	discoid	no	isolated	Brown	53
	sp. 1	Leaf	discoid	no	isolated	Green	54
Ochnaceae	*Ouratea spectabilis* Mart. exEngl.	Leaf	discoid	no	isolated	Brown	55
Proteaceae	*Roupala montana* Aubl.	Leaf	discoid	no	isolated	Green	56
		Stem	globular	no	isolated	Brown	57
Rubiaceae	*Psychotria carthagenensis* Jacq.	Leaf	globular	no	isolated	Brown	58
	Psychotria cf suterella Müll.Arg.	Leaf	swelling	no	isolated	Green	59
		Stem	swelling	no	isolated	Green	60
	Psychotria cf trichophora Müll.Arg.	Leaf	discoid	yes	isolated	Brown	61
Sapindaceae	*Serjania cf erecta* Radlk.	Leaf	discoid	no	isolated	Green-brown	62
		Stem	swelling	no	isolated	Brown	63
Sapotaceae	*Pouteria torta* (Mart.) Radlk.	Leaf	cylindrical	yes	isolated	Green	64
		Stem	swelling	no	isolated	Brown	65
Siparunaceae	*Siparuna guianensis* Aubl.	Leaf	swelling	no	isolated	Green	66
		Stem	globular	no	grouped	Green	67
		Leaf	globular	yes	isolated	Brown	68
Vochysiaceae	*Qualea grandiflora* Mart.	Stem	swelling	no	isolated	Brown	69

family found for Diptera) is even greater, with 88%. In addition, all Hymenoptera found in the galls are parasitoids of the families Eurytomidae, Torymidae and Eulophidae (Table 2). Of the 41 host plants, in 20 of them were identified insects with galling habit, tenant or parasitoid. Were identified 34 insects in galls, 25 were galling habit, one tenant and eight parasitoids. Only nine insects were obtained and identified from the rearing and emergence of the gall, the other 25 were determined based on the similarity to the description of the gall in several studies (Table 1).

The galls characterized for *Maprounea guianensis* Aubl. (Euphorbiaceae), *Acosmium subelegans* (Mohlenbr.) Yakovlev. (Fabaceae), *Strychnos bicolor* Progel (Loganiaceae), *Eriotheca gracilipes* K. Schum. (Malvaceae), *Stryphnodendron obovatum* Benth. (Minasaceae), *Broyesum gaudichaudii* Trécul (Moraceae), *Psychotria suterella* Müll. Arg., *Psychotria trichophora* Müll. Arg. (Rubiaceae) and *Serjania erecta* Radlk. (Sapindaceae) are the first records of gall in these species. According to the list of species of Management Plan of ES JATAÍ (2010), from 41 plant species found in this study, four of which do not appear on the list of species. The new species recorded are *Psychotria carthagenensis* Jacq., *P. tricophora* Müll. Arg., *P. suterella* Müll. Arg. (Rubiaceae) and *Serjania erecta* Radlk. (Sapindaceae).

For the organ were where found galls, 75% were on leaves, 19% on stems, 4,5% on leaf buds and 1.5% on the apical bud (Table 1). Regarding the shape of galls sampled, about 35% had discoid pattern, 23% swelling, 23% globular, 6% cylindrical, 4% triangular, 3% point, other patterns found were rolling around 3%, 1.5 % ravioli and 1.5% conical (Table 1). Regarding the color of the galls, about 52.1% were

Table 2. Table of the presented insects in the galls sampled in the Ecological Station of Jataí, SP, their habits and the identification method.

Host plant	Insect	Habit	Reference	Nº of type
Duguetia furfuraceae	*Bruggmanniella duguetiae* Urso-Guimarães & Amorim, 2005 (Cecidomyiidae)	galling	Urso-Guimarães & Scarelli-Santos (2006)	6
	Hymenoptera	parasitoid	Urso-Guimarães & Scarelli-Santos (2006)	6
	Cecidomyiidae sp.1	galling	Urso-Guimarães & Scarelli-Santos (2006)	10
	Eulophidae (Hymenoptera)	parasitoid	Obtained	4
Annona crassiflora	Hemiptera	galling	Maia & Fernandes (2004)	7
Annona coriacea	Lasiopteridi sp.1 (Cecidomyiidae)	galling	Urso-Guimarães & Scarelli-Santos (2006)	8
Gochnatia pulchra	Cecidomyiidae sp.2	galling	Urso-Guimarães & Scarelli-Santos (2006)	12
***Arrabidaea* sp.**	Cecidomyiidae sp.3	galling	Gonçalves-Alvim & Fernandes (2001)	13
	Cecidomyiidae sp.4	galling	Gonçalves-Alvim & Fernandes (2001)	14
Erythroxylum suberosum	Cecidomyiidae sp.5	galling	Maia & Fernandes (2004)	20
	Thysanoptera	galling	Obtained	21
	Hymenoptera	parasitoid	Obtained	21
Manihot caerulescens	*Iatrophobia brasiliensis* Rübsaamen, 1916 (Cecidomyiidae)	galling	Maia et al. (2008)	22
***Andira* sp.**	*Andirodiplosis bahiensis* Tavares, 1920 (Cecidomyiidae)	galling	Carneiro et al. (2009)	26
Bauhinia rufa	*Neolasioptera* sp. 1 (Cecidomyiidae)	galling	Urso-Guimarães et al. (2003)	30
Ocotea corymbosa	Coccicidae (Hemiptera)	galling	Maia et al. (2008)	32
***Nectandra* sp.**	*Neolasioptera* sp. 2 (Cecidomyiidae)	galling	Maia et al. (2008)	33
Byrsonima* cf *intermedia	Cecidomyiidae sp.6	galling	Gonçalves-Alvim & Fernandes (2001)	35
	Cecidomyiidae sp.7	galling	Gonçalves-Alvim & Fernandes (2001)	43
Banisteriopsis pubipetala	*Clinodiplosis* sp. (Cecidomyiidae)	galling	Urso-Guimarães & Scarelli-Santos (2006)	36
	Eurytomidae (Hymenoptera)	parasitoid	Obtained	39
Miconia albicans	Cecidomyiidae sp.8	galling	Maia & Fernandes (2004)	45
Eugenia aurata	Cecidomyiidae sp.9	galling	Obtained	49
Eugenia aurata	Hymenoptera	parasitoid	Obtained	49
Eugenia punicifolia	Cecidomyiidae sp.10	galling	Gonçalves-Alvim & Fernandes (2001)	52
Eugenia aurata	Lasiopteridi sp.2 (Cecidomyiidae)	galling	Maia et al. (2008)	50
Eugenia bimarginata	Lasiopteridi/*Asphondylia* (Cecidomyiidae)	galling	Maia et al. (2008) and Scarelli-Santos et al. (2005)	53
Roupala montana	Cecidomyiidae sp.11	galling	Gonçalves-Alvim & Fernandes (2001)	56
Psychotria carthaginensis	Oligotrophini (Cecidomyiidae)	galling	Maia et al. (2008)	58
Pouteria torta	*Youngomyia pouteriae* Maia, 2001(Cecidomyiidae)	galling	Urso-Guimarães & Scarelli-Santos (2006)	64
	Trotteria quadridentata Maia, 2001(Cecidomyiidae)	Tenant	Obtained	64
	Eurytomidae (Hymenoptera)	parasitoid	Obtained	64
	Torymidae (Hymenoptera)	parasitoid	Obtained	64
Qualea grandiflora	Hymenoptera	parasitoid	Gonçalves-Alvim & Fernandes (2001)	69

brown, 27.5% were green, 7% were green and brown (depending on the stage that was the gall), 5.6% were red, 2, 8% were black, 2.8% were green-brown and cream were 1.4% (Table 1). Galls were found isolatly (74.2%) or grouped (25.8%) (Table 1). For pubescence, 85.5% were glabrous and 14.4% present trichomes (Table 1).

Discussion

This study reported the galling insects, the associated fauna and their host plants in cerrado vegetation in the state of São Paulo, an area with limited studies. In this work the first records of galls in nine plant species were made, which shows how galls, gall makers and associated insects were little studied in the cerrado lato sensu the state of São Paulo, with many areas yet to be characterized. For 69 morphotypes characterized were found similar descriptions of only 24 in literature. Considering the high specificity of the relationship gall- gall maker, revised by the recent work of Carneiro et al. (2009), which indicates that each gall is specific as to their host plant and that his gall is a unique interaction between them, this indicates possibly 45 morphotypes (65.2%) who have never been described representing unknown species to science. This high percentage of unknown galls shows the lack of studies that characterize the galling community for cerrado of São Paulo, and which make the identification of gall maker with the use of the gall a more reliable methodology.

The sampling effort was 15 hours, a low figure compared to the monthly sampling for one year made by Bregonci et al. (2010), the monthly samplings for six months by Gonçalves-Alvim & Fernandes (2001), the monthly samplings for over a year of Urso-Guimarães & Scarelli-Santos (2006) and the 66 hours of samplings of Fernandes & Negreiros (2006). Of these works, only Fernandes & Negreiros (2006) used the same methodology, yet despite the difference in sampling methodology, we can consider that all other studies had higher samplings effort that the present study. Despite the relatively low sampling effort, the richness of galls morphotypes found in this study was higher than three of them (Bregonci et al. 2010, Urso-Guimarães & Scarelli-Santos 2006, Fernandes & Negreiros 2006).

The richest family in diversity gall morphotypes was Annonaceae, followed by Malpighiaceae, Myrtaceae and Fabaceae. These data differs slightly from the expected. In literature, Fabaceae, Myrtaceae and Euphorbiaceae are cited as the richest families of galls (Gagné 1994), for example, Fabaceae was appointed as the richest in the cerrado by Gonçalves-Alvim & Fernandes (2001) and Urso-Guimarães & Scarelli-Santos (2006). It is therefore the first record of Annonaceae as the richest family in galls in a study area.

The richest host plant on types of galls was *Byrsonima cf intermedia* A. Juss. (Malpighiaceae) with six different morphotypes, followed by *Duguetia furfuracea* (A. St.-Hil.) Saff. (Annonaceae), with five. Urso-Guimarães & Scarelli-Santos (2006) found *Duguetia furfuracea* (A. St.-Hil.) Saff. (Annonaceae) as the richest host plant in another cerrado area of São Paulo and this results indicates the importance of this host plant to the gall makers and associated fauna in this vegetation.

The fact that 75% of the galls have been found in leaves, corroborate the pattern found in studies in Brazil, that indicates the leaf as organ most commonly attacked by gall makers (Maia et al. 2008, Maia 2001, Urso-Guimarães et al. 2003, Fernandes & Negreiros 2006) and with the world pattern found by Mani (1964). This pattern of occurrence in the leaves happens because the leaves are abundant resources and constant (Maia 2001), besides having a continuous flow of nutrients needed for the maintenance of photosynthesis (Whitham 1978). Another important factor is that females of Cecidomyiidae, most of the gall makers, has a very small size (1-5 mm), their ovipositor is fragile and can only lay eggs on tender tissues (Gagné 1994). The leaves are in constant renewal and derives most tender tissues of the host plants, which may also explain this preference.

The patterns for gall shape found in this study corroborate the patterns found in other studies, (Fernandes & Negreiros 2006, Bregonci et al. 2010, Santos et al. 2011) with the predominance of discoid shape (34.7%), followed by swellings and globular (23.1% each). The fact that more discoid was found should be viewed with caution, because this shape may mean an early stage of a globular gall or even a scar of gall of another shape, as conical or globular (Figure 8).

Another point to note is the subjectivity present in the descriptions of the galls in the literature. Although several studies using the same characteristics (shape, pubescence, distribution, organ attacked and color), the descriptions are discrepant and the nomenclature used is not always the same. To standardize the descriptions in this study were examined pictures of the shapes of galls, in addition to the table.

As for pubescence, in 14.2% of galls with parasitoids, were observed trichomes, while the percentage of trichomes described for all galls is 14.4%. These data reinforce Urso-Guimarães et al. (2003) whose found parasitic Hymenoptera in all galls with trichomes of their study, not sharing the hypothesis of Fernandes & Price (1988) who attribute the presence of trichomes protection against parasitoids.

The galls of *Eugenia punicifolia* Kunth (DC.) *Stryphnodendron obovatum* Benth. and *Arrabidaea* sp. were found in the color green and also brown (Figure 9). Urso-Guimarães & Scarelli-Santos (2003) found three morphotypes those had different colors and also indicated those this change was related to the maturation time of the galls. These data indicates that the use of color as a characteristic to identify galls should be used with caution because galls will change color according to the maturation stage and this should be analyzed in the characterizations of galls.

Figure 9. Example of galls of *Eugenia punicifolia* Kunth (DC.) in two stages of development with green and brown coloration of Ecological Station of Jataí (SP).

Another data was the new record of the species, *Psychotria carthagenensis* Jacq., *P. tricophora* Müll.Arg., *P. suturella* Müll.Arg. (Rubiaceae) and *Serjania erecta* Radlk. (Sapindaceae) in ES JATAÍ, as they are species of vines, not sampled by Toppa (2004) in his inventory of woody species. This record extends geographic distribution of these species.

The Diptera of the family Cecidomyiidae were responsible for the highest percentage of induction galls found (67.4%), and for the galling habit (88%). This result corroborate another data reported in other major studies in the literature, those indicates 58% of galls induced by Cecidomyiidae, according to Maia et al. (2008), 54% Urso-Guimarães et al. (2006), and 93%, according to Fernandes & Negreiros (2006), demonstrating the importance of the family in community of gall makers.

The Hymenoptera parasitoids found are of the families Eurytomidae, Torymidae and Eulophidae, within the superfamily Chalcidoidea, which are known parasitoids wasp of Cecidomyiidae galls (Urso-Guimarães et al. 2003).

All Diptera identified are unpublished occurrences for ES JATAÍ, because as mentioned, there are no studies related to galling insects in that area. The occurrence of these species in ES JATAÍ increases their known geographical distribution.

More studies are needed to understand the heterogeneous distribution of fauna and flora within the various vegetation types of ES JATAÍ. Including studies that aim to explain the distribution of galls and gall makers of these environments, because as mentioned earlier, this fauna has great potential as bioindicator, but you need to know how it behaves under different vegetation types and changes in conservation status of areas.

Acknowledgements

To Luís Tauhyl and João Vitor and technician Almir Calazans for field assistance. To Prof. Dr. Ingrid Koch (Universidade Federal de São Carlos) for helping in botanical identifications, to the manager of the ES JATAÍ, Dr. Edson Montilha (Instituto Florestal, Secretaria do Meio Ambiente do Estado de São Paulo) for enabling research inside the conservation area and to CNPq for financial support (Victor Satoru Saito was supported by PIBIC/CNPq for this work).

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Received 29/05/2011
Revised 15/08/2012
Accepted 22/08/2012

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VALADÃO, R.M. **Birds of the Estação Ecológica Serra das Araras, Mato Grosso, Brazil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn02612032012

Abstract: There are 1801 bird species in Brazil and 856 of those occur in Cerrado. This Biome is the largest, most distinctive and the richest Savanna in the world and it is probably the world's most endangered tropical Savanna, becoming a Hotspot and priority area for biodiversity conservation. Ecological Station Serra das Araras (EESA) occupies an area of 28.700 hectares of Cerrado, located in the Southwest of the State of Mato Grosso. It is part of the Provincia Serrana, a 400 km long and 40 km large mountain corridor connecting the Amazonian and Pantanal Biomes. The bird community of EESA was sampled monthly from May 2006 through December 2007. We placed a 500 m transect in each of five vegetation types. Each transect was walked once a month for 4 hours starting at sunrise and for 2 hours starting at sunset. Total sampling effort was 600 hours, comprising 80 daylight hours and 40 evening hours per transect/habitat. The list of birds of ESSA has 431 bird species, including 13 endemic birds of Cerrado and 7 threatened species in Brazil. Of these, 396 were recorded during this sampling effort, 29 out the sampling effort and six species were not registered in this study, although listed in studies conducted at EESA between 1986 and 1988. In the semi deciduous forest were recorded 150 species of birds, 256 species in riparian forest, 218 species in cerradão, 206 in cerrado sensu strict and 176 in parquet cerrado. Data analysis splitted the phytophysiognomies in two groups, the savanna (cerrado sensu strict and parque cerrado) and forested (gallery forest, cerradão and semi deciduous forest) bird communities. EESA bird richness is high compared with other areas of Cerrado. Perhaps the environmental heterogeneity of this protected area, with varied topography and vegetation is the reason for this larger species number. Along with the number of bird species, the presence of endemic and endangered species reinforces the importance of EESA for the conservation of this group.
Keywords: *Cerrado, protected area, habitat use, community ecology, endemic species, red list.*

VALADÃO, R.M. **As aves da Estação Ecológica Serra das Araras, Mato Grosso, Brasil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn02612032012

Resumo: O Brasil possui 1.801 espécies de aves e o Cerrado abriga 856 dessas espécies. Esse bioma que cobre 24% do território nacional é a maior, mais distinta, mais rica e, provavelmente mais ameaçada savana tropical do mundo, o que lhe tornou "hot spot" mundial e área prioritária para conservação da biodiversidade. A Estação Ecológica Serra das Araras (EESA) ocupa 28.700 hectares de Cerrado no sudoeste do Mato Grosso, faz parte da Província Serrana, um corredor de serras com cerca de 400 km de comprimento por 40 km de largura, o qual conecta o Cerrado à transição do bioma Amazônico e ao Pantanal. Com o objetivo de inventariar a comunidade de aves da EESA, foi percorrido um transecto de 500 m em cada uma das seguintes fitofisionomias: mata semidecídua, mata ciliar, cerradão, cerrado sentido restrito e parque cerrado. Cada transecto foi amostrado uma vez por mês, de maio de 2006 a dezembro de 2007, durantes quatro horas a partir do nascer e duas horas a partir do por do sol, totalizando 600 horas de amostragem, sendo 80 horas de dia e 40 horas de noite por transecto/hábitat. A lista de aves da ESSA possui 431 espécies de aves, incluindo treze endêmicas do Cerrado e sete nacionalmente ameaçadas de extinção. Dessas, 396 foram registradas durante o esforço amostral, 29 fora do período amostral e seis constam somente na lista de 305 espécies registradas entre 1986 e 1988. Na mata semidecídua foram registradas 150 espécies, na mata ciliar 256, no cerradão 218, no cerrado sentido restrito 206 e no parque cerrado 176 espécies de aves. Quanto à similaridade, formaram-se dois grupos, o das fitofisionomias savânicas (cerrado sentido restrito e parque cerrado) e outro das florestais (mata ciliar, cerradão e mata semidecídua). A riqueza de espécies de aves na EESA é alta quando comparada com outros estudos realizados no Cerrado e provavelmente está relacionada heterogeneidade ambiental presente nessa unidade de conservação, com relevo e vegetação variados. Além de preservar um elevado número, a presença de espécies de aves endêmicas e ameaçadas de extinção reafirmam a importância da EESA para conservação desse grupo.
Palavras-chave: *Cerrado, unidade de conservação, uso de hábitat, ecologia de comunidade, espécies endêmicas, espécies ameaçadas de extinção.*

Introdução

Aves são importantes na avaliação da qualidade ambiental e peças chaves na determinação de áreas para a conservação, pois se trata de um grupo diversificado que ocupa diferentes hábitats, níveis tróficos e são altamente sensível às modificações ambientais. O comportamento conspícuo e facilidade de identificação de grande parte das espécies, além da rapidez na amostragem fazem delas um dos grupos mais bem conhecido da região neotropical (Kattan et al. 1994, Stotz et al. 1996, Tubelis & Cavalcanti 2000, Marini 2001, Eken et al. 2004).

O Brasil é o terceiro país em riqueza de aves, com 1.801 espécies (Comitê... 2011), dessas 856 tem registros para o Cerrado e 30 são endêmicas (Silva & Santos 2005). Esse pequeno número de espécies endêmicas pode ser explicado por sua interconexão como os demais biomas, o que influenciou no processo de especiação desse grupo (Sick 1966). Embora ocupe o terceiro lugar em riqueza de aves no Brasil, o Cerrado ainda é um ambiente pouco estudado em relação a sua avifauna, extensas porções de seu território ainda não tinham sido "minimamente estudadas" (localidades que tivessem pelo menos 80 espécimes coletados ou uma lista com no mínimo 100 espécies) em 1995, fato que pouco mudou em dez anos (Silva 1995, Silva & Santos 2005).

O Cerrado cobre aproximadamente 24% do território nacional e é hoje a maior, mais distinta, mais rica e, provavelmente, a mais ameaçada savana tropical do mundo (Silva & Bates 2002, Silva & Santos 2005, Serviço... 2011), o que lhe garante o título de "hot spots" mundial e área prioritária para conservação da biodiversidade (Myers et al. 2000). Um dos principais fatores determinantes da sua riqueza é a sua estratificação horizontal, pois Cerrado pode ser entendido como um grande mosaico, no qual as peças são as diferentes fitofisionomias, as quais produzem um gradiente em densidade e altura, definido por formações campestres a florestais (Coutinho 1978).

Nos últimos anos, tem havido uma intensa substituição das áreas de vegetação nativa do Cerrado por zonas urbanas, agricultura, pastagens e reflorestamentos com espécies vegetais exóticas (Machado & Lamas 1996). Dados do Serviço Florestal Brasileiro (2011) mostram que ao final de 2008 o percentual de área desmatada era de 47,8%, e que apenas 6,4% do bioma encontrava-se formalmente preservado em unidades de conservação, valor é bem inferior aos 10% assumido, via termo de compromisso, pelo Ministério do Meio Ambiente durante o Workshop "Ações Prioritárias para a conservação da biodiversidade do Cerrado e Pantanal" (Brasil 1999).

Inventariar um local é a forma mais direta para se acessar parte dos componentes da diversidade animal de uma localidade (Silveira et al. 2010). As listas de espécies, principal produto desses inventários, são importantes para análise futura de relações biogeográficas (Ribon et al. 1995, Nunes & Pacheco 2004), para a determinação de rotas migratórias (Ribon et al. 1995) e uma contribuição fundamental aos órgãos gestores das áreas protegidas brasileiras (Argel-de-Oliveira 1993). Podem ser utilizadas para investigação da dinâmica natural da flora e fauna, dos eventos ecológicos e da eficácia de gestão de uma Unidade de Conservação.

O objetivo deste trabalho foi inventariar a avifauna da Estação Ecológica Serra das Araras, comparar a riqueza de aves entre as fitofisionomias estudadas, comparar os resultados obtidos a estudos anteriores, bem como criar uma base de dados confiável que embase as tomadas de decisão e gestão dessa área protegida.

Material e Métodos

1. Área de estudo

A Estação Ecológica Serra das Araras é uma unidade de conservação federal que ocupa 28.700 ha do bioma Cerrado no sudoeste do Mato Grosso, nas cidades de Porto Estrela e Cáceres. Sua área está localizada entre as latitudes 15° 27' 11"-15° 51' 04" Sul e longitudes 57° 06' 06"-57° 16' 41" Oeste (Figura 1).

A região da unidade de conservação destaca-se das demais áreas do entorno por se encontrar fisicamente isolada e apresentar relevo e altitudes bem diferenciados das regiões adjacentes (vale do alto rio Paragai e Pantanal), sendo parte da Província Serrana. Essa unidade geomorfológica é um extenso corredor de serras paralelas, com cerca de 400 km de comprimento por 40 km de largura, estendendo-se do Pantanal de Cáceres até a cidade de Paranatinga. O Clima da região, segundo classificação de Köppen, é do tipo Aw Megatérmico com nítida sazonalidade, sendo o período chuvoso de outubro a abril e o período seco de maio a setembro (Ross 1991).

Cinco fitofisionomias foram amostradas sistematicamente durante o presente estudo. Sua classificação obedece Ribeiro & Walter (2008) e possuem as seguintes características:

- 1.1 Mata semidecídua: fitofisionomia florestal com árvores eretas, de 15 a 30 m de altura, que crescem sobre solo de origem calcária com afloramento rochoso. No período chuvoso a cobertura foliar é superior a 90%, e diminui para menos de 50% no período seco, com a queda das folhas das espécies decíduas.
- 1.2 Mata ciliar: fitofisionomia florestal que apresenta árvores eretas de 20 a 25 m de altura. A caducifólia, durante o período seco, permite o desenvolvimento de um denso sub-bosque e garante um estoque perene de serrapilheira.
- 1.3 Cerradão: fitofisionomia florestal com plantas de folhas duras e coriáceas, composto por espécies vegetais tanto do cerrado sentido restrito como de mata ciliar. A altura das árvores varia de 8 a 15 m de altura, proporcionando condições de luminosidade que favorece a formação de estrato arbustivo.
- 1.4 Cerrado sentido restrito: fitofisionomia savânica com denso estrato graminoso e presença de árvores baixas, inclinadas, tortuosas, com ramificações irregulares e retorcidas que variam entre 3 e 5 m de altura.
- 1.5 Parque cerrado: fitofisionomia savânica que apresenta árvores de cerrado sentido restrito de 3 a 6 m de altura, agrupadas em pequenas elevações bem drenadas do terreno, os "murundus". Neles a cobertura arbórea atinge de 50 a 60% e nas depressões, cobertas por um tapete graminoso denso que cresce em solo alagado de janeiro a abril, a cobertura arbórea cai para praticamente 0%.

2. Métodos

O levantamento da avifauna foi realizado no período de maio de 2006 a dezembro de 2007, em campanhas mensais, com intervalos médios de 27 (±3) dias entre elas.

Cinco fitofisionomias foram amostradas de forma sistemáticas: mata ciliar (Figura 2a), mata semi decídua (Figura 2b), cerradão (Figura 2c), cerrado sentido restrito (Figura 2d) e parque cerrado (Figura 2e). Um transecto de 500 m foi delimitado em trilhas preexistentes em cada uma das fitofisionomias (Figura 1b). Cada transecto foi amostrado uma vez por mês, percorrendo-se livremente sua extensão, durante quatro horas a partir do nascer e duas horas a partir do por do sol, totalizando 600 horas de amostragem, sendo 80 horas durante o dia e 40 horas durante a noite por transecto/hábitat.

Áreas de mata calcária (Figura 2f), campo rupestre (Figura 2g) e cerrado rupestre (Figura 2h) foram amostradas esporadicamente devido a sua dificuldade de acesso. Capturas eventuais, utilizando-se redes de neblina, foram também realizadas para confirmação de algumas espécies. Por não terem obedecido a uma metodologia padronizada, os registros obtidos nas áreas amostradas esporadicamente e nas capturas, somente serviram para compor a lista final de espécies, como registros não sistemáticos; o esforço amostral não foi considerado

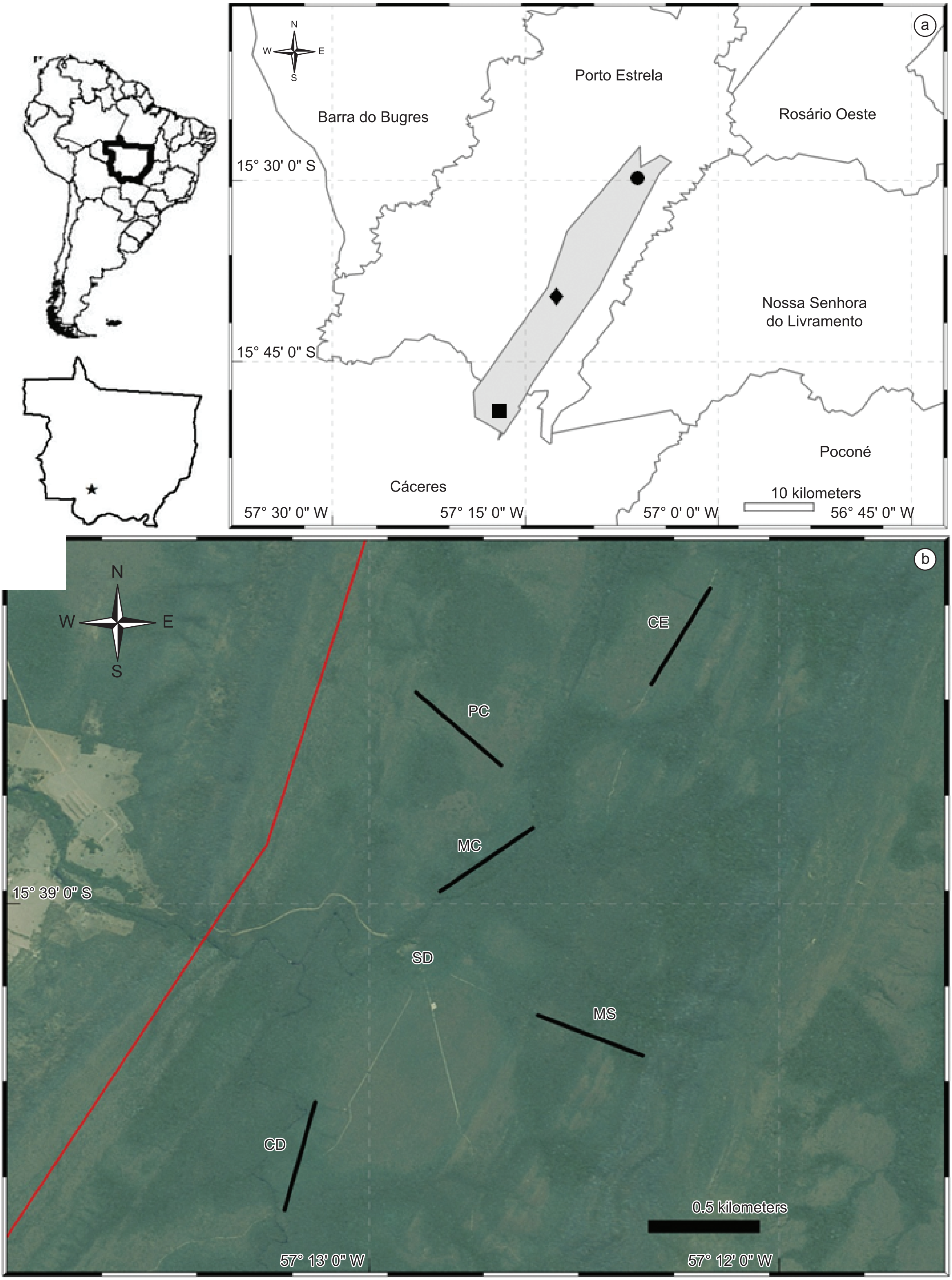

Figura 1. a) Localização da Estação Ecológica Serra das Araras (Porto Estrela e Cáceres, Mato Grosso), com indicação das áreas de amostragem da avifauna: ♦ (pontos de amostragem sistemática); ● (ponto de amostragem não sistemática: mata calcária) e ■ (pontos de amostragens não sistemáticas: campo e cerrado rupestres). b) Localização dos transectos nas áreas de amostragem sistemática: MS (mata semidecídua), MC (mata ciliar), CD (cerradão), CE (cerrado sentido restrito) e PC (parque cerrado). SD é a localização da sede da EESA e a linha vermelha indica o seu limite.

Figure 1. a) Location of the Serra das Araras Ecological Station (Porto Estrela e Cáceres, Mato Grosso), indicating the sampling areas: ♦ (systematic sampling spots), ● (sporadic sampling spot: limestone forest) and ■ (sporadic sampling points: *campo rupestre* and *cerrado rupestre*). b) Location of transects in the areas of systematic sampling: MS (semi-deciduos forest), MC (riparian forest), CD (*cerradão*) CE (*cerrado sentido restrito*) and PC (*parque cerrado*). SD is the location of EESA's headquarters and the red line is its limit.

Figura 2. Fotos das áreas de estudo amostradas de forma sistemática: a) (mata ciliar), b) (mata semidecídua), c) (cerradão), d) (cerrado sentido restrito) e e (parque cerrado); e) das áreas com amostragens não sistemáticas: f) (mata calcária), g) (campo rupestre) e h) (cerrado rupestre).

Figure 2. Photos of the study areas sampled in a systematic basis: a) (riparian forest), b) (semi-deciduous forest), c) (*Cerrado*), d) (*cerrado sentido restrito*) and e) (*parque cerrado*) and areas with sporadic sampling effort: f) (limestone forest), g) (*campo rupestre*) and h) (*cerrado rupestre*).

para esse trabalho e as espécies registradas não fizeram parte de nenhuma análise.

Os indivíduos coletados em estudos anteriores (Silva & Oniki 1988, Willis & Oniki 1990) e os eventualmente coletados no presente trabalho estão depositados na coleção de vertebrados da Universidade Federal de Mato Grosso.

As espécies de aves foram identificadas com auxílio de binóculos (8 × 42) e gravações de vocalizações, utilizando um gravador portátil de fita cassete e microfone direcional. Foram consultados guias de campo (Ridgely & Tudor 1989, 1994, Souza 1998, Fergusson-Lees et al. 2000) e CDs com gravações de vozes para a identificação das espécies (Vielliard 1995a, b, 1999).

Para verificar a eficiência da amostragem na coleta de dados foram confeccionadas curvas de acumulação de espécies. Os dados de riqueza de espécies foram testados quanto a homocedasticidade, normalidade e linearidade dos dados. Como a distribuição dos dados foi normal e não homocedástica, foi utilizado o teste não paramétrico Kruskall-Wallys para verificar possíveis diferenças nas riquezas entre as cinco fitofisionomias. Após isso, o teste *a posteriori* de Tukey foi utilizado para se determinar quais são os pares de médias diferentes. Utilizou-se o programa R (R Development... 2011) para realizar os testes estatísticos. Um cluster com o objetivo de analisar a similaridade entre as fitofisionomias foi gerado a partir do programa MultiVariate Statistical Package – MVSP.

A ordem filogenética e nomenclatura científica adotadas na lista final estão de acordo com o proposto pelo Comitê Brasileiro de Registros Ornitológicos (2011). As espécies foram classificadas em endêmicas do Cerrado (Silva 1995, 1997, Cavalcanti 1999, Silva & Santos 2005) e em ameaçadas de extinção (Instituto... 2005).

Resultados

A lista da avifauna da ESEC Serra das Araras é composta por 431 espécies (spp) de aves distribuídas em 295 gêneros, 63 famílias e 26 ordens. Desse total, 396 spp foram registradas de forma sistemática, 29 spp foram registradas exclusivamente durante o esforço não sistemático e 6 spp não foram registradas nesse estudo, porém foram listadas anteriormente por Silva & Oniki (1988) e Willis & Oniki (1990), os quais registraram juntos 305 espécies (Tabela 1).

Com relação à distribuição da avifauna entre as diferentes fitofisionomias, na mata ciliar foi registrado um total de 256 espécies, 218 spp no cerradão, 206 spp no cerrado sentido restrito, 176 spp no parque cerrado e 150 spp na mata semidecícua (Tabela 1).

A fitofisionomia com maior número de espécies exclusivas foi a Mata Ciliar, com 44 espécies; em seguida fica o parque cerrado com 11 spp, cerrado sentido restrito com 9 spp, a mata semidecídua com 8 spp e apenas 2 espécies foram registradas exclusivamente no cerradão.

Treze das espécies registradas na EESA são endêmicas do bioma Cerrado: *Penelope ochrogaster*, *Columbina cyanopis*, *Alipiopsitta xanthops*, *Herpsilochmus longirostris*, *Melanopareia torquata*, *Hylocryptus rectirostris*, *Antilophia galeata*, *Suiriri islerorum*, *Cyanocorax cristatellus*, *Saltatricula atricollis*, *Porphyrospiza caerulescens*, *Charitospiza eucosma* e *Basileuterus leucophrys* (Silva 1995, 1997, Cavalcanti 1999, Silva & Santos 2005). Além disso, sete das espécies registradas na EESA estão presentes na lista brasileira de espécies ameaçadas de extinção: *Penelope ochrogaster*, *Tigrisoma fasciatum*, *Urubitinga coronata*, *Columbina cyanopis*, *Anodorhynchus hyacinthinus*, *Culicivora caudacuta*, *Sporophila maximiliani* (Instituto... 2005).

Discussão

O presente estudo adiciona 126 novas espécies a lista com 305 espécies de aves registradas anteriormente por Silva & Oniki (1988) e Willis & Oniki (1990) na EESA. Tal resultado já era esperado por Silva & Oniki (1998). O táxon "*Icterus hauxwelli*" fora considerado por Willis & Oniki (1990) como uma espécie diferente de *I. croconotus*, entretanto Lopes et al. (2009) considera "duvidosa" a validade do táxon. Ressalta-se que no presente trabalho foi registrado somente *I. croconotus* e caso *I. hauxwelli* torne-se válida para a região, será mais uma espécie somente com registro histórico para a EESA.

A riqueza de espécies de aves registrada nessa unidade de conservação representa mais de 50% das aves listadas para o Cerrado (Silva & Santos 2005) o que é uma riqueza de espécies elevada, sobretudo quando comparada à outras áreas de Cerrado (Tabela 2), a despeito das diferenças metodológicas entre os estudos.

A alta riqueza de espécies de aves obtina na EESA certamente está relacionada à variedade dos ambientes amostrados, os quais formam um gradiente em densidade e altura definido por formações campestres, savânicas e florestais. Cabe destacar também a localização da EESA em área de transição entre Cerrado, Amazônia e Pantanal. Vale ressaltar ainda o esforço amostral desse trabalho, o qual foi suficiente para uma amostragem exaustiva, conforme a tendência à estabilização das curvas do coletor observadas na Figura 3.

O teste Kruskal-Walis indicou diferenças significativas entre as riquezas de espécies entre as áreas (Kruskal-Wallis: $p < 0{,}001$; $H = 50.962$; g.l. = 4) e o teste de Tukey indicou que a média das riquezas de espécie mensais registradas na mata-ciliar difere da de todas obtidas nas outras áreas; que a do cerrado sentido restrito é igual as do cerradão e parque cerrado e indicou também que as médias das riquezas observadas na mata semidecídua, no cerradão e no parque cerrado não diferem quando comparadas (Figura 4).

Certamente a maior riqueza de espécies de aves observada na mata ciliar se deve ao fato desta fitofisionomia possuir maior heterogeneidade espacial, e conseqüente maior quantidade de micro-hábitat que ambientes mais simples o que permite o estabelecimento de um maior número de espécies (MacArthur et al. 1962, August 1983, Antas 1995, Pianka, 2000). Uma maior riqueza de espécies em mata ciliar já era observada por Silva & Oniki (1988) na ESEC Serra das Araras na década de oitenta e foi observado por Blamires et al. (2001) em Goiás, por Antas (1995) no Parque Nacional de Brasília (DF), por Purificação & Castilho (2009) no Mato Grosso e também por Ferreira et al. (2009) em estudo realizado na RPPN Mata Samuel de Paula, Minas Gerais. Tais resultados reafirmam importância das matas-ciliares para conservação da avifauna do Cerrado, conforme já sugerido por Cavalcanti (1988).

Purificação & Castilho (2009) no Parque Estadual da Serra Azul (MT) e Ferreira et al. (2009) na RPPN Mata Samuel de Paula (MG) também identificaram a dominância de registros de espécies exclusivas em matas ciliares no Cerrado, o que pode indicar que, além de servir como refúgio para algumas espécies de aves durante o período de estresse hídrico desse bioma, o que faz dela um hábitat chave para conservação desse grupo animal (Cavalcanti 1992) essa fitofisionomia também apresenta uma avifauna peculiar.

Quando comparadas as fitofisionomias quanto à similaridade, a avifauna da EESA forma dois grupos bem característicos, um grupo formado pelas fitofisionomias savânicas, cerrado sentido restrito e parque cerrado, com índice se similaridade de Sörensen superior a 0,8; e outro formado pelas fitofisionomias florestais mata ciliar e cerradão ($S = 0{,}75$) e essas duas fitofisionomias e a mata semidecídua ($S = 0{,}63$) (Figura 5). A grosso modo, o mesmo foi observado por Almeida et al. (2003) quando analisa a diversidade beta em hábitats da Pré-Amazônia.

Tabela 1. Lista sistemática das espécies de aves registradas na área da Estação Ecológica Serra das Araras. A nomenclatura científica e a seqüência filogenética seguem a proposta do CBRO (Comitê... 2011). Fitofisionomia: MS (mata semidecídua); MC (mata ciliar); CD (cerradão); CE (cerrado sentido restrito); PC (parque cerrado), NS (registro não sistemático: fora das áreas estudadas de forma sistemática) e RH [registros históricos: Silva & Oniki (1988) e Willis & Oniki (1990)]. ***AM (espécie presente na lista oficial das espécies de aves ameaçadas no Brasil) e ***EC (espécie endêmica do Cerrado).

Table 1. List of bird species registered at Serra das Araras Ecological Station. The scientific nomenclature and the phylogenetic sequence follow the proposal of CBRO (Comitê… 2011). Fitofisionomia (phytophysiognomies): MS (semi-deciduous forest), MC (riparian forest), CE (cerradão), CD (cerrado sentido restrito), PC (parque cerrado), NS (registered outside the areas studied systematically) and e RH [historical records: Silva & Oniki (1988) and Willis & Oniki (1990)]. ***AM (species present in the official list of threatened bird species in Brazil) and ***EC (endemic species of the Cerrado).

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Rheidae Bonaparte, 1849							
Rhea americana (Linnaeus, 1758)						x	
Tinamidae Gray, 1840							
Tinamus tao Temminck, 1815	x	x					x
Crypturellus soui (Hermann, 1783)	x	x	x				x
Crypturellus undulatus (Temminck, 1815)	x	x	x				x
Crypturellus parvirostris (Wagler, 1827)				x	x		x
Crypturellus tataupa (Temminck, 1815)	x	x					x
Rhynchotus rufescens (Temminck, 1815)				x	x		x
Anhimidae Stejneger, 1885							
Chauna torquata (Oken, 1816)						x	
Anatidae Leach, 1820							
Dendrocygna viduata (Linnaeus, 1766)						x	
Dendrocygna autumnalis (Linnaeus, 1758)		x					
Cairina moschata (Linnaeus, 1758)		x					
Amazonetta brasiliensis (Gmelin, 1789)						x	
Netta peposaca (Vieillot, 1816)						x	
Cracidae Rafinesque, 1815							
Ortalis canicollis (Wagler, 1830)	x	x	x	x			x
Penelope superciliaris Temminck, 1815	x	x	x	x			x
Penelope ochrogaster Pelzeln, 1870 *** ^{AM,EC}		x					
Aburria cujubi (Pelzeln, 1858)		x					x
Crax fasciolata Spix, 1825	x	x	x	x	x		x
Odontophoridae Gould, 1844							
Odontophorus gujanensis (Gmelin, 1789)	x	x	x				x
Podicipedidae Bonaparte, 1831							
Tachybaptus dominicus (Linnaeus, 1766)						x	
Podilymbus podiceps (Linnaeus, 1758)						x	
Ciconiidae Sundevall, 1836							
Jabiru mycteria (Lichtenstein, 1819)						x	
Mycteria americana Linnaeus, 1758						x	
Phalacrocoracidae Reichenbach, 1849							
Phalacrocorax brasilianus (Gmelin, 1789)		x					
Anhingidae Reichenbach, 1849							
Anhinga anhinga (Linnaeus, 1766)		x					x
Ardeidae Leach, 1820							
Tigrisoma lineatum (Boddaert, 1783)		x					
Tigrisoma fasciatum (Such, 1825) *** ^{AM}		x					
Cochlearius cochlearius (Linnaeus, 1766)						x	
Nycticorax nycticorax (Linnaeus, 1758)		x					
Butorides striata (Linnaeus, 1758)		x					
Bubulcus ibis (Linnaeus, 1758)						x	
Ardea cocoi Linnaeus, 1766		x					
Ardea alba Linnaeus, 1758		x					
Syrigma sibilatrix (Temminck, 1824)		x			x		
Pilherodius pileatus (Boddaert, 1783)		x					x
Egretta thula (Molina, 1782)		x					

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Threskiornithidae Poche, 1904							
Mesembrinibis cayennensis (Gmelin, 1789)		x		x	x		
Phimosus infuscatus (Lichtenstein, 1823)					x		
Theristicus caudatus (Boddaert, 1783)				x	x		
Cathartidae Lafresnaye, 1839							
Cathartes aura (Linnaeus, 1758)				x	x		x
Cathartes burrovianus Cassin, 1845	x	x	x	x	x		
Coragyps atratus (Bechstein, 1793)	x	x	x	x	x		x
Sarcoramphus papa (Linnaeus, 1758)	x			x	x		x
Accipitridae Vigors, 1824							
Leptodon cayanensis (Latham, 1790)	x	x					
Chondrohierax uncinatus (Temminck, 1822)		x	x	x			
Elanoides forficatus (Linnaeus, 1758)				x	x		x
Gampsonyx swainsonii Vigors, 1825				x	x		x
Elanus leucurus (Vieillot, 1818)				x	x		
Accipiter striatus Vieillot, 1808		x					
Accipiter bicolor (Vieillot, 1817)	x	x	x				
Ictinia mississippiensis (Wilson, 1811)				x	x		
Ictinia plumbea (Gmelin, 1788)	x	x	x	x	x		
Busarellus nigricollis (Latham, 1790)		x					
Rostrhamus sociabilis (Vieillot, 1817)						x	x
Geranospiza caerulescens (Vieillot, 1817)	x	x					x
Heterospizias meridionalis (Latham, 1790)	x	x		x			x
Urubitinga urubitinga (Gmelin, 1788)		x					
Urubitinga coronata (Vieillot, 1817)***$^{\text{AM}}$				x			
Rupornis magnirostris (Gmelin, 1788)	x	x	x	x	x		x
Parabuteo unicinctus (Temminck, 1824)						x	
Geranoaetus albicaudatus (Vieillot, 1816)				x	x		x
Geranoaetus melanoleucus (Vieillot, 1819)						x	
Pseudastur albicollis (Latham, 1790)	x	x					x
Buteo nitidus (Latham, 1790)	x	x			x		x
Buteo brachyurus Vieillot, 1816			x	x			
Buteo albonotatus Kaup, 1847						x	
Harpia harpyja (Linnaeus, 1758)	x			x			
Spizaetus tyrannus (Wied, 1820)	x						
Spizaetus melanoleucus (Vieillot, 1816)	x	x					x
Spizaetus ornatus (Daudin, 1800)	x	x					x
Falconidae Leach, 1820							
Daptrius ater Vieillot, 1816		x					
Caracara plancus (Miller, 1777)				x	x		x
Milvago chimachima (Vieillot, 1816)			x	x	x		x
Herpetotheres cachinnans (Linnaeus, 1758)	x	x	x	x	x		x
Micrastur ruficollis (Vieillot, 1817)	x	x					x
Micrastur semitorquatus (Vieillot, 1817)		x	x				x
Falco sparverius Linnaeus, 1758				x	x		x
Falco rufigularis Daudin, 1800				x	x		x
Falco femoralis Temminck, 1822				x	x		
Eurypygidae Selby, 1840							
Eurypyga helias (Pallas, 1781)		x	x				x
Aramidae Bonaparte, 1852							
Aramus guarauna (Linnaeus, 1766)					x		
Rallidae Rafinesque, 1815							
Micropygia schomburgkii (Schomburgk, 1848)				x	x		x

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Aramides cajanea (Statius Muller, 1776)		x	x	x	x		
Laterallus viridis (Statius Muller, 1776)		x			x		x
Laterallus melanophaius (Vieillot, 1819)					x		x
Porzana albicollis (Vieillot, 1819)					x		
Porphyrio martinica (Linnaeus, 1766)						x	
Cariamidae Bonaparte, 1850							
Cariama cristata (Linnaeus, 1766)				x	x		x
Charadriidae Leach, 1820							
Vanellus cayanus (Latham, 1790)						x	
Vanellus chilensis (Molina, 1782)				x	x		
Scolopacidae Rafinesque, 1815							
Gallinago paraguaiae (Vieillot, 1816)					x		
Gallinago undulata (Boddaert, 1783)						x	
Tringa solitaria Wilson, 1813					x		
Jacanidae Chenu & Des Murs, 1854							
Jacana jacana (Linnaeus, 1766)						x	
Columbidae Leach, 1820							
Columbina minuta (Linnaeus, 1766)				x	x		x
Columbina talpacoti (Temminck, 1811)	x		x	x	x		x
Columbina squammata (Lesson, 1831)			x	x	x		x
Columbina cyanopis (Pelzeln, 1870)***$^{\text{AM, EC}}$						x	x
Claravis pretiosa (Ferrari-Perez, 1886)	x	x	x	x			x
Uropelia campestris (Spix, 1825)				x	x		x
Patagioenas speciosa (Gmelin, 1789)		x					x
Patagioenas picazuro (Temminck, 1813)	x	x	x	x	x		x
Patagioenas cayennensis (Bonnaterre, 1792)	x	x	x		x		x
Patagioenas plumbea (Vieillot, 1818)	x	x	x				x
Zenaida auriculata (Des Murs, 1847)				x	x		
Leptotila verreauxi Bonaparte, 1855	x	x	x	x			x
Leptotila rufaxilla (Richard & Bernard, 1792)		x					x
Geotrygon montana (Linnaeus, 1758)	x	x					x
Psittacidae Rafinesque, 1815							
Anodorhynchus hyacinthinus (Latham, 1790) ***$^{\text{AM}}$					x		x
Ara ararauna (Linnaeus, 1758)				x	x		x
Ara chloropterus Gray, 1859				x			x
Orthopsittaca manilata (Boddaert, 1783)				x	x		x
Primolius maracana (Vieillot, 1816)			x	x	x		
Diopsittaca nobilis (Linnaeus, 1758)			x	x	x		x
Aratinga leucophthalma (Statius Muller, 1776)	x	x	x	x	x		x
Aratinga weddellii (Deville, 1851)	x						x
Aratinga aurea (Gmelin, 1788)				x	x		x
Forpus xanthopterygius (Spix, 1824)		x		x	x		
Brotogeris chiriri (Vieillot, 1818)	x	x	x	x	x		x
Alipiopsitta xanthops (Spix, 1824)***$^{\text{EC}}$				x	x		
Pionus menstruus (Linnaeus, 1766)	x	x	x	x	x		x
Amazona amazonica (Linnaeus, 1766)		x	x	x	x		
Amazona aestiva (Linnaeus, 1758)	x	x		x	x		
Cuculidae Leach, 1820							
Coccycua minuta (Vieillot, 1817)		x					x
Piaya cayana (Linnaeus, 1766)	x	x	x	x	x		x
Crotophaga major Gmelin, 1788		x					
Crotophaga ani Linnaeus, 1758				x	x		x
Guira guira (Gmelin, 1788)				x	x		x

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Tapera naevia (Linnaeus, 1766)	x	x	x	x	x		x
Dromococcyx phasianellus (Spix, 1824)			x				x
Dromococcyx pavoninus Pelzeln, 1870		x	x				x
Tytonidae Mathews, 1912							
Tyto alba (Scopoli, 1769)				x	x		x
Strigidae Leach, 1820							
Megascops choliba (Vieillot, 1817)	x	x	x				x
Megascops usta (Sclater, 1858)	x	x	x				
Pulsatrix perspicillata (Latham, 1790)	x	x	x				x
Bubo virginianus (Gmelin, 1788)				x	x		
Strix virgata (Cassin, 1849)	x	x					
Strix huhula Daudin, 1800	x	x	x				
Glaucidium brasilianum (Gmelin, 1788)	x	x	x	x	x		x
Athene cunicularia (Molina, 1782)				x	x		x
Asio clamator (Vieillot, 1808)			x	x			
Asio stygius (Wagler, 1832)						x	
Nyctibiidae Chenu & Des Murs, 1851							
Nyctibius grandis (Gmelin, 1789)	x	x		x			x
Nyctibius griseus (Gmelin, 1789)	x	x			x		
Caprimulgidae Vigors, 1825							
Antrostomus rufus (Boddaert, 1783)	x		x	x			x
Hydropsalis albicollis (Gmelin, 1789)				x	x		x
Hydropsalis parvula (Gould, 1837)			x	x	x		
Hydropsalis longirostris (Bonaparte, 1825)						x	
Hydropsalis torquata (Gmelin, 1789)				x	x		x
Chordeiles pusillus Gould, 1861				x	x		
Chordeiles nacunda (Vieillot, 1817)				x	x		
Chordeiles minor (Forster, 1771)					x		
Chordeiles acutipennis (Hermann, 1783)				x	x		x
Apodidae Olphe-Galliard, 1887							
Cypseloides fumigatus (Streubel, 1848)				x			x
Streptoprocne zonaris (Shaw, 1796)	x			x	x		x
Streptoprocne biscutata (Sclater, 1866)						x	
Chaetura chapmani Hellmayr, 1907							x
Chaetura meridionalis Hellmayr, 1907			x	x	x		x
Tachornis squamata (Cassin, 1853)					x		x
Trochilidae Vigors, 1825							
Glaucis hirsutus (Gmelin, 1788)		x	x	x			x
Phaethornis nattereri Berlepsch, 1887		x	x				x
Phaethornis ruber (Linnaeus, 1758)			x				
Phaethornis subochraceus Todd, 1915		x	x				x
Phaethornis pretrei (Lesson & Delattre, 1839)	x	x	x	x	x		x
Eupetomena macroura (Gmelin, 1788)	x	x	x	x	x		x
Colibri serrirostris (Vieillot, 1816)			x	x	x		
Anthracothorax nigricollis (Vieillot, 1817)		x	x	x			x
Chrysolampis mosquitus (Linnaeus, 1758)		x		x			
Chlorostilbon lucidus (Shaw, 1812)			x	x	x		x
Thalurania furcata (Gmelin, 1788)	x	x	x				x
Hylocharis chrysura (Shaw, 1812)				x	x		
Polytmus guainumbi (Pallas, 1764)		x			x		
Amazilia fimbriata (Gmelin, 1788)	x	x	x	x	x		x
Heliactin bilophus (Temminck, 1820)				x	x		x
Heliomaster longirostris (Audebert & Vieillot, 1801)	x	x	x	x	x		x

Tabela 1. Continuação...

Taxa	**Fitofisionomia**					**NS**	**RH**
	MS	**MC**	**CD**	**CE**	**PC**		
Heliomaster furcifer (Shaw, 1812)			x	x	x		
Calliphlox amethystina (Boddaert, 1783)				x	x		
Trogonidae Lesson, 1828							
Trogon melanurus Swainson, 1838	x	x					
Trogon viridis Linnaeus, 1766	x	x	x				x
Trogon curucui Linnaeus, 1766		x	x				x
Trogon collaris Vieillot, 1817	x	x	x				
Alcedinidae Rafinesque, 1815							
Megaceryle torquata (Linnaeus, 1766)		x					x
Chloroceryle amazona (Latham, 1790)		x					x
Chloroceryle aenea (Pallas, 1764)		x					x
Chloroceryle americana (Gmelin, 1788)		x					x
Chloroceryle inda (Linnaeus, 1766)		x					x
Momotidae Gray, 1840							
Electron platyrhynchum (Leadbeater, 1829)	x						x
Momotus momota (Linnaeus, 1766)	x	x	x				x
Galbulidae Vigors, 1825							
Brachygalba lugubris (Swainson, 1838)	x	x	x				x
Galbula ruficauda Cuvier, 1816	x	x	x		x		x
Bucconidae Horsfield, 1821							
Notharchus macrorhynchos (Gmelin, 1788)	x						x
Notharchus tectus (Boddaert, 1783)				x			x
Bucco tamatia Gmelin, 1788	x	x		x			
Nystalus striolatus (Pelzeln, 1856)	x	x	x				
Nystalus chacuru (Vieillot, 1816)				x	x		x
Nystalus maculatus (Gmelin, 1788)				x	x		
Nonnula ruficapilla (Tschudi, 1844)				x			
Monasa nigrifrons (Spix, 1824)	x	x	x				x
Monasa morphoeus (Hahn & Küster, 1823)							x
Chelidoptera tenebrosa (Pallas, 1782)		x	x		x		x
Ramphastidae Vigors, 1825							
Ramphastos toco Statius Muller, 1776		x		x	x		x
Ramphastos vitellinus Lichtenstein, 1823	x	x					x
Pteroglossus inscriptus Swainson, 1822		x	x				x
Pteroglossus bitorquatus Vigors, 1826		x					x
Pteroglossus castanotis Gould, 1834	x	x	x	x	x		x
Picidae Leach, 1820							
Picumnus albosquamatus d'Orbigny, 1840	x	x	x				x
Melanerpes candidus (Otto, 1796)	x	x	x	x	x		
Melanerpes cruentatus (Boddaert, 1783)	x	x	x	x			x
Veniliornis passerinus (Linnaeus, 1766)	x	x					x
Veniliornis mixtus (Boddaert, 1783)	x						x
Piculus leucolaemus (Natterer & Malherbe, 1845)	x						
Piculus chrysochloros (Vieillot, 1818)	x	x	x				x
Colaptes melanochloros (Gmelin, 1788)	x	x		x			x
Colaptes campestris (Vieillot, 1818)				x	x		x
Celeus elegans (Statius Muller, 1776)	x	x	x				x
Celeus lugubris (Malherbe, 1851)	x	x	x				x
Dryocopus lineatus (Linnaeus, 1766)	x	x	x				x
Campephilus rubricollis (Boddaert, 1783)	x	x	x				x
Campephilus melanoleucos (Gmelin, 1788)	x	x	x	x			x
Thamnophilidae Swainson, 1824							
Microrhopias quixensis (Cornalia, 1849)		x	x				x

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Myrmeciza atrothorax (Boddaert, 1783)		x	x				x
Epinecrophylla haematonota (Sclater, 1857)		x					
Myrmotherula hauxwelli (Sclater, 1857)	x						x
Formicivora grisea (Boddaert, 1783)		x	x	x			x
Formicivora rufa (Wied, 1831)		x	x	x			x
Dysithamnus mentalis (Temminck, 1823)	x	x	x				x
Herpsilochmus longirostris Pelzeln, 1868***^{EC}		x	x				
Thamnophilus doliatus (Linnaeus, 1764)	x		x	x	x		x
Thamnophilus torquatus Swainson, 1825			x	x	x		x
Thamnophilus punctatus (Shaw, 1809)		x	x				x
Thamnophilus pelzelni Hellmayr, 1924	x	x	x				
Thamnophilus caerulescens Vieillot, 1816							x
Cymbilaimus lineatus (Leach, 1814)							x
Taraba major (Vieillot, 1816)	x	x	x	x			x
Hypocnemoides maculicauda (Pelzeln, 1868)		x	x				x
Pyriglena leuconota (Spix, 1824)		x	x				x
Myrmoborus myotherinus (Spix, 1825)		x					x
Cercomacra nigrescens (Cabanis & Heine, 1859)		x	x				x
Hypocnemis cantator (Boddaert, 1783)	x	x	x				x
Willisornis poecilinotus (Cabanis, 1847)		x					x
Rhegmatorhina hoffmannsi (Hellmayr, 1907)		x					x
Melanopareiidae Ericson, Olson, Irested, Alvarenga & Fjeldsa, 2010							
Melanopareia torquata (Wied, 1831)***^{EC}				x	x		x
Conopophagidae Sclater & Salvin, 1873							
Conopophaga lineata (Wied, 1831)		x	x				x
Dendrocolaptidae Gray, 1840							
Dendrocincla fuliginosa (Vieillot, 1818)	x	x					x
Sittasomus griseicapillus (Vieillot, 1818)	x	x	x				x
Glyphorynchus spirurus (Vieillot, 1819)	x	x	x	x			x
Xiphorhynchus guttatus (Lichtenstein, 1820)	x	x					x
Dendroplex picus (Gmelin, 1788)	x		x				x
Lepidocolaptes angustirostris (Vieillot, 1818)			x	x	x		x
Lepidocolaptes albolineatus (Lafresnaye, 1845)	x	x		x			x
Dendrocolaptes platyrostris Spix, 1825	x	x	x				x
Hylexetastes perrotii (Lafresnaye, 1844)		x					x
Furnariidae Gray, 1840							
Xenops rutilans Temminck, 1821	x	x	x				x
Furnarius rufus (Gmelin, 1788)			x	x	x		x
Lochmias nematura (Lichtenstein, 1823)	x	x					
Hylocryptus rectirostris (Wied, 1831)***^{EC}		x	x				
Syndactyla dimidiata (Pelzeln, 1859)	x						x
Phacellodomus rufifrons (Wied, 1821)					x		
Phacellodomus ruber (Vieillot, 1817)		x			x		
Synallaxis frontalis Pelzeln, 1859			x	x	x		x
Synallaxis albescens Temminck, 1823			x	x	x		x
Synallaxis rutilans Temminck, 1823	x				x		x
Synallaxis gujanensis (Gmelin, 1789)			x	x			x
Cranioleuca vulpina (Pelzeln, 1856)	x	x	x				x
Pipridae Rafinesque, 1815							
Neopelma pallescens (Lafresnaye, 1853)	x	x	x				x
Tyranneutes stolzmanni (Hellmayr, 1906)		x					x
Pipra fasciicauda Hellmayr, 1906	x	x	x				x
Manacus manacus (Linnaeus, 1766)		x	x				x

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Machaeropterus pyrocephalus (Sclater, 1852)	x	x	x				x
Antilophia galeata (Lichtenstein, 1823)***^{EC}	x	x	x				x
Tityridae Gray, 1840							
Oxyruncus cristatus Swainson, 1821	x	x					x
Terenotriccus erythrurus (Cabanis, 1847)							x
Schiffornis turdina (Wied, 1831)		x	x				x
Tityra inquisitor (Lichtenstein, 1823)	x	x	x	x			
Tityra cayana (Linnaeus, 1766)	x	x	x				x
Tityra semifasciata (Spix, 1825)		x					x
Pachyramphus viridis (Vieillot, 1816)		x	x				
Pachyramphus polychopterus (Vieillot, 1818)			x	x	x		x
Cotingidae Bonaparte, 1849							
Xipholena punicea (Pallas, 1764)		x	x				x
Platyrinchus mystaceus Vieillot, 1818		x	x				x
Piprites chloris (Temminck, 1822)		x					x
Rhynchocyclidae Berlepsch, 1907							
Mionectes oleagineus (Lichtenstein, 1823)	x	x	x				x
Leptopogon amaurocephalus Tschudi, 1846	x	x	x				x
Corythopis delalandi (Lesson, 1830)	x	x	x				
Tolmomyias sulphurescens (Spix, 1825)	x	x	x				x
Todirostrum cinereum (Linnaeus, 1766)			x	x	x		x
Poecilotriccus latirostris (Pelzeln, 1868)		x	x				x
Hemitriccus flammulatus Berlepsch, 1901		x	x				
Hemitriccus striaticollis (Lafresnaye, 1853)		x	x				x
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837)		x	x	x	x		x
Tyrannidae Vigors, 1825							
Hirundinea ferruginea (Gmelin, 1788)				x			x
Euscarthmus meloryphus Wied, 1831				x			x
Euscarthmus rufomarginatus (Pelzeln, 1868)						x	x
Camptostoma obsoletum (Temminck, 1824)		x	x	x	x		x
Elaenia flavogaster (Thunberg, 1822)			x	x	x		x
Elaenia albiceps (d'Orbigny & Lafresnaye, 1837)		x	x				x
Elaenia parvirostris Pelzeln, 1868			x	x	x		x
Elaenia cristata Pelzeln, 1868			x	x	x		x
Elaenia chiriquensis Lawrence, 1865				x	x		x
Suiriri suiriri (Vieillot, 1818)		x	x	x	x		x
Suiriri islerorum Zimmer, Whittaker & Oren, 2001***^{EC}		x	x	x	x		
Myiopagis gaimardii (d'Orbigny, 1839)		x	x				x
Myiopagis caniceps (Swainson, 1835)		x	x				x
Myiopagis viridicata (Vieillot, 1817)	x	x	x				x
Phaeomyias murina (Spix, 1825)			x	x	x		x
Phyllomyias fasciatus (Thunberg, 1822)		x	x				x
Culicivora caudacuta (Vieillot, 1818) ***^{AM}				x	x		x
Attila bolivianus Lafresnaye, 1848	x	x	x				x
Legatus leucophaius (Vieillot, 1818)		x	x				x
Ramphotrigon ruficauda (Spix, 1825)		x	x				x
Myiarchus tuberculifer (d'Orbigny & Lafresnaye, 1837)	x	x	x	x			x
Myiarchus swainsoni Cabanis & Heine, 1859		x	x	x	x		x
Myiarchus ferox (Gmelin, 1789)		x	x	x	x		x
Myiarchus tyrannulus (Statius Muller, 1776)			x	x	x		x
Sirystes sibilator (Vieillot, 1818)	x	x	x				x
Casiornis rufus (Vieillot, 1816)		x	x	x			x
Pitangus sulphuratus (Linnaeus, 1766)	x	x	x	x	x		x

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Philohydor lictor (Lichtenstein, 1823)		x	x	x			x
Machetornis rixosa (Vieillot, 1819)				x	x		x
Myiodynastes maculatus (Statius Muller, 1776)	x	x	x	x	x		x
Megarynchus pitangua (Linnaeus, 1766)	x	x	x	x	x		x
Myiozetetes cayanensis (Linnaeus, 1766)		x	x				x
Tyrannus albogularis Burmeister, 1856	x	x	x	x	x		
Tyrannus melancholicus Vieillot, 1819	x	x	x	x	x		x
Tyrannus savana Vieillot, 1808	x	x	x	x	x		x
Griseotyrannus aurantioatrocristatus (d'Orbigny & Lafresnaye, 1837)	x	x	x	x	x		
Empidonomus varius (Vieillot, 1818)	x	x	x	x	x		x
Colonia colonus (Vieillot, 1818)	x	x	x				x
Myiophobus fasciatus (Statius Muller, 1776)		x	x	x	x		x
Sublegatus modestus (Wied, 1831)				x	x		x
Pyrocephalus rubinus (Boddaert, 1783)				x	x		
Gubernetes yetapa (Vieillot, 1818)					x		x
Cnemotriccus fuscatus (Wied, 1831)		x	x				x
Lathrotriccus euleri (Cabanis, 1868)		x	x				x
Knipolegus lophotes Boie, 1828		x					
Xolmis cinereus (Vieillot, 1816)				x	x		x
Xolmis velatus (Lichtenstein, 1823)				x	x		
Vireonidae Swainson, 1837							
Cyclarhis gujanensis (Gmelin, 1789)			x	x	x		x
Vireo olivaceus (Linnaeus, 1766)			x	x	x		x
Hylophilus muscicapinus Sclater & Salvin, 1873							x
Corvidae Leach, 1820							
Cyanocorax cyanomelas (Vieillot, 1818)	x	x	x	x			x
Cyanocorax cristatellus (Temminck, 1823)***^{EC}				x	x		x
Hirundinidae Rafinesque, 1815							
Pygochelidon cyanoleuca (Vieillot, 1817)				x	x		
Stelgidopteryx ruficollis (Vieillot, 1817)		x	x	x			x
Progne tapera (Vieillot, 1817)				x	x		x
Progne chalybea (Gmelin, 1789)				x	x		
Tachycineta leucorrhoa (Vieillot, 1817)				x	x		
Hirundo rustica Linnaeus, 1758				x	x		
Troglodytidae Swainson, 1831							
Troglodytes musculus Naumann, 1823				x	x		x
Campylorhynchus turdinus (Wied, 1831)	x	x	x				x
Pheugopedius genibarbis (Swainson, 1838)		x	x				x
Cantorchilus leucotis (Lafresnaye, 1845)		x	x				x
Donacobiidae Aleixo & Pacheco, 2006							
Donacobius atricapilla (Linnaeus, 1766)						x	
Polioptilidae Baird, 1858							
Polioptila dumicola (Vieillot, 1817)	x	x	x	x	x		x
Turdidae Rafinesque, 1815							
Catharus fuscescens (Stephens, 1817)	x	x	x				x
Turdus rufiventris Vieillot, 1818	x	x	x	x	x		x
Turdus leucomelas Vieillot, 1818	x	x	x	x	x		x
Turdus fumigatus Lichtenstein, 1823		x	x				
Turdus amaurochalinus Cabanis, 1850	x	x	x				x
Turdus albicollis Vieillot, 1818						x	x
Mimidae Bonaparte, 1853							
Mimus saturninus (Lichtenstein, 1823)			x	x	x		x
Coerebidae d'Orbigny & Lafresnaye, 1838							

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Coereba flaveola (Linnaeus, 1758)	x	x	x	x	x		x
Thraupidae Cabanis, 1847							
Saltator maximus (Statius Muller, 1776)	x	x	x				x
Saltator coerulescens Vieillot, 1817	x	x	x	x	x		
Saltator similis d'Orbigny & Lafresnaye, 1837		x	x	x			
Saltatricula atricollis (Vieillot, 1817)***^{EC}				x	x		x
Cypsnagra hirundinacea (Lesson, 1831)			x	x	x		x
Tachyphonus rufus (Boddaert, 1783)		x	x	x			x
Ramphocelus carbo (Pallas, 1764)	x	x	x	x			x
Lanio luctuosus (d'Orbigny & Lafresnaye, 1837)		x					x
Lanio cucullatus (Statius Muller, 1776)				x	x		x
Lanio versicolor (d'Orbigny & Lafresnaye, 1837)		x	x				x
Lanio penicillatus (Spix, 1825)	x	x	x				x
Tangara mexicana (Linnaeus, 1766)		x					x
Tangara chilensis (Vigors, 1832)		x					x
Tangara sayaca (Linnaeus, 1766)	x	x	x	x	x		x
Tangara palmarum (Wied, 1823)	x	x	x	x			x
Tangara cyanicollis (d'Orbigny & Lafresnaye, 1837)		x	x				x
Tangara cayana (Linnaeus, 1766)	x	x	x	x	x		x
Neothraupis fasciata (Lichtenstein, 1823)				x	x		x
Cissopis leverianus (Gmelin, 1788)	x	x	x	x	x		x
Schistochlamys melanopis (Latham, 1790)			x	x	x		x
Paroaria capitata (d'Orbigny & Lafresnaye, 1837)				x	x		x
Tersina viridis (Illiger, 1811)		x	x	x			x
Dacnis lineata (Gmelin, 1789)		x	x	x			x
Dacnis cayana (Linnaeus, 1766)	x	x	x	x	x		x
Cyanerpes caeruleus (Linnaeus, 1758)		x	x	x	x		x
Cyanerpes cyaneus (Linnaeus, 1766)		x	x	x			x
Chlorophanes spiza (Linnaeus, 1758)		x					x
Hemithraupis guira (Linnaeus, 1766)	x	x	x				x
Hemithraupis flavicollis (Vieillot, 1818)		x	x				x
Conirostrum speciosum (Temminck, 1824)		x	x				
Emberizidae Vigors, 1825							
Zonotrichia capensis (Statius Muller, 1776)				x	x		x
Ammodramus humeralis (Bosc, 1792)				x	x		x
Porphyrospiza caerulescens (Wied, 1830)***^{EC}						x	x
Sicalis citrina Pelzeln, 1870				x	x		
Sicalis flaveola (Linnaeus, 1766)			x	x	x		x
Emberizoides herbicola (Vieillot, 1817)				x	x		x
Volatinia jacarina (Linnaeus, 1766)				x	x		x
Sporophila plumbea (Wied, 1830)			x	x	x		
Sporophila collaris (Boddaert, 1783)						x	
Sporophila lineola (Linnaeus, 1758)				x	x		
Sporophila nigricollis (Vieillot, 1823)				x	x		
Sporophila caerulescens (Vieillot, 1823)				x			x
Sporophila leucoptera (Vieillot, 1817)				x	x		x
Sporophila angolensis (Linnaeus, 1766)			x	x			x
Sporophila maximiliani (Cabanis, 1851)***^{AM}						x	
Tiaris fuliginosus (Wied, 1830)		x	x				
Arremon taciturnus (Hermann, 1783)	x	x	x				x
Arremon flavirostris Swainson, 1838	x	x	x				
Charitospiza eucosma Oberholser, 1905***^{EC}				x			
Cardinalidae Ridgway, 1901							

Tabela 1. Continuação...

Taxa	Fitofisionomia					NS	RH
	MS	MC	CD	CE	PC		
Piranga flava (Vieillot, 1822)			x	x	x		x
Cyanoloxia brissonii (Lichtenstein, 1823)		x	x	x			x
Parulidae Wetmore, Friedmann, Lincoln, Miller, Peters, van Rossem, Van Tyne & Zimmer 1947							
Parula pitiayumi (Vieillot, 1817)	x	x	x				x
Geothlypis aequinoctialis (Gmelin, 1789)		x	x				x
Basileuterus hypoleucus Bonaparte, 1830	x	x					x
Basileuterus flaveolus (Baird, 1865)	x	x	x				x
Basileuterus leucophrys Pelzeln, 1868***^{EC}		x					
Icteridae Vigors, 1825							
Psarocolius decumanus (Pallas, 1769)	x	x	x		x		x
Procacicus solitarius (Vieillot, 1816)		x					
Cacicus haemorrhous (Linnaeus, 1766)		x	x	x			x
Cacicus cela (Linnaeus, 1758)	x	x	x	x	x		x
Icterus cayanensis (Linnaeus, 1766)		x	x	x			x
Icterus croconotus (Wagler, 1829)				x	x		x
Gnorimopsar chopi (Vieillot, 1819)			x	x	x		x
Molothrus oryzivorus (Gmelin, 1788)		x	x	x			x
Molothrus bonariensis (Gmelin, 1789)	x	x		x	x		x
Fringillidae Leach, 1820							
Euphonia chlorotica (Linnaeus, 1766)	x	x	x	x	x		x
Euphonia violacea (Linnaeus, 1758)		x					x
Euphonia laniirostris (d'Orbigny & Lafresnaye, 1837)	x	x	x	x			x
Euphonia rufiventris (Vieillot, 1819)		x	x				x

Tabela 2. Número de espécies de aves registradas em diferentes áreas do bioma Cerrado.

Table 2. Number of bird species registered in different areas of the Cerrado Biome.

Local (estado)	Nº de espécies	Fonte
Vila Bela da Santíssima Trindade (MT)	312	Silveira & D'Horta (2002)
Chapada dos Guimarães (MT)	393	Lopes et al. (2009)
Parque Estadual da Serra Azul (MT)	131	Purificação & Castilho (2009)
Planalto da Bodoquena (MS)	353	Pivatto et al. (2006)
ESEC Itirapina (SP)	231	Mota-Júnior et al. (2008)
ESEC Caetus (SP)	293	Cavarzere et al. (2009)
Três Marias (MG)	101	Ribon et al. (1995)
PARNA Serra da Canastra (MG)	282	Silveira (1998)
RPPN do Panga (MG)	231	Marçal-Júnior et al. (2006)
Fazenda Brejão (MG)	273	Faria et al. (2009)
RPPN Mata Samuel de Paula (MG)	188	Ferreira et al. (2009)
PARNA Serra do Cipó (MG)	338	Melo-Júnior et al. (2001), Rodrigues et al. (2005, 2011)
Caldazinha (GO)	124	Blamires et al. (2001)
Niquelândia (GO)	156	Curcino et al. (2007)
PARNA de Brasília (DF)	265	Antas (1995)
ESEC Água Emendadas (DF)	301	Bagno (1998), Lopes et al. (2005)
ESEC Jardim Botânico (DF)	238	Tubelis & Cavalcanti (2001)
PARNA Chapada Diamantina (BA)	359	Parrini et al. (1999)
ESEC Serra Geral do Tocantins (BA/TO)	254	Rego et al. (2011)
Sudeste do Estado do Tocantins (TO)	308	Pacheco & Olmos (2006)
Pedro Afonso (TO)	254	Lopes & Braz (2007)
Região do Cantão (TO)	418	Pinheiro & Dornas (2009)

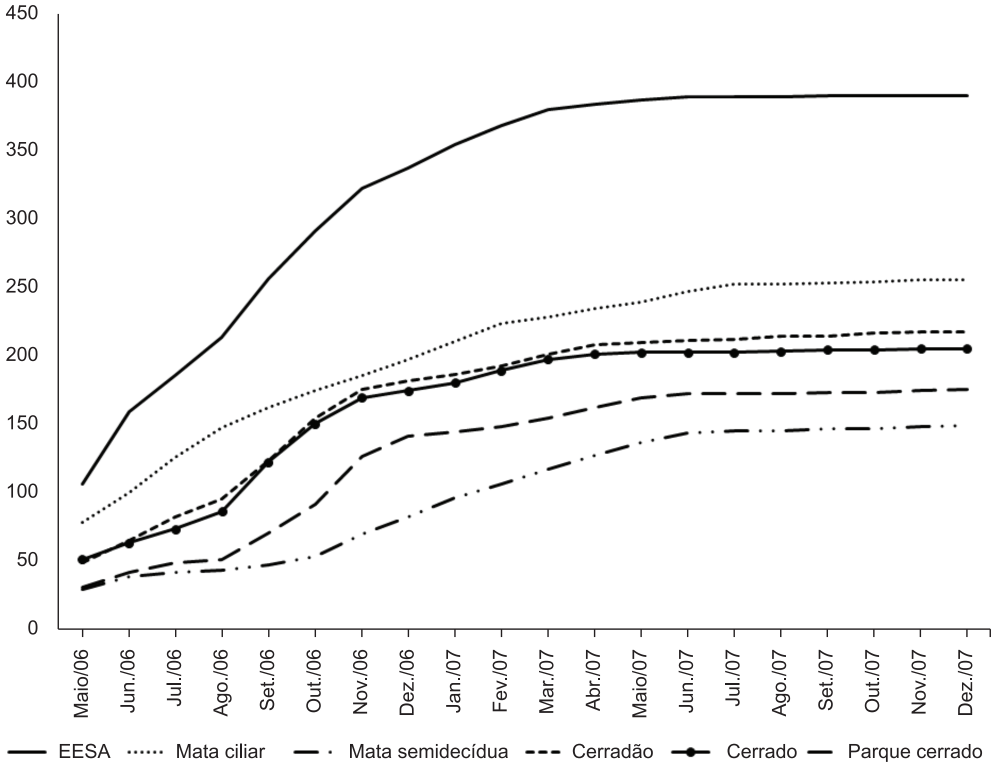

Figura 3. Curva do coletor observada que mostra o acúmulo de espécies registradas nas áreas amostradas de forma sistemática e da ESEC Serra das Araras, no eixo das abscissas temos os meses de amostragem e no das ordenadas temos o número acumulativo de espécies registrados durante o período de estudo.

Figure 3. Collector's Curve indicates an accumulation of species registered in the areas sampled in a systematic basis and the EESA, the x-axis indicates the month of sampling and in the ordinate shows the cumulative number of species recorded during the study period.

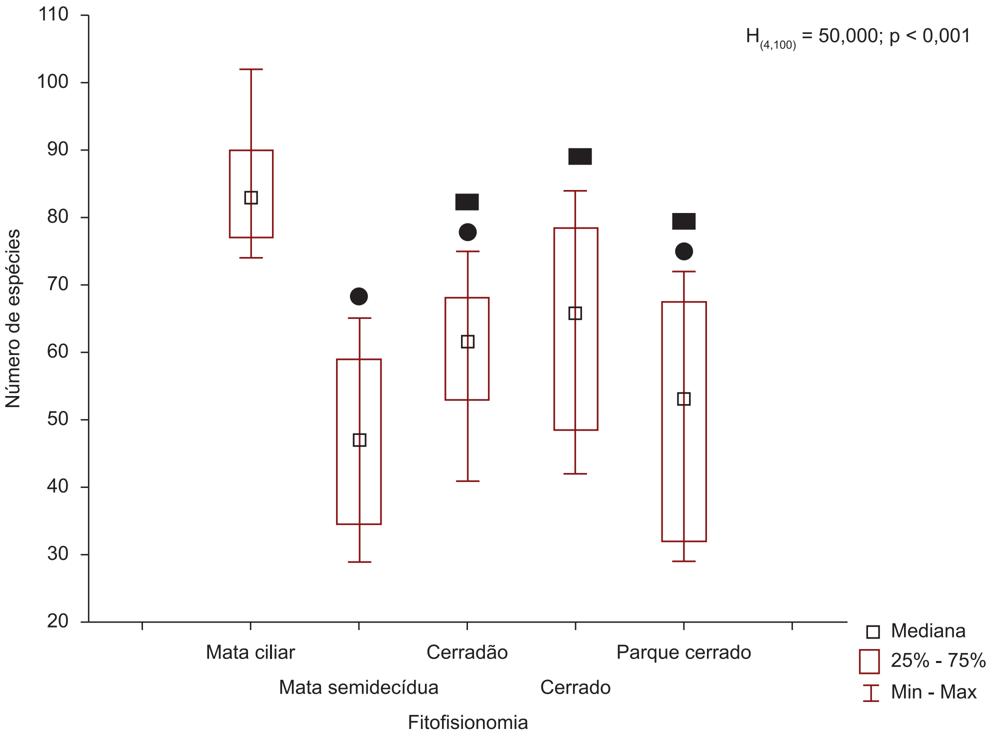

Figura 4. Box-plot do número de espécies de aves observadas nas cinco fitofisionomias amostradas na Estação Ecológica Serra das Araras. Os símbolos indicam as áreas que não apresentaram diferenças das médias quando comparadas pelo teste de Tukey.

Figure 4. Box-plot of the number of bird species found in five vegetation types sampled in the Ecological Station of Serra das Araras. The symbols that indicate the areas that showed no differences of means compared by Tukey test.

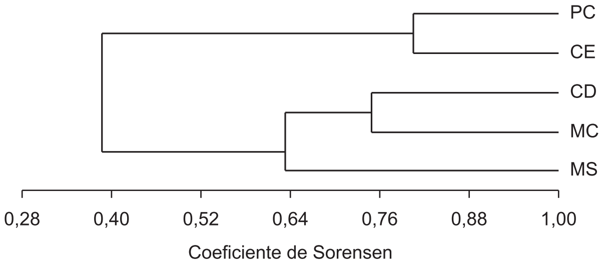

Figura 5. Dendrograma do índice de similaridade de Sörensen para as áreas amostradas de forma sistemática em que: MS (mata semidecídua), MC (mata Ciliar), CD (cerradão), CE (cerrado sentido restrito) e PC (parque cerrado).

Figure 5. Sorensen's similarity coefficient for the areas sampled in a systematic basis in which: MS (semi-deciduous forest), MC (riparian forest), CD (*cerradão*), CE (*cerrado sentido restrito*) and PC (*parque cerrado*).

O registro de 13 espécies de aves endêmicas do Cerrado, que representam 43,3% das espécies endêmicas desse Bioma (Silva 1995, 1997, Cavalcanti 1999, Silva & Santos 2005) e das sete espécies nacionalmente ameaçadas de extinção ressalta a importância da Estação Ecológica Serra das Araras na proteção dessas aves. Devido a sua particularidade, o registro de *C. cyanopis* merece destaque. Ele foi realizado no campo rupestre (Figura 2g) em março de 2007, por volta das oito horas, quando um único indivíduo foi avistado junto com três indivíduos de *C. talpacoti* que bebiam água numa poça em meio as rochas. No ano de 2011 fora montada uma equipe para tentar documentar a espécie durante duas viagens de sete dias, entretanto não foi obtido sucesso. Os registros realizados por Silva & Oniki (1988) não indica o local, somente que fora nos limites da EESA. Willis & Oniki (1990) esclarecem que os registros foram realizados em "campos cerrados". A elaboração de um plano de conservação para essa espécie deve ser considerado dentre os programas de conservação de espécies nacionalmente ameaçadas de extinção.

A presença de alguns elementos do Pantanal e a influência de elementos amazônicos, quando considerado Silva (1996), pode sugerir que a Província Serrana atue como um corredor entre o Cerrado e esses outros dois biomas. Dessa maneira, além dos extensos corredores ribeirinhos, conforme apontado por Silva & Santos (2005); a preservação dessa cadeia de serras é outra estratégia para conservação dessas aves na região, mesmo que sua origem tenha sido relictual. A partir disso, ficam as sugestões de ampliação da ESEC Serra das Araras para sua região nordeste e sudoeste (vale do Rio Jauquara), a criação de um mosaico de unidades de conservação ao longo da Província Serrana e a sugestão de futuros estudos nessa cadeia de montanhas para corroborar ou negar essa "sugestão".

A partir dos resultados apresentados e discutidos, conclui-se que a Estação Ecológica Serra das Araras é uma das áreas no Cerrado com maior riqueza de espécies de aves registradas até o momento; e que além de preservar um elevado número, a presença de espécies endêmicas e nacionalmente ameaçadas de extinção faz dessa área protegida um local de grande importância para a conservação desse grupo animal, o que corrobora o proposto Oliveira et al. (2007) e Pinto et al. (2008), os quais indicam essa região como área prioritária para conservação de aves no Cerrado.

Agradecimentos

Ao colega Fabiano Ficagna de Oliveira pelo auxílio com a identificação de algumas espécies. Ao Nuno Rodrigues da Silva pelo auxílio na elaboração do mapa e a Carolina Pöter de Castro pelo auxílio com o abstract. Aos dois referis anônimos por suas críticas e sugestões para o melhoramento da qualidade do manuscrito.

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Recebido em 27/09/2011
Versão reformulada recebida em 10/08/2012
Publicado em 19/08/2011

Fishes of Paranaguá Estuarine Complex, South West Atlantic

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PASSOS, A.C., CONTENTE, R.F., VILAR, C.C., DAROS, F.A., SPACH, H.L., ABILHÔA, V. & FÁVARO, L.F. **Fishes of Paranaguá Estuarine Complex, South West Atlantic.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn01312032012

Abstract: The objective of this work was to present an updated checklist of the currently known fishes in the Paranaguá Estuarine Complex (PEC) and provides comments on conservation status for the treated species. We used a large dataset derived from a pool of studies which have been conducted within there along the last 30 years. Each study was based on monthly samplings and conducted in several estuarine habitat; thus, the pool covers practically all estuarine habitats and takes into account the seasonal cycle in the system. The PEC ichthyofauna represents a mixture between that fauna typical from the tropical Brazilian coast and that with affinities of temperate Argentinean and Uruguayan zones. The PEC harbors a rich fish fauna of 213 species, inserted in the families that are common along the Brazilian coast. Only a minor part (8%) of the PEC fish fauna was evaluated as regards the conservation status, mostly because of the lack of basic biological and ecological information for most species. Despite part of the among-estuaries differences are due to different and incomplete sampling efforts, the richness in the PEC is surprisingly higher than other systems in Brazil and around world, which emphasize the importance of the region for global biodiversity conservation.
Keywords: *ichthyofauna, species list, Paraná, West Atlantic.*

PASSOS, A.C., CONTENTE, R.F., VILAR, C.C., DAROS, F.A., SPACH, H.L., ABILHÔA, V. & FÁVARO, L.F. **Peixes do Complexo Estuarino de Paranaguá, Atlântico Sul Oeste.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn01312032012

Resumo: O objetivo deste trabalho é apresentar uma lista de espécies atualizada a partir do conhecimento atual dos peixes no Complexo Estuarino de Paranaguá (CEP), com comentários sobre o status de conservação das espécies. Nós utilizamos um grande conjunto de dados derivados de diversos estudos conduzidos na região ao longo dos últimos 30 anos. Cada estudo foi baseado em amostragens mensais realizadas em diferentes habitats estuarinos. Dessa forma, os dados abrangem praticamente todos os habitats estuarinos e leva em conta o ciclo sazonal no sistema. A ictiofauna do CEP representa uma mistura entre a fauna típica da costa tropical brasileira e da fauna com afinidade com as zonas temperadas argentinas e uruguaias. O CEP abriga 213 espécies, inseridas em famílias que são comuns ao longo da costa brasileira. Apenas uma pequena parte (8%) das espécies foi avaliada quanto ao status de conservação, principalmente por causa da falta de informações biológicas e ecológicas básicas para a maioria das espécies. Apesar de parte das diferenças entre estuários ser devido a diferentes e incompletos esforços amostrais, a riqueza do CEP é surpreendentemente elevada em comparação com outros sistemas do Brasil e ao redor do mundo, o que enfatiza a importância da região para a conservação da biodiversidade global.
Palavras-chave: *ictiofauna, lista de espécies, Paraná, Atlântico Oeste.*

Introduction

The Paranaguá Estuarine Complex (PEC), situated on the coast of Paraná state (Brazil) (25° 16' and 25° 34' S and 48° 17' and 48° 42' W), represents the southern sector of one of the last and least impacted, large Brazilian coastal ecosystems, the subtropical Iguape-Cananéia-Paranaguá estuarine system. This system harbors an important biodiversity, as it is inserted in a global biodiversity hotspot, the southern sector of Brazil's Atlantic Forest Biosphere Reserve (Diegues 1995), and an abundance of socio-economically important fishery stocks (Lana et al. 2001). Several surveys and ecological studies on the fish fauna, most of which based on a monthly sampling design including a diversity of estuarine habitats, have been conducted in the PEC along the last 30 years (e.g. Corrêa et al. 1986, Spach et al. 2003, Félix et al. 2007, Queiroz et al. 2007, Schwarz Junior. et al. 2007, Barletta et al. 2008, Contente et al. 2011). Sampling several areas within several temporal scales increases the species detectability and, thus, our ability to estimate the species richness of a given system (Magurran 2003); thus, such robust spatio-temporal information included in the data derived from the pool of these studies provide a unique opportunity to produce a full list of fish species for this system. A compilation of this nature has twofold: (I) helping to improve our understanding on the geographical distribution and macro-ecological traits of the SW Atlantic estuarine fishes (Barletta & Blaber 2007); and (II) supporting conservation efforts (Barletta et al. 2010). Particular concern must be placed to the region's fish biodiversity that is faced to serious treats, notably due to overfishing, introduction of non-native species, and habitat loss (Lana et al. 2001, Vitule et al. 2006, Caires et al. 2007), and a full check-list of species may be an important tool in impact assessments. For instance, dredgings and buildings of ports result in large impact and an ecosystem scale check-list may serve as a parameter against which the potentially affected pattern of the fish fauna may be compared, thus helping to assess the strength of impact (Sheaves 2006, Barletta et al. 2010). The objective of the present work is, therefore, to present an updated checklist of the currently known fishes in the PEC. Additionally, we provided comments on conservation status for the treated species.

Materials and Methods

1. *Study area*

The PEC (Figure 1) has an area of 612 km^2 (see map in Lana et al. 2001) characterized by distinct areas and densities of drainage, tidal flats and mean depths (Noernberg et al. 2004). The system has a diversity of habitats, like tidal flats, channels, mangroves (mainly composed by *Rhizophora mangle*, *Avicennia schaueriana*, *Laguncularia racemosa*, and *Conocarpus erectus*; Lana et al. 2001) fringed by *Spartina alterniflora* bank salt-marshes, tidal creeks, estuarine beaches, rivers, and rock shores near the mouth of the

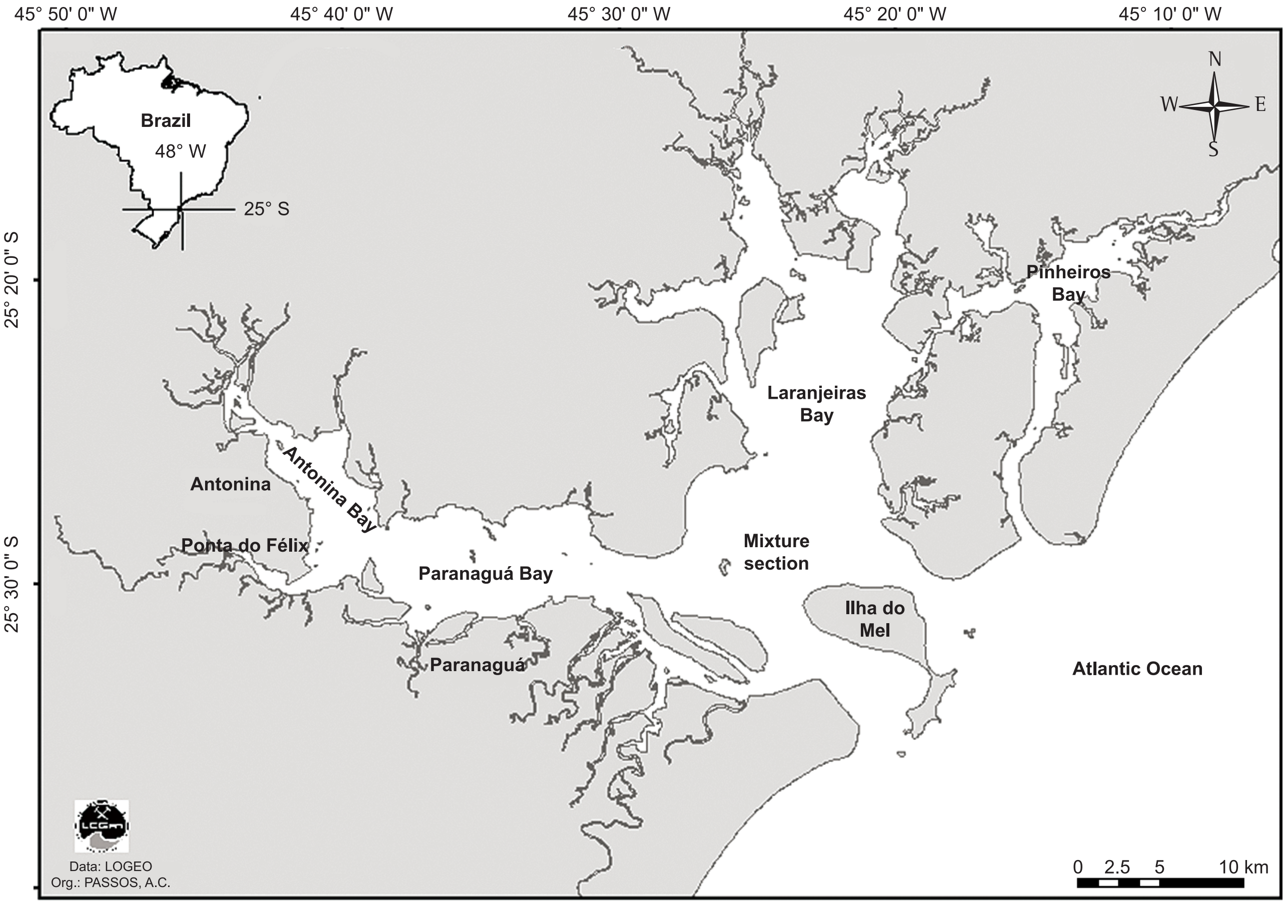

Figure 1. Map of Paranaguá Estuarine Complex, showing the five central sectors (Antonina, Paranaguá, Laranjeiras, mixing zone and Pinheiros); and the position of port areas (ports of Paranaguá, Antonina and Ponta do Félix).

Figura 1. Mapa do Complexo Estuarino de Paranaguá, mostrando as Baías de Antonina, Paranaguá, das Laranjeiras, Pinheiros e setor de mistura; e a localização dos Portos de Paranaguá, Antonina e Ponta do Félix.

estuary. The PEC, a partially mixed estuary with semidiurnal tides and diurnal inequality (Knoppers et al. 1987), is connected to the Cananéia Estuarine Complex, in the north, by the Ararapira Channel and to the Atlantic Ocean, in the east, by Sueste Channel and Galheta Channel. The climate of the region is tropical (transition), with a mean annual rainfall of 2500 mm (maximum 3500 mm). The rainy season typically starts at the end of spring and lasts until nearly the end of summer. The dry season lasts from the end of autumn to the end of winter, but is interrupted by a short low-intensity rainy period that occurs at the beginning of winter (Lana et al. 2001). To further details on the system, see Lana et al. (2001) and Marone et al. (2005).

2. *Data collection and treatment of the data*

This work is based on the compilation of data from unpublished PhD thesis and master dissertations (i.e. Abilhôa 1998, Pinheiro 1999, Fávaro 2004, Nakayama 2004, Stefanoni 2007, Pichler 2009) and from the literature dealing with the PEC fish community (e.g. Corrêa et al. 1986, Godefroid et al. 1997, 1999, Santos et al. 2002, Vendel et al. 2002, Spach et al. 2003, Vendel et al. 2003, Spach et al. 2004a, b, 2006, Félix et al. 2007, Queiroz et al. 2007, Schwarz Junior et al. 2007, Barletta et al. 2008, Oliveira Neto et al. 2008, Pichler et al. 2008, Cortellete et al. 2009, Hackradt et al. 2009, Ignácio & Spach 2009, Contente et al. 2011). It is important to highlight that this study is representative of most habitats (e.g. tidal flats, channels, vegetated wetlands, tidal creeks, estuarine beaches, rivers) and the extension of the system, i.e., from the representative, upper tidal freshwater reaches (like upper Antonina Bay Estuary and upper Guaragaçu River Estuary) to the mouths of the estuary (like Pontal do Sul and Ilha das Peças beaches). Practically all studies were took place with monthly samplings along the seasonal cycle. The species in this study were reviewed as regards the taxonomic classification and the nomenclature based on Marceniuk (2005), Craig & Hastings (2007), Smith & Craig (2007), Eschmeyer (2010), Carvalho-Filho et al. (2010), Figueiredo et al. (2010), and Menezes et al. (2010). *Mugil* sp. was used for the species usually identified under the invalid name *Mugil gaimardianus* (Menezes et al. 2003). The orders and families were listed in phylogenetic order according to Eschmeyer (2010) and the species were organized within each family in alphabetical order. To analyze zoogeographic affinities, the distribution of each species was verified from the literature and then inserted into the adapted categories based on Floeter et al. (2008) and Luiz Junior et al. (2008) as follows: CT = Circumtropical, TA = Trans-Atlantic (western and eastern Atlantic Ocean), WA = Western Atlantic (northern and southern Atlantic Ocean), SWA = Southern West Atlantic (from northern Brazil to Argentina), SSWA = Southern South West Atlantic (species with temperate affinities occurring from Argentina and Uruguay to the south and southeast of Brazil), Ca = Caribbean (from Florida state to Venezuela), Br = Brazilian Province (area between the Orinoco Delta in Venezuela and Santa Catarina in Brazil), EA = Eastern Atlantic and EP = Eastern Pacific. The status of species conservation was based both on the International Union for Conservation of Nature list (International... 2012) and the Ministry of the Environment list for endangered fauna (Brasil 2004, 2008).

Results and Discussion

The ichthyofauna of the PEC consists of 213 species, distributed in 21 orders and 65 families (Table 1). A total of 97% (208 spp.) are Actinopterygii and 3% (5), Elasmobranchii. Twenty species (i.e. *H. robertii*, *O. vespertilio*, *A. clupeoides*, *A. januaria*, *G. ocellatus*, *S. brasiliensis*, *S. plumieri*, *A. brasilianus*, *M. bonaci*, *L. synagris*, *A. probatocephalus*, *C. penna*, *P. cromis*, *U. parvus*, *G. brasiliensis*, *E. pisonis*, *S. picudilla*, *A. solandri*, *P. patagonicus* and *T. microphthalmus*) were recorded for the first time for the PEC. Perciformes (116) dominated in number of species, followed by Clupeiformes (20), Pleuronectiformes (17), and Syngnathiformes (8). The most speciose family was Sciaenidae (23), followed by Carangidae (17), Engraulidae (12), Gobiidae (9), Haemulidae (9), and Paralichthyidae (9). This is supported by Andrade-Tubino et al. (2008) that state such families among the most important in Brazilian coast, and by Vieira & Musick (1994), which reveal them as the most conspicuous in SW Atlantic estuarine fish assemblages. Carangidae and Sciaenidae were also the two most speciose families in the two large estuaries near the PEC, the Guaratuba Bay, located just south of the PEC, and the Babitonga Bay, located 70 Km south of the PEC (Chaves & Corrêa 1998, Chaves & Vendel 2001, Vilar et al. 2011). *Anchoa* and *Cynoscion* had six species each and were the richest genera in the PEC. The following were *Mugil*, with five species, and *Ctenogobius*, *Paralichthys*, *Sphoeroides*, *Sphyraena* and *Trachinotus*, with four species each. This pattern was not found in such nearby estuaries, as *Ctenogobius*, followed by *Eucinostomus* and *Oligoplites* were the richest genera in Guaratuba (Chaves & Corrêa 1998, Chaves & Vendel 2001), and *Mycteroperca*, *Mugil*, *Anchoa*, *Cynoscion*, *Eucinostomus* and *Sphoeroides* were those most rich in Babitonga (Vilar et al. 2011). Comparing the species composition of PEC with that of Babitonga and Guaratuba estuaries reveals a relatively low number shared (just 35%) and relatively a high number of exclusive species (about 40%) of the PEC. This is unexpected because the distribution for most species occurring in all such estuaries overlaps. Such taxonomic differences are most likely due to differences in number of fish survey as well as in fish sampling gear and strategies (see discussion below).

In terms of number of species, the total species richness in the PEC is higher than those reported for large estuaries in Western Atlantic [Guaratuba Bay, southern Brazil (87 spp.; Chaves & Corrêa 1998, Chaves & Vendel 2001); Río de la Plata estuary, northern Argentina (60 spp.; Jaureguizar et al. 2004); Caeté River estuary, northern Brazil (82spp.; Barletta et al. 2005), Sergipe River estuary (136 spp.; Alcântara 2006), Curuçá estuary (98 spp.; Hercos 2006, Giarrizzo & Krumme 2007, Sarpedonti et al. 2008), Babitonga Bay (152 spp.; Vilar et al. 2011), Estuary of Mataripe area (36 spp.; Dias et al. 2011) and Paraguaçu River estuary (124 spp.; Reis-Filho et al. 2010)] as well as for other large, permanently open, tropical estuaries around world (number of species ranging from 81 to 197, Blaber 2002), including those of estuaries from the species-rich Indo Pacific biogeographical zones. Moreover, the PEC has a comparable fauna to large coastal ecosystems, like Gulf of Carpentaria (237 spp.) (Blaber et al. 1990) and Embley estuary (203 spp.) (Barletta & Blaber 2007), which has a large diversity of estuarine habitats, similar to that of PEC. These differences in richness and taxonomic composition may be difficult to explain. Multiple area specific synergic factors act in determining fish fauna patterns, including diversity of estuarine habits, rainfall pattern, hydrograph, oceanographic patterns, and historic dispersion pattern of taxa and so on. These operate in different intensity and scale, producing very distinct fish fauna patterns. For example, in a continental scale, the estuarine area may be critical to determine the fish richness in accordance with the species-area theory. This theory states that, the larger a given system, the larger the number of species, because the number of habitat tend to increase with the area. In fact, the PEC is larger (612 km^2) than the Guaratuba Bay (48 km^2), Babitonga Bay (130 km^2), Sergipe River estuary (47.1 km^2) and Paraguaçu River estuary (127.9 km^2) and this may explain, at least in part, the higher richness in PEC. However, a considerable part of such differences among tropical fish faunas can be attributed to the incomplete effort of surveys on all range of estuarine habitats

Table 1. Taxonomic classification of the ichthyofauna recorded in the Paranaguá Estuarine Complex, Southwest Atlantic.

Tabela 1. Classificação taxonômica da ictiofauna encontrada no Complexo Estuarino de Paranaguá, Atlântico Sul Oeste.

Orders/Families/Species	Geographic distribution	Source
Torpediniformes		
Narcinidae		
Narcine brasiliensis (Olfers 1831)	WA	Spach et al. (2004a)
Rajiformes		
Rhinobatidae		
Rhinobatos horkelii Müller & Henle 1841†	SWA	Barletta et al. (2008)
R. percellens (Walbaum 1792)	TA	Pichler et al. (2008)
Dasyatidae		
Dasyatis guttata (Bloch & Schneider 1801)	Ca+Br	Schwarz Junior et al. (2007)
Gymnuridae		
Gymnura altavela (Linnaeus 1758)	TA	Schwarz Junior et al. (2007)
Elopiformes		
Elopidae		
Elops saurus Linnaeus 1766	WA	Pichler et al. (2008)
Albuliformes		
Albulidae		
Albula vulpes (Linnaeus 1758)	WA	Pichler et al. (2008)
Anguilliformes		
Muraenidae		
Gymnothorax ocellatus Agassiz 1831	Ca+SWA	Nakayama (2004)
Ophichthidae		
Echiophis intertinctus (Richardson 1848)	WA	Spach et al. (2004a)
Myrophis punctatus Lütken 1852	WA	Spach et al. (2004a)
Ophichthus gomesii (Castelnau 1855)	WA	Oliveira Neto et al. (2008)
Congridae		
Conger orbignianus Valenciennes 1837	SSWA	Spach et al. (2004a)
Muraenesocidae		
Cynoponticus savanna (Bancroft 1831)	Ca+Br	Spach et al. (2004a)
Nettastomatidae		
Hoplunnis tenuis Ginsburg 1951	WA	Spach et al. (2004a)
Clupeiformes		
Clupeidae		
Brevoortia sp.	?	Godefroid et al. (1999)
Chirocentrodon bleekerianus (Poey 1867)	Ca+Br	Oliveira Neto et al. (2008)
Harengula clupeola (Cuvier 1829)	WA	Pichler et al. (2008)
H. jaguana Poey 1865	WA	Godefroid et al. (1997)
Opisthonema oglinum (Lesueur 1818)	WA	Pichler et al. (2008)
Platanichthys platana (Regan 1917)	SSWA	Pichler et al. (2008)
Sardinella brasiliensis (Steindachner 1879) ††	SSWA	Pichler et al. (2008)
Engraulidae		
Anchoa filifera (Fowler 1915)	Ca+Br	Godefroid et al. (1997)
A. hepsetus (Linnaeus 1758)	WA	Barletta et al. (2008)
A. januaria (Steindachner 1879)	Br	Pichler (2009)
A. lyolepis (Evermann & Marsh 1900)	WA	Pichler et al. (2008)
A. spinifer (Valenciennes 1848)	Ca+Br+EP	Barletta et al. (2008)
A. tricolor (Spix & Agassiz 1829)	SWA	Pichler et al. (2008)
Anchovia clupeoides (Swainson 1839)	Ca+Br	Nakayama (2004)
Anchoviella brevirostris (Günther 1868)	Br	Barletta et al. (2008)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
A. lepidentostole (Fowler 1911)	Br	Vendel et al. (2002)
Cetengraulis edentulus (Cuvier 1829)	Ca+Br	Pichler et al. (2008)
Engraulis anchoita Hubbs & Marini 1935	SSWA	Ignácio & Spach (2009)
Lycengraulis grossidens (Agassiz 1829)	Br+SWA	Pichler et al. (2008)
Pristigasteridae		
Pellona harroweri (Fowler 1917)	Ca+Br	Spach et al. (2004a)
Siluriformes		
Ariidae		
Bagre bagre (Linnaeus 1766)	Ca+Br	Schwarz Junior et al. (2007)
Cathorops spixii (Agassiz 1829)	Ca+Br	Pichler et al. (2008)
Genidens barbus (Lacepède 1803) ††	SSWA	Queiroz et al. (2007)
G. genidens (Cuvier 1829)	SSWA	Pichler et al. (2008)
Notarius luniscutis (Valenciennes 1840)	Br	Schwarz Junior et al. (2007)
Osmeriformes		
Argentinidae		
Glossanodon pygmaeus Cohen 1958	WA	Godefroid et al. (1999)
Aulopiformes		
Synodontidae		
Synodus foetens (Linnaeus 1766)	WA	Pichler et al. (2008)
Gadiformes		
Phycidae		
Urophycis brasiliensis (Kaup 1858)	SSWA	Barletta et al. (2008)
Batrachoidiformes		
Batrachoididae		
Batrachoides sp.	?	Barletta et al. (2008)
Opsanus beta (Goode & Bean 1880)	Ca	Ignácio & Spach (2009)
Porichthys porosissimus (Cuvier 1829)	SSWA	Oliveira Neto et al. (2008)
Lophiiformes		
Ogcocephalidae		
Ogcocephalus vespertilio (Linnaeus 1758)	Ca+SWA	Pinheiro (1999)
Gobiesociformes		
Gobiesocidae		
Gobiesox strumosus Cope 1870	WA	Godefroid et al. (1997)
Atheriniformes		
Atherinopsidae		
Atherinella brasiliensis (Quoy & Gaimard 1825)	Ca+Br	Pichler et al. (2008)
Membras dissimilis (Carvalho 1956)	SSWA	Godefroid et al. (1999)
Odontesthes bonariensis (Valenciennes 1835)	SSWA	Spach et al. (2004a)
O. incisa (Jenyns 1841)	SSWA	Spach et al. (2004a)
Cyprinodontiformes		
Poeciliidae		
Poecilia vivipara Bloch & Schneider 1801	Br+SWA	Spach et al. (2004a)
Beloniformes		
Belonidae		
Strongylura marina (Walbaum 1792)	WA	Pichler et al. (2008)
S. timucu (Walbaum 1792)	WA	Pichler et al. (2008)
Hemiramphidae		
Hemiramphus brasiliensis (Linnaeus 1758)	TA	Oliveira Neto et al. (2008)
Hyporhamphus roberti (Valenciennes 1847)	WA+EP	Pichler (2009)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
H. unifasciatus (Ranzani 1841)	WA+EP	Pichler et al. (2008)
Exocoetidae		
Parexocoetus brachypterus (Richardson 1846)	TA+EP	Spach et al. (2004a)
Syngnathiformes		
Fistulariidae		
Fistularia petimba Lacepède 1803	TA	Pichler et al. (2008)
F. tabacaria Linnaeus 1758	TA	Spach et al. (2004a)
Syngnathidae		
Bryx dunckeri (Metzelaar 1919)	WA	Spach et al. (2004a)
Cosmocampus elucens (Poey 1868)	WA	Spach et al. (2004a)
Hippocampus reidi Ginsburg 1933 ††/‡	WA	Spach et al. (2004a)
Pseudophallus mindii (Meek & Hildebrand 1923)	Ca+Br	Spach et al. (2004a)
Syngnathus folletti Herald 1942	SWA	Spach et al. (2004a)
S. pelagicus Linnaeus 1758	WA	Pichler et al. (2008)
Scorpaeniformes		
Scorpaenidae		
Pontinus rathbuni Goode & Bean 1896	WA	Spach et al. (2004a)
Scorpaena brasiliensis Cuvier 1829	WA	Nakayama (2004)
S. isthmensis Meek & Hildebrand 1928	WA	Spach et al. (2007)
S.plumieri Bloch 1789	WA	Pinheiro (1999)
Dactylopteridae		
Dactylopterus volitans (Linnaeus 1758)	TA	Spach et al. (2004a)
Triglidae		
Prionotus nudigula Ginsburg 1950	SSWA	Queiroz et al. (2007)
P. punctatus (Bloch 1793)	Ca+SWA	Spach et al. (2004a)
Perciformes		
Centropomidae		
Centropomus parallelus Poey 1860	WA	Pichler et al. (2008)
C.undecimalis (Bloch 1792)	WA	Spach et al. (2004a)
Acropomatidae		
Synagrops bellus (Goode & Bean 1896)	TA	Spach et al. (2004a)
Serranidae		
Acanthistius brasilianus (Cuvier 1828)	SSWA	Fávaro (2004)
Alphestes afer (Bloch 1793) §	TA	Spach et al. (2004a)
Diplectrum radiale (Quoy & Gaimard 1824)	WA	Spach et al. (2004a)
Epinephelus itajara (Lichtenstein 1822) ††/*	WA	Barletta et al. (2008)
Hyporthodus nigritus (Holbrook 1855) *	WA	Godefroid et al. (1997)
Mycteroperca bonaci (Poey 1860) ††/#	WA	Fávaro (2004)
M. rubra (Bloch 1793) §	TA	Spach et al. (2004a)
Rypticus randalli Courtenay 1967	Ca+Br	Spach et al. (2004a)
Pomatomidae		
Pomatomus saltatrix (Linnaeus 1766) ††	CT	Spach et al. (2004a)
Carangidae		
Carangoides bartholomaei Cuvier 1833	WA	Barletta et al. (2008)
Caranx hippos (Linnaeus 1766)	TA	Oliveira Neto et al. (2008)
C. latus Agassiz 1831	TA	Pichler et al. (2008)
C. ruber (Bloch 1793)	WA	Spach et al. (2004a)
Chloroscombrus chrysurus (Linnaeus 1766)	TA	Pichler et al. (2008)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
Hemicaranx amblyrhynchus (Cuvier 1833)	WA	Corrêa et al. (1986)
Oligoplites palometa (Cuvier 1832)	Ca+Br	Barletta et al. (2008)
O. saliens (Bloch 1793)	Ca+SWA	Pichler et al. (2008)
O. saurus (Bloch & Schneider 1801)	WA	Spach et al. (2004a)
Selene setapinnis (Mitchill 1815)	WA	Spach et al. (2004a)
S. vomer (Linnaeus 1758)	WA	Pichler et al. (2008)
Seriola lalandi Valenciennes 1833	CT	Spach et al. (2004a)
Trachinotus carolinus (Linnaeus 1766)	WA	Pichler et al. (2008)
T. falcatus (Linnaeus 1758)	WA	Pichler et al. (2008)
T. goodei Jordan & Evermann 1896	WA	Spach et al. (2004a)
T. marginatus Cuvier 1832	SSWA	Spach et al. (2004a)
Uraspis secunda (Poey 1860)	CT	Godefroid et al. (1997)
Lutjanidae		
Lutjanus analis (Cuvier 1828) ††/•	WA	Spach et al. (2004a)
L. griseus (Linnaeus 1758)	WA	Spach et al. (2003)
L. synagris (Linnaeus 1758)	WA	Pinheiro (1999)
Lobotidae		
Lobotes surinamensis (Bloch 1790)	CT	Godefroid et al. (1997)
Gerreidae		
Diapterus auratus Ranzani 1842	WA	Ignácio & Spach (2009)
Diapterus rhombeus (Cuvier 1829)	Ca+Br	Pichler et al. (2008)
Eucinostomus argenteus Baird & Girard 1855	WA+EP	Pichler et al. (2008)
E. gula (Quoy & Gaimard 1824)	WA	Pichler et al. (2008)
E. melanopterus (Bleeker 1863)	TA	Pichler et al. (2008)
Eugerres brasilianus (Cuvier 1830)	WA	Oliveira Neto et al. (2008)
Ulaema lefroyi (Goode 1874)	Ca+Br	Spach et al. (2003)
Haemulidae		
Anisotremus surinamensis (Bloch 1791)	WA	Pichler et al. (2008)
A. virginicus (Linnaeus 1758)	WA	Spach et al. (2004a)
Boridia grossidens Cuvier 1830	SSWA	Spach et al. (2006)
Conodon nobilis (Linnaeus 1758)	WA	Spach et al. (2004a)
Genyatremus luteus (Bloch 1790)	Ca+Br	Spach et al. (2004a)
Haemulon steindachneri (Jordan & Gilbert 1882)	Ca+SWA	Godefroid et al. (1997)
Orthopristis ruber (Cuvier 1830)	Ca+SWA	Pichler et al. (2008)
Pomadasys corvinaeformis (Steindachner 1868)	Ca+SWA	Spach et al. (2004a)
P. ramosus (Poey 1860)	Ca+Br	Hackradt et al. (2009)
Sparidae		
Archosargus probatocephalus (Walbaum 1792)	WA	Pichler (2009)
Archosargus rhomboidalis (Linnaeus 1758)	WA	Godefroid et al. (1997)
Calamus penna (Valenciennes 1830)	WA	Pinheiro (1999)
Diplodus argenteus (Valenciennes 1830)	SWA	Spach et al. (2004a)
Sciaenidae		
Bairdiella ronchus (Cuvier 1830)	Ca+Br	Pichler et al. (2008)
Ctenosciaena gracilicirrhus (Metzelaar 1919)	Ca+Br	Spach et al. (2004a)
Cynoscion acoupa (Lacepède 1801)	Ca+SWA	Oliveira Neto et al. (2008)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
C. jamaicensis (Vaillant & Bocourt 1883)	Ca+SWA	Schwarz Junior et al. (2007)
C. leiarchus (Cuvier 1830)	Ca+Br	Spach et al. (2004a)
C. microlepidotus (Cuvier 1830)	Br	Spach et al. (2004a)
C. striatus (Cuvier 1829)	SSWA	Ignácio & Spach (2009)
C. virescens (Cuvier 1830)	Ca+Br	Schwarz Junior et al. (2007)
Isopisthus parvipinnis (Cuvier 1830)	Ca+Br	Spach et al. (2004a)
Larimus breviceps Cuvier 1830	Ca+Br	Spach et al. (2004a)
Macrodon atricauda (Bloch & Schneider 1801) ††	Br+SWA	Schwarz Junior et al. (2007)
Menticirrhus americanus (Linnaeus 1758)	WA	Pichler et al. (2008)
M. littoralis (Holbrook 1847)	WA	Spach et al. (2004a)
Micropogonias furnieri (Desmarest 1823) ††	Ca+SWA	Pichler et al. (2008)
Nebris microps Cuvier 1830	Br	Schwarz Junior et al. (2007)
Ophioscion punctatissimus Meek & Hildebrand 1925	Ca+Br	Spach et al. (2004a)
Paralonchurus brasiliensis (Steindachner 1875)	Ca+SWA	Schwarz Junior et al. (2007)
Pogonias cromis (Linnaeus 1766)	WA	Pichler (2009)
Stellifer brasiliensis (Schultz 1945)	Br	Spach et al. (2004a)
S. rastrifer (Jordan 1889)	Br+SSWA	Ignácio & Spach (2009)
S. stellifer (Bloch 1790)	Br	Spach et al. (2004a)
Umbrina canosai Berg 1895 ††	SSWA	Spach et al. (2004a)
U. coroides Cuvier 1830	WA	Ignácio & Spach (2009)
Polynemidae		
Polydactylus oligodon (Günther 1860)	WA	Godefroid et al. (1999)
P. virginicus (Linnaeus 1758)	WA	Spach et al. (2004a)
Mullidae		
Mullus auratus Jordan & Gilbert 1882	WA	Barletta et al. (2008)
Pseudupeneus maculatus (Bloch 1793)	WA	Spach et al. (2004a)
Upeneus parvus Poey 1852	WA	Pinheiro (1999)
Mugilidae		
M. curema Valenciennes 1836	TA+EP	Pichler et al. (2008)
M. curvidens Valenciennes 1836	Ca+Br	Spach et al. (2004a)
M. incilis Hancock 1830	Ca+Br	Spach et al. (2004a)
M. liza Valenciennes 1836 ††	WA	Pichler et al. (2008)
Mugil sp.	?	Spach et al. (2004a)
Cichlidae		
Geophagus brasiliensis (Quoy & Gaimard 1824)	SSWA	Pichler (2009)
Oreochromis niloticus (Linnaeus 1758)	EA	Contente et al.(2010)
Uranoscopidae		
Astroscopus sexspinosus (Steindachner 1876)	SSWA	Spach et al. (2004a)
A. y-graecum (Cuvier 1829)	WA	Pichler et al. (2008)
Pinguipedidae		
Pinguipes brasilianus Cuvier 1829	SSWA	Spach et al. (2004a)
Clinidae		
Ribeiroclinus eigenmanni (Jordan 1888)	SSWA	Spach et al. (2004a)
Blenniidae		
Hypleurochilus sp.	?	Corrêa et al. (1986)
Parablennius pilicornis (Cuvier 1829)	TA	Spach et al. (2004b)
Eleotridae		
Dormitator maculatus (Bloch 1792)	WA	Queiroz et al. (2007)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
Eleotris pisonis (Gmelin 1789)	WA	Fávaro (2004)
Guavina guavina (Valenciennes 1837)	WA	Pichler et al. (2008)
Gobiidae		
Awaous tajasica (Lichtenstein 1822)	WA	Vendel et al. (2002)
Bathygobius soporator (Valenciennes 1837)	TA	Pichler et al. (2008)
Ctenogobius boleosoma (Jordan & Gilbert 1882)	WA	Pichler et al. (2008)
C. shufeldti (Jordan & Eigenmann 1887)	WA	Pichler et al. (2008)
C. smaragdus (Valenciennes 1837)	WA	Pichler et al. (2008)
C. stigmaticus (Poey 1860)	WA	Vendel et al. (2002)
Gobioides broussonnetii Lacepède 1800	WA	Cortellete et al. (2009)
Gobionellus oceanicus (Pallas 1770)	WA	Pichler et al. (2008)
Microgobius meeki Evermann & Marsh 1899	Ca+Br	Pichler et al. (2008)
Ephippidae		
Chaetodipterus faber (Broussonet 1782)	WA	Pichler et al. (2008)
Sphyraenidae		
Sphyraena barracuda (Edwards 1771)	CT	Spach et al. (2004a)
S. guachancho Cuvier 1829	TA	Spach et al. (2004a)
S. picudilla Poey 1860	WA	Abilhôa (1998)
S. tome Fowler 1903	SSWA	Vendel et al. (2003)
Trichiuridae		
Trichiurus lepturus Linnaeus 1758	CT	Spach et al. (2004a)
Scombridae		
Acanthocybium solandri (Cuvier 1832) §	CT	Fávaro (2004)
Scomberomorus brasiliensis Collette, Russo & Zavala-Camin 1978 §	Ca+Br	Pichler et al. (2008)
S. cavalla (Cuvier 1829) §	WA	Spach et al. (2004a)
Stromateidae		
Peprilus paru (Linnaeus 1758)	WA	Spach et al. (2004a)
Pleuronectiformes		
Paralichthyidae		
Citharichthys arenaceus Evermann & Marsh 1900	WA	Pichler et al. (2008)
C. macrops Dresel 1885	WA	Félix et al. (2007)
C. spilopterus Günther 1862	WA	Pichler et al. (2008)
Etropus crossotus Jordan & Gilbert 1882	WA+EP	Pichler et al. (2008)
Paralichthys brasiliensis (Ranzani 1842)	SWA	Pichler et al. (2008)
P. orbignyanus (Valenciennes 1839)	SSWA	Pichler et al. (2008)
P. patagonicus Jordan 1889	SSWA+EP	Stefanoni (2007)
P. tropicus Ginsburg 1933	WA	Santos et al. (2002)
Syacium papillosum (Linnaeus 1758)	WA	Félix et al. (2007)
Pleuronectidae		
Oncopterus darwinii Steindachner 1874	SSWA	Godefroid et al. (1997)
Pleuronectes sp.	?	Barletta et al. (2008)
Achiridae		
Achirus declivis Chabanaud 1940	WA	Ignácio & Spach (2009)
A. lineatus (Linnaeus 1758)	WA	Pichler et al. (2008)

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Table 1. Continued...

Orders/Families/Species	Geographic distribution	Source
Trinectes microphthalmus (Chabanaud 1928)	Ca+Br	Fávaro (2004)
T. paulistanus (Miranda Ribeiro 1915)	Ca+Br	Spach et al. (2004a)
Cynoglossidae		
Symphurus plagusia (Bloch & Schneider 1801)	Ca+Br	Spach et al. (2004a)
S. tesselatus (Quoy & Gaimard 1824)	Ca+Br+SSWA	Spach et al. (2004a)
Tetraodontiformes		
Monacanthidae		
Stephanolepis hispidus (Linnaeus 1766)	TA	Spach et al. (2004a)
Tetraodontidae		
Lagocephalus laevigatus (Linnaeus 1766)	TA	Pichler et al. (2008)
Sphoeroides greeleyi Gilbert 1900	Ca+Br	Spach et al. (2004a)
S. spengleri (Bloch 1785)	TA	Schwarz Junior et al. (2007)
S. testudineus (Linnaeus 1758)	WA	Pichler et al. (2008)
S. tyleri Shipp 1972	Br	Vendel et al. (2002)
Diodontidae		
Chilomycterus spinosus (Linnaeus 1758)	SWA	Pichler et al. (2008)

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and/or the use of different sampling gears across tropical estuaries around the world (Blaber 2002).

The species' classification into the geographical categories used in this study present here, which were adapted from Floeter et al. (2008) and Luiz Junior et al. (2008), fits well with the species' distribution described on the literature. This is an indicative of utility of such a classification for future studies aiming to classify SW Atlantic estuarine fishes. Most species in the PEC are widely distributed throughout the Western Atlantic (40%), followed by those that are restricted to (and occur both in) the Caribbean and Brazilian (15%), and South-West Atlantic (11%) provinces (Figure 2). Thus, the PEC fish fauna can be regarded as a mixture between the fish fauna typical from the tropical Brazilian coast and those with affinities of temperate Argentinean and Uruguayan zones.

Our results suggest an expansion of the geographical distribution for *G. pygmaeus* and *M. auratus*. *G. pygmaeus*, recorded in Godefroid et al. (1997, 1999), which was previously reported only for the tropical Western Atlantic, from South Carolina state to the tropical coast of Brazil, near the equator (Eschmeyer 2010), and *Mullus auratus*, recorded by Barletta et al. (2008), previously reported from North Carolina, USA, to the Caribbean (Floeter et al. 2008).

Only a minor part (8%) of the PEC fish fauna was evaluated as regards the conservation status: ten are on the IUCN Red List (International... 2012), 12 on the ME list (Brasil 2004, 2008), and four are on both. Of the ten species on the IUCN Red List (International... 2012), two (*Epinephelus itajara* and *Hyporthodus nigritus*) are critically endangered, one (*Mycteroperca bonaci*) is near threatened, one (*Lutjanus analis*) is vulnerable, five (*Alphestes afer*, *Mycteroperca rubra*, *Acanthocybium solandri*, *Scomberomorus brasiliensis* and *S. cavalla*) are least concern and one (*Hippocampus reidi*) is data deficient. Among the 12 species on the Ministry of the Environment List, 11 are overexploited and one is endangered (*Rhinobatus horkelii*). Many fishery species in PEC are found to be classified as threatened on the list for endangered fauna of the adjacent state of São Paulo (São Paulo 2010). It is supposed that many species in PEC have similar conservation status 'threatened' as face similar threats to those of São Paulo state coast, where the fishing pressure is similar to that of Paraná state. Such a setting reinforces the urgent need for critical, basic information for fish species to support their conservation effort through IUCN classification in this important estuary.

Particular concern must be place to introduction in the PEC of the species *Opsanus beta*, from the North Atlantic (Eschmeyer 2010), and *Oreochromis niloticus* from Africa. Although the impact of *O. beta* on the native fish fauna is still unknown (Caires et al. 2007), it is supposed to be serious, as it is a voracious, generalized predator (Gray & Winn 1961). Moreover, recent field observations have already reported *O. beta* as a very common by-catch in long-line inside estuary, thus affecting local fisheries. *O. niloticus* is classified as a pest and has been reported to adversely impact ecosystem after its introduction (Froese & Pauly 2010). Future studies assessing the degree of establishment success of such species and their impact on the local fish biodiversity are strongly recommended.

This study provides a full list of fish species of the Paranaguá Estuarine Complex based on a robust dataset, which takes into account a wide and representative spatio temporal variability, largely improving the species detectability. The ichthyofauna of the PEC contains taxa with affinities from the tropical Brazilian coast and those with affinities of temperate Argentinean and Uruguayan waters. The fish richness of the system of 213 species is surprisingly higher than other systems in Brazil and around world, which emphasize the importance of the region for global biodiversity conservation. Once we have knowledge of the species and the richness of PEC, we suggest a fauna monitoring for a regional analysis of conservation status and more details about impacts of exotic species for the creation of management and conservation proposals.

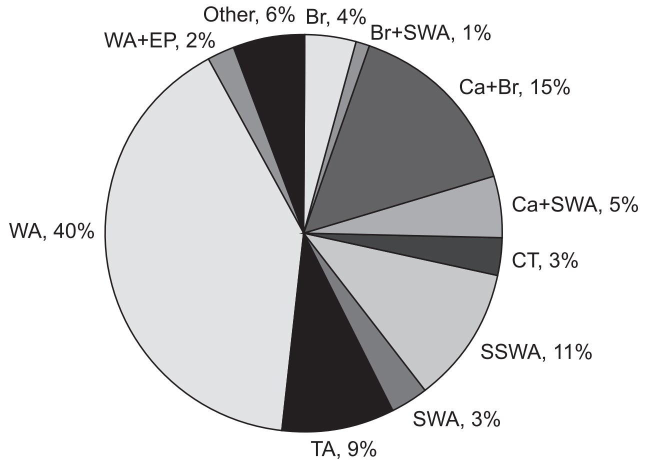

Figure 2. Geographic distribution of the ichthyofauna recorded in the Paranaguá Estuarine Complex, Southwest Atlantic (CT = circuntropical, TA = Trans-Atlantic, WA = Western Atlantic, SWA = Southern West Atlantic, SSWA = Southern South West Atlantic, Ca = Caribbean, Br = Brazilian Province, EA = Eastern Atlantic, EP = Eastern Pacific and Other = categories (Trans-Atlantic + Eastern Pacific, Brazilian Province + southern South-West Atlantic, Caribbean, Caribbean + Brazilian Province + Eastern Pacific, Caribbean + Brazilian Province + southern South-West Atlantic, southern South-West Atlantic + Eastern Pacific, Eastern Atlantic) that represent less than 1% each).

Figura 2. Distribuição Geográfica da ictiofauna encontrada no Complexo Estuarino de Paranaguá, Atlântico Sul (CT = circuntropical, TA = Trans-Atlantic, WA = Western Atlantic, SWA = Southern West Atlantic, SSWA = Southern South West Atlantic, Ca = Caribbean, Br = Brazilian Province, EA = Eastern Atlantic, EP = Eastern Pacific e Outros = categorias (Trans-Atlantic + Eastern Pacific, Brazilian Province + southern South-West Atlantic, Caribbean, Caribbean + Brazilian Province + Eastern Pacific, Caribbean + Brazilian Province + southern South-West Atlantic, southern South-West Atlantic + Eastern Pacific, Eastern Atlantic) que representam menos de 1% cada.

Acknowledgements

We would like to thank the CEM Geological Oceanography Laboratory for the map data base and Pâmela Emanuelly Cattani for their valuable help with the map. Funding was provided by CAPES foundation through a master grant to Ana Carolina dos Passos.

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Received 21/01/2011
Revised 13/03/2012
Accepted 02/08/2012

Borboletas frugívoras (Lepidoptera: Nymphalidae) de uma área urbana (Área de Proteção Especial Manancial Cercadinho) em Belo Horizonte, Minas Gerais, Brasil

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SILVA, A.R.M., CASTRO, C.O., MAFIA, P.O., MENDONÇA, M.O.C., ALVES, T.C.C. & BEIRÃO, M.V. **Fruit-feeding butterflies (Lepidoptera: Nymphalidae) in an urban area (Area of Special Protection Manancial Cercadinho) in Belo Horizonte, Minas Gerais State, Brazil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn03312032012

Abstract: Aiming to increase the knowledge of fruit-feeding butterflies in an urban area in Minas Gerais State, a inventory was carried out in the Área de Proteção Especial Manancial Cercadinho, located in the suburban area of Belo Horizonte. Thirty baited traps were arranged in two habitats: 15 in a Cerrado area (Cerrado field) and 15 in a riparian forest. We recorded 1219 individuals belonging to 45 species of Nymphalidae. The rarefaction analyses didn't indicate difference in species richness between the riparian forest and Cerrado. The species accumulation curve did not show an asymptote. The four most abundant species belonged to Satyrinae. Our results about species richness in Cercadinho emphasize the need to protect this area, because it preserves 40% of the whole butterfly fauna estimated for the region, which could be managed as a source of colonization to other urban areas.
Keywords: *biodiversity, Cerrado, conservation, riparian forest, species richness.*

SILVA, A.R.M., CASTRO, C.O., MAFIA, P.O., MENDONÇA, M.O.C., ALVES, T.C.C. & BEIRÃO, M.V. **Borboletas frugívoras (Lepidoptera: Nymphalidae) de uma área urbana (Área de Proteção Especial Manancial Cercadinho) em Belo Horizonte, Minas Gerais, Brasil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn03112032012

Resumo: Com o objetivo de conhecer as borboletas frugívoras de uma área urbana em Minas Gerais, foi realizado um inventário na Área de Proteção Especial Manacial Cercadinho, localizada na periferia de Belo Horizonte. Foram instaladas 30 armadilhas em dois ambientes: 15 em uma área de Cerrado (campo Cerrado) e 15 na mata ciliar, durante o período de um ano. Foram coletados 1219 indivíduos pertencentes a 45 espécies da família Nymphalidae. A análise de rarefação não indicou diferença entre a riqueza de espécies da mata ciliar e do Cerrado. A curva acumulativa de ocorrência de espécies não resultou em uma assíntota. As quatro espécies mais abundantes pertencem à subfamília Satyrinae. Os resultados em relação à riqueza de espécies no Cercadinho apontam a importância da sua preservação, pois abriga 40% de toda a fauna de borboletas frugívoras estimadas para a região, podendo ser manejada como fonte de colonização de outras áreas urbanas.
Palavras-chave: *biodiversidade, Cerrado, conservação, mata ciliar, riqueza de espécies.*

Introdução

A diversidade biológica não está homogeneamente distribuída pelo planeta, e o entendimento dos padrões de distribuição dos organismos é essencial para a tomada de decisões corretas visando a conservação (Ribeiro et al. 2008). Porém, o conhecimento sobre a biodiversidade ainda é escasso, principalmente de insetos em regiões tropicais, fator preocupante frente ao ritmo atual de destruição dos ecossistemas e extinção de espécies (Wilson 1997). Sem um conhecimento mínimo sobre quais organismos ocorrem em determinado local, é virtualmente impossível desenvolver qualquer projeto de conservação (Santos 2003), e este conhecimento é gerado através da realização de inventários de diversidade e posterior monitoramento.

Os insetos correspondem a quase 60% de todos os animais do planeta, mas têm sido pouco utilizados como espécies bandeira na conservação, mesmo sendo considerados excelentes indicadores biológicos (Freitas et al. 2003). Determinados grupos de insetos, como as borboletas, são importantes no monitoramento ambiental, pois respondem rapidamente a eventuais alterações, sendo fundamentais para a definição de conservação de áreas pequenas e hábitats fragmentados ou com longa história de influência antrópica (Freitas et al. 2003).

As borboletas frugívoras fazem parte da família Nymphalidae e estão distribuídas em quatro subfamílias: Satyrinae, Charaxinae, Biblidinae e Nymphalinae (Wahlberg et al. 2009), representando aproximadamente 20% da fauna de borboletas da região Neotropical (Lamas 2004). Estudos importantes já foram realizados envolvendo borboletas frugívoras, como por exemplo, os pioneiros de De Vries et al. (1997, 1999) e o mais atuais de Uehara-Prado et al. (2007) e Ribeiro et al. (2008).

Em Minas Gerais, estima-se que existam 1.600 espécies de borboletas, já que não existe uma lista disponível. Destas, 20 se encontram ameaçadas de extinção, sendo seis frugívoras (Casagrande et al. 1998). Apesar disso, existem apenas por volta de dez estudos sobre as comunidades de borboletas neste estado, sendo que os primeiros estudos foram de Brown Junior & Mielke (1968), que publicaram uma lista para Belo Horizonte e Ebert (1969) que estudaram as borboletas de Poços de Caldas.

Além disso, nos últimos anos, aproximadamente oito estudos envolvendo também borboletas frugívoras foram realizados na região do cerrado brasileiro, local onde foi realizado o presente trabalho, como por exemplo, Pinheiro & Ortiz (1992), que estudaram áreas de cerrado em Brasília, Fortunato & Ruszczyk (1997), estudaram áreas de cerrado e matas de galeria na região central e periférica de Uberlândia, Soares et al. (1999), que estudaram áreas de cerrado ao longo da calha do Rio São Francisco, na região Noroeste de Minas Gerais e Pinheiro & Emery (2006) que realizaram um levantamento das borboletas de uma área de proteção no Distrito Federal.

O objetivo do trabalho foi realizar um levantamento das espécies de borboletas frugívoras, comparando dois ambientes, cerrado e mata ciliar, da Área de Proteção Especial Manancial Cercadinho.

Material e Métodos

1. *Área de estudo*

A Área de Proteção Especial (APE) Manancial Cercadinho (19° 58’ 18,4” S e 43° 54’ 30” W), é administrada pela Companhia de Saneamento de Minas Gerais (COPASA-MG). Está localizada no sul do município de Belo Horizonte, em uma área urbana com 151 ha (Figura 1). Dentro da APE é realizada a captação de água que abastece alguns bairros da Zona Sul da capital mineira e parte da cidade de Nova Lima, sendo o córrego do Cercadinho o principal contribuinte para a barragem de captação que integra o Sistema de Abastecimento Morro Redondo (Companhia... 2009).

A região apresenta duas estações, uma seca entre abril e setembro, e outra chuvosa entre outubro e março e o clima é o tropical de altitude. A APE Cercadinho é definida como uma área de transição entre o Cerrado e a Mata Atlântica, possuindo 40 ha de vegetação arbórea, incluindo a mata ciliar (Companhia... 2009). As fitofisionomias do cerrado presentes na área são cerradão e campo cerrado, este último formado por árvores e arbustos espaçados entre si, com um estrato contínuo de gramíneas e espécies herbáceas (Companhia... 2002). As coletas foram realizadas apenas no campo cerrado.

2. *Amostragem*

As amostragens foram realizadas mensalmente de outubro de 2006 a setembro de 2007 em duas áreas: cerrado (campo cerrado) e mata ciliar, com a metodologia de armadilhas atrativas para borboletas frugívoras.

As armadilhas consistem de um cilindro de tela fina com 90 cm de altura, fechado na extremidade superior e montado em uma plataforma de madeira com 35 cm de cada lado, com uma abertura de 3 cm para a entrada das borboletas (De Vries 1987). As borboletas entram pela abertura inferior, se alimentam na isca sobre a plataforma e, no momento de sair ficam presas no interior do cilindro (Freitas et al. 2003).

Foram utilizadas 30 armadilhas, sendo 15 na mata ciliar e 15 no cerrado. As mesmas foram dispostas em cinco unidades amostrais (UA), cada uma com três armadilhas distando 20 m entre si, e cada UA se distanciava 200 m uma da outra. As amostragens foram realizadas durante quatro dias, sendo que no primeiro dia as armadilhas eram instaladas e revisadas nos três dias subsequentes. A isca utilizada consistia de banana fermentada com caldo de cana, preparada 48 horas antes do início das amostragens.

Os espécimes capturados foram colocados em envelopes entomológicos numerados e conduzidos ao laboratório para posterior identificação. Dois indivíduos de cada espécie foram montados e a coleção está depositada no Laboratório de Zoologia do Centro Universitário UNA em Belo Horizonte. Indivíduos de fácil identificação em campo foram registrados, marcados e soltos.

A nomenclatura utilizada foi baseada em Lamas (2004). A divisão das subfamílias foi baseada em Wahlberg et al. (2009), considerando Morphini e Brassolini como tribos de Satyrinae.

3. *Análise dos dados*

Os dados foram analisados através da abundância e riqueza de espécies de borboletas frugívoras. Foi plotada a curva de suficiência amostral para verificar se a maior parte das espécies foram amostradas (Freitas et al. 2003). A constância das espécies foi calculada considerando: espécies presentes em mais de 50% das coletas como constantes ou comuns, entre 25 e 50% (entre três e cinco coletas) acessórias e as coletadas em menos de 25% das amostragens (uma ou duas coletas) consideradas raras (Dajoz 1973). Foi realizada uma análise de rarefação baseada em indivíduos para comparar a riqueza de espécies entre cerrado e mata ciliar, através do programa Analytic Rarefaction 1.3.

Resultados e Discussão

Foram coletados 1219 indivíduos pertencentes a 45 espécies (Tabela 1). Brown Junior & Mielke (1968), encontraram 50 espécies de borboletas frugívoras em Belo Horizonte e estimaram a presença de 107 espécies. Já Brown Junior & Freitas (2000), registraram 80 espécies em uma localidade na Floresta Atlântica em Belo

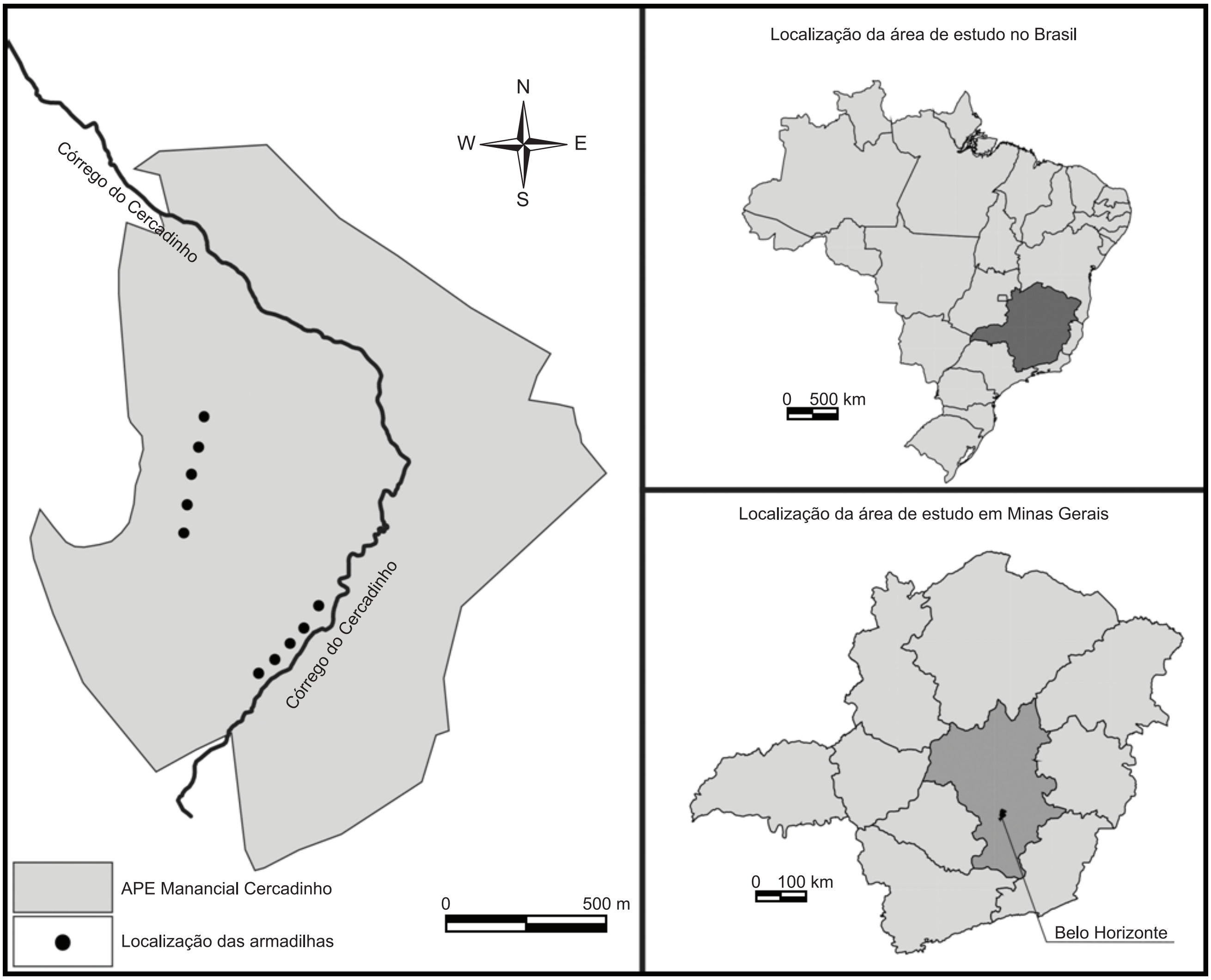

Figura 1. Localização da APE Cercadinho e das Unidades Amostrais (UA). Cada ponto representa uma unidade amostral com três armadilhas.

Figure 1. Location of APE Cercadinho and sampling points. Each point represents a sampling point with three traps.

Horizonte. A riqueza encontrada na APE Manancial Cercadinho equivale a 56% da fauna registrada por Brown Junior & Freitas (2000) e a 42% do total estimado por Brown Junior & Mielke (1968).

Vinte e três espécies pertencem à subfamília Satyrinae (51,1%), 13 a Biblidinae (28,9%), seis a Charaxinae (13,3%) e três a Nymphalinae (6,7%). A subfamília com maior abundância foi Satyrinae com 955 indivíduos (78%), seguida por Biblidinae (179 indivíduos; 15%), Charaxinae (64 indivíduos; 5%) e Nymphalinae (21 indivíduos; 2%). A subfamília com maior riqueza de espécies na região Neotropical é Satyrinae, seguida por Biblidinae, Charaxinae, Brassolinae, Morphinae e Nymphalinae (Lamas 2004). O presente trabalho (se considerarmos Morphinae e Brassolinae como subfamílias) apresenta quase a mesma seqüência, apenas alterando a colocação dos dois últimos taxa, demonstrando que a comunidade de borboletas frugívoras em questão segue o padrão geral evidenciado para os Neotrópicos. Uma distribuição muito similar à do Cercadinho foi verificada por Pinheiro & Ortiz (1992), no Jardim Botânico de Brasília, apenas com a diferença de Nymphalinae estar à frente de Brassolinae.

Comparações entre a riqueza obtida em diferentes trabalhos são difíceis de serem realizadas pela falta de padronização nos métodos de coleta e intensidade amostral. Entretanto, uma avaliação cuidadosa do número de espécies em diferentes áreas pode revelar informações interessantes. A riqueza de borboletas frugívoras encontradas no presente estudo foi maior que a registrada por Silva et al. (2007), estudando uma outra área urbana em Belo Horizonte (20 espécies), porém estes autores utilizaram apenas duas armadilhas (mais rede entomológica) ao longo de um ano. Fortunato & Ruszczyk (1997), estudando áreas urbanas e extra urbanas em Uberlândia encontraram 36 espécies, utilizando 27 armadilhas ao longo de um ano e meio. Riqueza semelhante ao do presente trabalho foi encontrada por Pinheiro & Ortiz (1992) em uma área de mata ciliar, cerrado e campo em Brasília, onde foram registradas 44 espécies, utilizando 14 armadilhas ao longo de um ano. A APE Manancial Cercadinho apresentou maior riqueza em comparação às localidades acima citadas, sendo todas possuidoras de ambientes similares, além de 13 espécies exclusivas: *Diaethria candrena*, *Epiphile hubneri*, *Archaeoprepona chalciope*, *Euptychoides castrensis*, *Godartiana muscosa*, *Moneuptychia itapeva*, *Pharneuptychia innocentia*, *Taygetomorpha celia*, *Taygetis rectifascea*, *Yphthimoides manasses*, *Yphthimoides renata*, *Caligo arisbe* e *Opoptera syme*.

As quatro espécies mais abundantes pertencem à Satyrinae, sendo elas *Y. manasses*, *Pharneuptychia* sp.1, *Taygetis laches* e *G. muscosa*, representado respectivamente 21,6%, 8%, 7,5% e 7,1% do total de indivíduos.

Tabela 1. Lista de espécies e abundância de borboletas frugívoras na mata ciliar e cerrado da Área de Proteção Especial Manancial Cercadinho, Belo Horizonte, Minas Gerais, Brasil, (outubro de 2006 e setembro de 2007).

Table 1. List of fruit-feeding butterflies species and abundance in the cerrado and riparian forest from the Área de Proteção Especial Manancial Cercadinho, Belo Horizonte, Minas Gerais State, Brazil, (October 2006 to September 2007).

Subfamílias/tribos/espécies	Cerrado	Mata ciliar
Biblidinae: Biblidini		
Biblis hyperia nectanabis (Fruhstorfer, 1909)	39	12
Callicore sorana (Godart, 1824)	69	-
Callicore pygas thamyras (Ménétriés, 1857)	3	-
Diaethria candrena (Godart, 1824)	1	-
Diaethria clymena (Cramer, 1775)*	7	-
Epiphile hubneri Hewitson, 1867	-	3
Eunica bechina (Hewitson, 1867)*	1	-
Eunica cuvierii (Godart, 1819)	1	-
Hamadryas amphinome amphinome (Linnaeus, 1767)	8	4
Hamadryas epinome (Felder & Felder, 1867)	-	12
Hamadryas februa februa (Hübner, 1823)*	10	-
Hamadryas feronia feronia (Linnaeus, 1758)	4	-
Temenis laothoe meridionalis Ebert, 1965*	5	-
Charaxinae: Anaeini		
Fountainea ryphea (Cramer, 1775)	24	13
Memphis moruus stheno (Prittwitz, 1865)	7	8
Siderone galanthis (Cramer, 1775)	3	-
Zaretis isidora (Cramer, 1777)	5	-
Charaxinae: Preponini		
Archaeoprepona chalciope (Hübner, 1823)	-	1
Archaeoprepona demophon thalpius (Hübner, 1814)	4	3
Nymphalinae: Coeini		
Colobura dirce (Linneus, 1758)*	1	13
Historis odius (Fabricius, 1775)	4	-
Smyrna blomfildia (Fabricius, 1781)*	1	2
Satyrinae: Satyrini		
Euptychoides castrensis (Schaus, 1902)	1	1
Godartiana muscosa (Butler, 1870)	14	73
Moneuptychia itapeva Freitas, 2007	17	-
Paryphthimoides phronius (Godart, 1823)	11	5
Paryphthimoides poltys (Prittwitz, 1865)	5	2
Pharneuptychia innocentia (C. Felder e R. Felder, 1867)	12	1
Pharneuptychia sp. 1	93	5
Pharneuptychia sp. 2	52	3
Taygetis laches (Fabricius, 1793)*	24	67
Taygetis rectifascia Weymer, 1907	12	31
Taygetomorpha celia (Cramer, 1779)	-	1
Yphthimoides celmis (Godart, 1824)	31	-
Yphthimoides manasses (C. Felder e R. Felder, 1867)	261	2
Yphthimoides ochracea (Butler, 1867)	10	3
Yphthimoides renata (Stoll, 1780)	62	16
Yphthimoides sp. 1	46	2
Yphthimoides sp. 2	5	-
Satyrinae: Morphini		
Morpho helenor mielkei (Blandin, 2007)	9	43
Satyrinae: Brassolini		
Blepolenis batea batea (Hübner, 1821)	1	-
Caligo arisbe Hübner, 1822	-	1
Eryphanis reevesii (Doubleday, 1849)	3	3
Opoptera syme (Hübner, 1821)	1	3
Opsiphanes invirae (Hübner, 1808)*	20	3
Total	883	336

*Espécies comuns em ambientes antropizados ou secundários.

*Species that may appear in both anthropic or secondary environments.

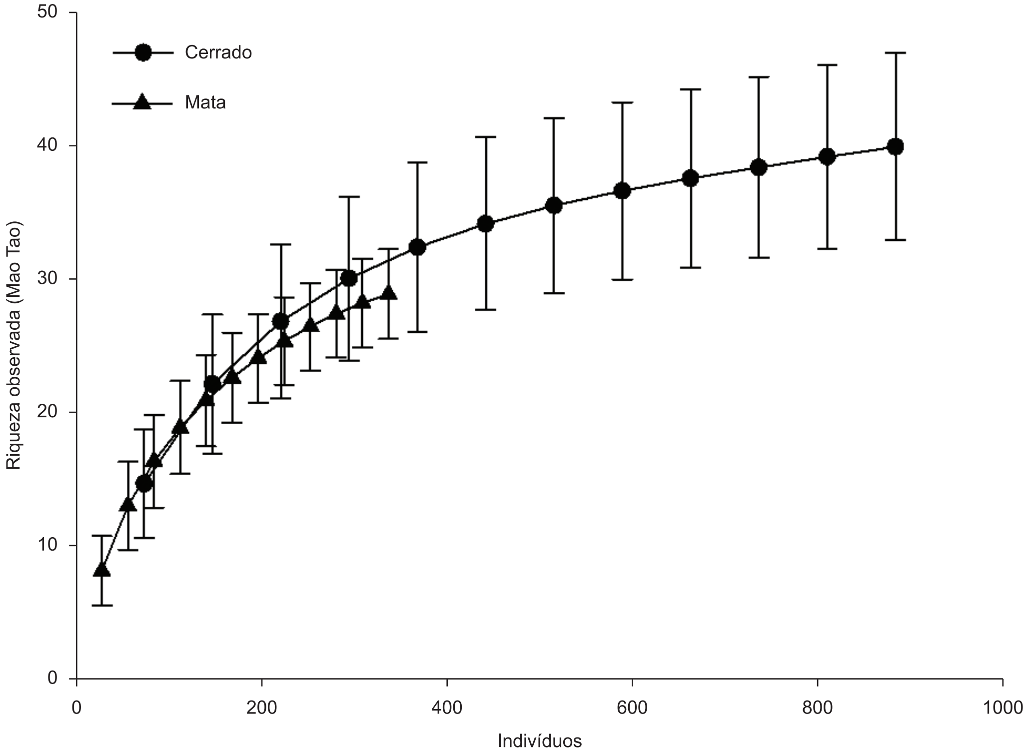

Figura 2. Curva de rarefação das borboletas frugívoras do cerrado e da mata ciliar, com o intervalo de confiança de 95%.

Figure 2. Rarefaction curve of fruit-feeding butterflies of the Cerrado and riparian forest, with confidence interval (95%).

Dezessete espécies foram constantes, 15 acessórias e 13 raras na área de estudo. Destas últimas, oito são *singletons*. Segundo Brown Junior & Freitas (2000), embora a maioria dos grupos de borboletas possa sobreviver em fragmentos urbanos, muitas espécies são pouco representadas ou ausentes. Iserhard & Romanowski (2004), sugerem que para a conservação de áreas de preservação e seu entorno, é aconselhável direcionar os esforços nas espécies de borboletas indicadoras ou raras, pois estes locais podem ser importantes para a conservação, por manter populações destas espécies. Das 45 espécies da APE Manancial Cercadinho, oito são consideradas comuns em ambientes antropizados por Brown Junior (1992) e Raimundo et al. (2003) (Tabela 1).

A curva de suficiência amostral não mostrou uma tendência nítida à estabilização após os 12 meses de coleta. Isto indica que apesar deste Parque possuir em torno de 50% das espécies de borboletas frugívoras registradas para Belo Horizonte, o aumento do esforço amostral provavelmente acrescentaria mais espécies para a APE Manancial Cercadinho.

A análise de rarefação não mostrou diferença entre a riqueza de espécies da mata ciliar e cerrado (Figura 2). Entretanto, no cerrado foi encontrada maior riqueza e mais que o dobro da abundância de espécies do que na mata ciliar. Na mata ciliar, foram coletados 336 indivíduos de 29 espécies, e destas cinco foram exclusivas deste ambiente (*E. hubneri*, *Hamadryas epinome*, *A. chalciope*, *T. celia* e *C. arisbe*), representadas por 18 indivíduos. Já no cerrado, foram coletados 883 indivíduos pertencentes a 40 espécies, sendo 16 exclusivas, representadas por 167 indivíduos (Tabela 1).

Diferenças marcantes ocorrem na comunidade total de borboletas quando a floresta semidecídua dá espaço ao cerrado (Pinheiro & Ortiz 1992, Brown Junior & Freitas 2002), semelhante ao que ocorre no Cercadinho. A distribuição dos recursos de larvas e adultos poderia explicar os padrões de agrupamentos de espécies dentro de um mesmo fragmento, bem como características de temperatura, umidade e luminosidade (Ribeiro et al. 2008). No presente estudo, as duas fitofisionomias estudadas compreendem formações totalmente diferentes (mata e campo), influenciando a temperatura, umidade e luminosidade, fator que poderia explicar a diferença entre a abundância de borboletas frugívoras nestes locais. De acordo com Pinheiro & Ortiz (1992) e Emery et al. (2006), a variedade de fitofisionomias do Cerrado provém uma grande heterogeneidade ambiental que proporciona uma variação espacial de distribuição de uma enorme variedade de borboletas, pois são encontrados microambientes propícios a uma ampla gama de espécies.

Isso evidencia a importante riqueza de borboletas frugívoras no cerrado, ecossistema historicamente pouco valorizado em relação à sua biodiversidade, ressaltando a importância de se amostrar várias fitofisionomias dentro de um mesmo bioma. Além disso, chama a atenção para a necessidade de um melhor conhecimento da fauna do Cerrado, considerado um *hotspot* mundial de diversidade (Myers et al. 2000).

A preservação de áreas verdes urbanas pode contribuir para a conservação da fauna de borboletas. Estes ambientes podem sustentar uma alta diversidade de espécies, por disponibilizar diferentes recursos e um local menos perturbado nas cidades, promovendo a melhoria do ecossistema urbano. Segundo Ruszczyk (1986) e Fortunato & Ruszczyk (1997), para que haja uma riqueza considerável de borboletas em ambientes urbanos, é importante a preservação de fragmentos nativos no interior e periferia das cidades, pois são importantes como fonte de colonizadores potenciais do ambiente urbano.

Segundo Brown Junior & Freitas (2002) e Ribeiro et al. (2008), para uma conservação efetiva de comunidades de borboletas em cidades de regiões tropicais, é necessário manter corredores de áreas verdes ao longo de ruas e avenidas, bem como reservas com água permanente (lagos ou córregos), vegetação nativa diversa e vegetação aberta. Sugere-se que tais locais sejam mais distantes dos aglomerados de edifícios dos grandes centros urbanos, e que se conectem com outras áreas verdes. A descrição acima se encaixa com as características da APE Manancial Cercadinho. Apesar de estar inserida em uma área urbana, localizada na periferia da cidade, também está próxima a outras áreas de preservação, como o Parque Estadual do Rola Moça, justificando possivelmente a alta riqueza de borboletas frugívoras registrada no presente trabalho.

Desta forma, o Cercadinho constitui-se numa área de preservação importante para a manutenção da riqueza de borboletas de Belo Horizonte, já que possui uma rica fauna de borboletas frugívoras, reforçando a importância de sua conservação.

Agradecimentos

Ao Centro Universitário UNA, à COPASA-MG, à bióloga Maria Aparecida Souza (COPASA-MG), ao professor Dr. André Victor Lucci Freitas (Universidade Estadual de Campinas, UNICAMP), pela identificação da maior parte dos espécimes, ao Dr. Márcio Uehara-Prado e ao doutorando Luiz Dolabela Falcão pelo auxílio em algumas análises e a todos que ajudaram nas coletas.

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Recebido em 01/02/2012
Versão reformulada recebida em 14/09/2012
Publicado em 17/09/2012

Lagartos de áreas de Cerrado na Reserva Biológica Unilavras-Boqueirão, Ingaí, sul de Minas Gerais, Brasil

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NOVELLI, I.A., LUCAS, P.S., CARVALHO, R.G., SANTOS, R.C. & SOUSA, B.M. **Lizards of the Cerrado areas in the Reserva Biológica Unilavras-Boqueirão, Ingaí, Minas Gerais Southern, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?inventory+bn00312032012

Abstract: Studies with emphasis on assessment and quantification of species biological diversity should be recognized as important tools in the process of knowledge, especially where basic data are scarce. This study was conducted at the Reserva Biológica Unilavras-Boqueirão (21° 20' 47" S and 44° 59' 27" W) inserted in the Cerrado, Ingaí municipality, southern Minas Gerais, southeastern Brazil. We aimed to characterize and understand local lizard species. Sampling occurred between June 2008 and February 2010 in weekly excursions during the day in the field. Captures were carried out by means of pitfall traps, distributed in six sets, three in Cerrado *sensu stricto* and three in the gallery forest, making a sampling effort of 6120 buckets per day. Animals viewed, occasionally found or collected by third parties were also included in the sample. A total of 10 lizard species from seven families were captured. The richest vegetation type was the Cerrado *sensu stricto* with nine species. Only *Heterodactylus imbricatus* was restricted to gallery forests, where pitfalls sampled 74.12% of lizards captured. The lizard fauna is well represented in the area with species typical of open areas as *Ameiva ameiva*, *Polychrus acutirostris* and *Mabuya frenata*. The species *Urostrophus vautieri* and *Heterodactylus imbricatus*, not yet reported for the Cerrado, were also found in the area.
Keywords: *squamata, Cerrado, gallery forest, rocky fields, Minas Gerais state.*

NOVELLI, I.A., LUCAS, P.S., CARVALHO, R. G., SANTOS, R.C. & SOUSA, B. M. **Lagartos de áreas de Cerrado na Reserva Biológica Unilavras-Boqueirão, Ingaí, Sul de Minas Gerais, Brasil.** Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory+bn00312032012

Resumo: Estudos com ênfase em levantamentos e quantificação da diversidade biológica das espécies devem ser reconhecidos como ferramentas importantes no processo de produção de conhecimento básico principalmente onde dados sobre a fauna são escassos. O presente estudo objetivou caracterizar a fauna de lagartos da Reserva Biológica Unilavras-Boqueirão (21° 20' 47" S e 44° 59' 27" W), inserida no domínio do Cerrado, situada no município de Ingaí, Sul de Minas Gerais, Sudeste do Brasil. A amostragem ocorreu entre junho de 2008 a fevereiro de 2010, em excursões semanais no período diurno em campo. As capturas foram realizadas por meio de armadilhas de queda, distribuídas em seis conjuntos, três em área de Cerrado *sensu stricto* e três em Mata de galeria, perfazendo um esforço amostral de 6.120 baldes/dia. Animais visualizados, encontrados ocasionalmente ou coletados por terceiros também foram incluídos na amostragem. Um total de 10 espécies de lagartos foram capturados, distribuídos em sete famílias. A fitofisionomia onde foi amostrado o maior número de espécies foi o Cerrado *sensu stricto*, com nove espécies. Apenas *Heterodactylus imbricatus* esteve restrita à fitofisionomia de mata de galeria, onde as armadilhas de queda capturaram 74,12% dos lagartos. A fauna de lagartos é representada por espécies típicas de áreas abertas como *Ameiva ameiva*, *Polychrus acutirostris* e *Mabuya frenata* e espécies florestais como *Urostrophus vautieri* e *Heterodactylus imbricatus* até então não registradas para o Cerrado.
Palavras-chave: *squamata, Cerrado, mata de galeria, campos rupestres, Minas Gerais.*

Introdução

Estudos com ênfase em levantamentos e quantificação da diversidade biológica devem ser reconhecidos como ferramentas importantes no processo de produção de conhecimento básico para subsidiar posteriores pesquisas nas áreas de sistemática, ecologia, biogeografia e biologia da conservação (Heyer et al. 1994). Os lagartos, incluídos na ordem Squamata, apresentam grande diversidade e ampla distribuição geográfica, sendo encontrados em vários habitats e compreendendo cerca de 5079 espécies descritas atualmente (Uetz & Hallerman 2010). Destas, 241 espécies são de ocorrência natural no Brasil (Bérnils 2010), várias endêmicas e com padrão de distribuição restrito e outras com uma distribuição ampla contínua ou disjunta no território brasileiro.

O estado de Minas Gerais possui uma ampla área territorial e a uma variedade de ecorregiões (i.e. Mata Atlântica, Caatinga e Cerrado) e de ambientes que os compõem, com possibilidade de abrigar uma rica biodiversidade. As áreas de Cerrado no Estado, que já ocuparam aproximadamente 57% da extensão territorial, atualmente se encontram em rápido processo de transformação, cedendo espaço para culturas/monoculturas agrícolas e florestais ou para a implantação de atividades agropecuárias (Drummond et al. 2009). Apesar do Cerrado ser reconhecido como um dos 34 *hotspots* para estudo e conservação da diversidade mundial (Mittermeier et al. 2004), as áreas mineiras deste bioma carecem ainda de uma amostragem sistemática e com cobertura geográfica ampla. Entretanto, alguns estudos sobre conservação, diversidade de répteis (Brites & Bauab 1988, Assis 1999, Mesquita et al. 2007, Recoder & Nogueira 2007, São Pedro & Pires 2009) e distribuição geográfica (Barros Filho et al. 2005, Sousa & Novelli 2009) existem para estas áreas. Recentemente foram registradas pela primeira no Cerrado as espécies de lagartos *Urostrophus vautieri* (Santos et al. 2009) e *Heterodactylus imbricatus* (Novelli et al. 2010), provenientes da Reserva Biológica Unilavras – Boqueirão, que está inserida em uma área prioritária para conservação no Estado (Drummond et al. 2005).

O Cerrado é a segunda ecorregião mais rica em lagartos no Brasil (Rodrigues 2005a, Nogueira et al. 2011), perdendo apenas para a Amazônia. Em Minas Gerais, os dados sobre a fauna de répteis estão restritos a poucas localidades, apesar de 57 espécies de lagartos serem conhecidas para o Estado (Bérnils et al. 2009). Informações biológicas sobre o grupo são escassas, dificultando a definição de áreas prioritárias de preservação de maior interesse específico para os répteis (Drummond et al. 2005). Dessa forma, o presente estudo teve como objetivo registrar as espécies de lagartos que ocorrem em três fisionomias características de uma área de Cerrado no município de Ingaí, sul de Minas Gerais, até então não inventariada em relação a sua fauna de lagartos.

Material e Métodos

1. *Área de estudo*

A Reserva Biológica Unilavras – Boqueirão - RBUB (21° 20’ 47” S e 44° 59’ 27” W) está localizada no município de Ingaí, na região sul do Estado de Minas Gerais e ocupa uma área total de 159,5 hectares. As elevações da região variam entre 1100 e 1250 m. A precipitação média anual é de 1.411 mm, com chuvas mal distribuídas durante o ano, predominando no verão, com 66,77% incidindo entre novembro e fevereiro. O inverno tem cerca de quatro meses com pequeno déficit hídrico, entre 10 mm e 30 mm. A temperatura média anual situa-se em torno de 19,3 °C. A área da Reserva enquadra-se como uma das áreas prioritárias para conservação da biodiversidade de Minas Gerais, onde podem ser observadas diversas fitofisionomias que caracterizam o Cerrado, inclusive algumas de baixa representatividade e com pouco conhecimento no território nacional, como os campos rupestres (Pereira & Volpato 2005). A área da reserva possui cinco nascentes e a paisagem é composta pelas fisionomias vegetacionais de mata de galeria, Cerrado *sensu stricto* e campo rupestre.

2. *Coleta de dados*

A amostragem da fauna de lagartos foi realizada entre junho de 2008 e fevereiro de 2010, em excursões semanais diurnas. As coletas/capturas foram realizadas em três áreas distintas da RBUB: Cerrado *sensu stricto* (sítio 01), Mata de Galeria (sítio 02) e Campo Rupestre (sítio 3). Para a amostragem dos espécimes na áreas de Cerrado *sensu stricto* e em mata de galeria foram instalados no total seis conjuntos de armadilhas de interceptação e queda (Cechin & Martins 2000, Enge 2001, Bernarde 2008), três conjuntos em cada sítio de coleta. Cada conjunto de armadilhas foi composto por quatro linhas paralelas de 12 m, cada uma com três baldes de 30 L enterrados, distantes 6 m um do outro, com cercas direcionadoras em cada uma das linhas, constituída por tela de mosqueteiro. Assim, foram instaladas 36 armadilhas em cada sítio de coleta. Na área de campo rupestre não foi possível a instalação de armadilhas de interceptação e queda, pois essa fitofisionomia possui um substrato rochoso que não possibilitou a instalação dos baldes de coleta. Em todos os três sítios de amostragem também foram utilizadas armadilhas de cola instaladas em locais estratégicos de provável encontro dos lagartos conforme metodologia proposta por Bauer & Sadlier (1992) e Zani & Vitt (1995), durante os períodos de vistoria das armadilhas e dos outros métodos de amostragem. Animais avistados, encontrados ocasionalmente ou coletados por terceiros também foram contabilizados.

Os espécimes capturados foram fotografados e marcados com elásticos coloridos de silicone (Ribeiro & Sousa 2006) e soltos no seu habitat natural, nos locais onde foram capturados. Espécimes representativos (voucher) foram coletados, mortos com Tiopental, fixados em formaldeído a 10%, conservados em etanol 70% e depositados na Coleção de Répteis do Laboratório de Zoologia do Centro Universitário de Lavras (CRLZ – UNILAVRAS).

Para quantificar o esforço amostral foram construídas curvas de rarefação de espécies a partir da média de 1.000 aleatorizações dos dias de coleta com o programa EstimateS V.8.2.0 através do método *Bootstrap* (Colwell 2006) para a totalidade da amostra.

Resultados

Foram realizadas 85 expedições ao campo e um esforço amostral de 3.060 horas-balde/dia nos sítios 01 e 02 e 765 horas por unidade amostral, totalizando 6.120 horas-balde/dia. Foram capturados no total 85 espécimes de lagartos, pertencentes a 10 espécies (Tabela 1). Destes, 63 espécimes foram capturados em armadilhas de interceptação e queda, 12 em encontros ocasionais, sete por terceiros e três capturados em armadilhas de cola. Os espécimes registrados no presente estudo estão distribuídos em sete famílias: Anguidae (uma espécie), Gymnophthalmidae (duas espécies), Leiosauridae (duas espécies), Polychrotidae (uma espécie), Scincidae (duas espécies), Teiidae (uma espécie) e Tropiduridae (uma espécie) (Tabela 1).

A fitofisionomia que apresentou maior número de espécies foi o Cerrado *sensu stricto* (sítio 01) com nove espécies registradas: *Enyalius bilineatus* Duméril & Bibron, 1837 (Leiosauridae) (Figura 1d)*, Ameiva ameiva* (Linnaeus, 1758) (Teiidae) (Figura 2c), *Urostrophus vautieri* Duméril & Bibron, 1837 (Leiosauridae) (Figura 1e)*, Tropidurus itambere* Rodrigues, 1987 (Tropiduridae) (Figura 2d)*, Polychrus acutirostris* Spix, 1825 (Polychrotidae) (Figura 1f)*, Ophiodes striatus* (Spix, 1825) (Anguidae) (Figura 1a), *Cercosaura ocellata* Wagler, 1830 (Gymnophthalmidae) (Figura 1c), *Mabuya frenata* (Cope, 1862) (Scincidae) e *M. dorsivittata* Cope, 1862 (Scincidae) (Figura 2a, b). Na Mata de Galeria (sítio 02) foram registradas cinco espécies: *E. bilineatus, U. vautieri, M. frenata, M. dorsivittata* e *Heterodactylus imbricatus* Spix, 1825 (Gymnophthalmidae) (Figura 1b); e no campo rupestre (sítio 03) foram registradas três espécies: *M. frenata*, *T. itambere* e *C. ocellata* (Figura 3, Tabela 1).

Um total de 11 indivíduos foram capturados, marcados, medidos, fotografados, identificados e soltos nos locais onde foram encontrados: quatro *P. acutirostris,* um *M. frenata*, dois *U. vautieri* e quatro *E. bilineatus*. Não foi registrada nenhuma recaptura durante todo período de estudo.

O método que amostrou o maior número de espécies (n = 9) e espécimes (74,12%) de lagartos foi a armadilha de interceptação e queda. Avistamentos, encontros ocasionais, armadilhas de cola e coleta por terceiros amostraram juntos 25,88% dos espécimes de lagartos.

A curva de rarefação de espécies apresentou um rápido aumento conforme o esforço amostral. A curva tendeu a uma assíntota, mas provavelmente mais espécies devem ser encontradas com maiores esforços na área, uma vez que a assíntota plena não foi atingida. Com base no estimador *Bootstrap*, a riqueza estimada para a área de estudo é de aproximadamente 11 espécies (Figura 4).

Discussão

Os resultados encontrados no presente estudo corroboram outros estudos realizados focados na distribuição local de lagartos em áreas de Cerrado (Colli et al. 2002, Nogueira et al. 2005, 2009), onde as Matas de galeria abrigaram menor número de espécies quando comparada com áreas abertas. De acordo com Colli et al. (2002) e Rodrigues (2005b), as Matas de galeria não apresentam fauna própria específica e muitas espécies encontradas nos Cerrados abertos também utilizam essas áreas.

Entre as cinco espécies registradas nas Matas de galeria, somente a espécie *H. imbricatus* não foi registrada na área de Cerrado, sendo aparentemente dependente de habitats florestais (Figura 3, Tabela 1). Essa espécie está restrita a áreas de clima mais frio associadas com altas elevações e áreas montanhosas do leste do Brasil (Rodrigues et al. 2009) e geralmente é encontrada na serrapilheira (Dixo & Verdade 2006). Inicialmente, esta espécie estava restrita a áreas de Mata Atlântica e posteriormente Novelli et al. (2010) registraram a sua ocorrência no domínio do bioma Cerrado.

A espécie *U. vautieri* foi registrada pela primeira vez em uma área de mata na região do Cerrado na RBUB (Santos et al. 2009), ampliando sua distribuição geográfica para este domínio. Embora esta espécie fosse conhecida somente para a Mata Atlântica (Etheridge & Williams 1991, Pellegrino et al. 1999), no presente trabalho foram registrados indivíduos na área de Cerrado *sensu stricto.* Sua associação com o Cerrado pode estar relacionada ao fato de várias áreas naturais desse bioma no sul de Minas Gerais se encontrarem em áreas transicionais com áreas isoladas de Mata Atlântica no Estado.

No Cerrado, *M. dorsivittata*, é mais abundante em ambientes de campo limpo, campo sujo e bordas de campo úmido, geralmente com densa cobertura de gramíneas (Nogueira et al. 2005). É uma espécie típica de formações abertas, habitando preferencialmente fisionomias campestres (Valdujo 2003, Nogueira et al. 2005). Sua associação com áreas de Cerrado nesse estudo esteve mais relacionada com áreas abertas, assim como relatado também por Nogueira et al. (2005) e Sousa et al. (2010), podendo mais raramente ocorrer também em hábitats florestados, como matas de galeria (Colli et al. 2002). *Mabuya frenata* foi a única espécie encontrada em todas as fitofisionomias. Esta espécie ocorre em áreas abertas na América do Sul, nos biomas Cerrado e Chaco (Vanzolini 1988) e no Brasil, nas regiões Centro-Oeste e Sudeste (Peters & Donoso-Barros 1986). Apenas um espécime foi coletado no campo rupestre sobre uma rocha (talvez devido à dificuldade de uma maior amostragem nesta fitofisionomia), mas segundo Vrcibradic & Rocha (1998) esses ambientes são altamente utilizados por esta espécie. Esta espécie também está associada a áreas de Mata Atlântica no Rio de Janeiro (Vrcibradic et al. 2006) e em Minas Gerais (Costa et al. 2008).

A maioria das espécies distribuídas dentro da região do Cerrado ocorre principalmente em áreas com vegetação aberta, como no caso das espécies *A. ameiva* e *P. acutirostris*, que são espécies de ampla distribuição geográfica. *Polychrus acutirostris* no Brasil pode ser encontrado nas regiões Nordeste, Sul e Centro-Oeste e também nos Estados de São Paulo, Minas Gerais e no sul do Pará. (Vitt & Lacher 1981; Vanzolini 1983; Nogueira et al. 2005; Recorder & Nogueira 2007). A maioria dos espécimes de *P. acutirostris* capturados neste estudo foi coletada nas armadilhas de interceptação e queda, constatando que a espécie pode ser encontrada no chão, como também observado por Vitt & Lacher (1981). *Enyalius bilineatus* é encontrada no sudeste e leste de Minas Gerais (Jackson 1978, Sousa et al. 2010) e é a única espécie do gênero *Enyalius* associada ao Cerrado, em áreas florestadas, principalmente em matas de galeria (Bertolotto et al. 2002, Colli et al. 2002, Bertoluci et al. 2009, Sousa et al. 2010. Contudo, neste trabalho apenas um indivíduo de *E. bilineatus* foi registrado em matas de galeria, sendo em sua maioria registrados no Cerrado *sensu stricto*. O tipo de habitat fossorial encontrado em algumas espécies dificulta na amostragem destas, como observado para a espécie *Ophiodes striatus* em área de Cerrado. Colli et al. (2002) também constataram a presença dessa espécie em áreas de Cerrado, porém sempre associada a áreas florestadas e, na região core

Tabela 1. Composição da fauna de lagartos da Reserva Biológica Unilavras-Boqueirão. Fitofisionomias: CE = Cerrado *sensu stricto*; MA = Mata de Galeria e CR = Campo Rupestre.

Table 1. Composition of lizard fauna from Reserva Biológica Unilavras-Boqueirão. Physionomies: CE = Cerrado *sensu stricto*; MA = Gallery Forest and CR = Campo Rupestre.

Táxon	N	Área		
		CE	MA	CR
SQUAMATA - SAURIA				
ANGUIDAE				
Ophiodes striatus (Spix, 1824)	1	1		
GYMNOPHTHALMIDAE				
Heterodactylus imbricatus Spix, 1825	2		2	
Cercosaura ocellata Wagler, 1830	2	1		1
LEIOSAURIDAE				
Enyalius bilineatus Duméril & Bibron, 1837	24	23	1	
Urostrophus vautieri Duméril & Bibron, 1837	8	3	5	
POLYCHROTIDAE				
Polychrus acutirostris Spix, 1825	15	15		
SCINCIDAE				
Mabuya frenata (Cope, 1862)	9	6	2	1
Mabuya dorsivittata Cope, 1862	6	5	1	
TEIIDAE				
Ameiva ameiva (Linnaeus, 1758)	7	7		
TROPIDURIDAE				
Tropidurus itambere Rodrigues, 1987	11	1		10
Número de indivíduos	85	62	11	12

do Cerrado, é principalmente encontrada em formações de campos (Nogueira et al. 2009).

Apesar do esforço dedicado na verificação da composição e riqueza de lagartos do Cerrado, os estudos para o estado de Minas Gerais são ainda incipientes quando comparados aos realizados em outras áreas de Cerrado como no Centro-oeste do Brasil. Dentre as espécies registradas, *T. itambere* estava frequentemente associado a lugares com afloramentos rochosos, confirmando a observação de Rodrigues (1987) e de Colli et al. (2002), de que esta espécie é típica de áreas abertas de Cerrado. O mesmo padrão também foi observado por Ávila Pires (1995) e Sousa et al. (2010) para *C. ocellata,* que pode habitar formações savânicas e áreas marginais nas formações

Figura 1. Espécies de lagartos registradas na Reserva Biológica Unilavras – Boqueirão, no município de Ingaí, Estado de Minas Gerais, Brasil. a) *Ophiodes striatus;* b) *Heterodactylus imbricatus;* c) *Cercosaura ocellata;* d) *Enyalius bilineatus;* e) *Urostrophus vautieri;* f) *Polychrus acutirostris.*

Figure 1. Lizard species recorded in Reserva Biológica Unilavras – Boqueirão, municipality of Ingaí, Minas Gerais State, Brazil. a) *Ophiodes striatus;* b) *Heterodactylus imbricatus;* c) *Cercosaura ocellata;* d) *Enyalius bilineatus;* e) *Urostrophus vautieri;* f) *Polychrus acutirostris.*

Figura 2. Espécies de lagartos registradas na Reserva Biológica Unilavras – Boqueirão, no município de Ingaí, Estado de Minas Gerais, Brasil. a) *Mabuya dorsivittata;* b) *Mabuya dorsivittata;* c) *Ameiva ameiva*; d) *Tropidurus itambere.*

Figure 2. Lizard species recorded in Reserva Biológica Unilavras – Boqueirão, municipality of Ingaí, Minas Gerais State, Brazil. a) *Mabuya frenata;* b) *Mabuya dorsivittata;* c) *Ameiva ameiva*; d) *Tropidurus itambere.*

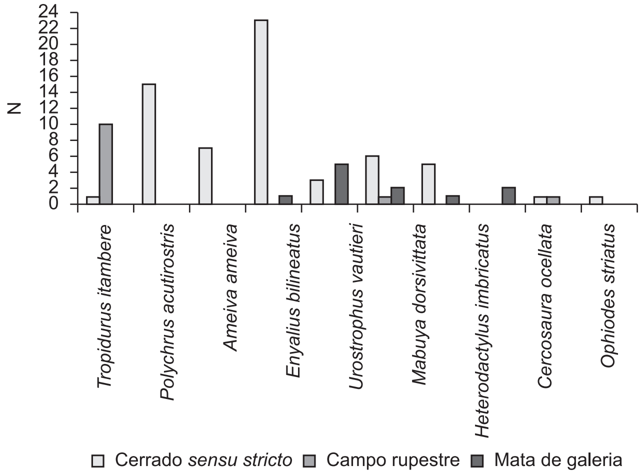

Figura 3. Número de espécimes (N) de lagartos coletadas nas três áreas na Reserva Biológica Unilavras-Boqueirão: Cerrado *sensu stricto*, Campo Rupestre e Mata de Galeria.

Figure 3. Number of lizard specimens (N) collected in three areas in the Reserva Biológica Unilavras-Boqueirão: Cerrado *sensu stricto*, rocky outcrops and gallery forests.

florestais. Neste estudo um espécime de *C. ocellata* foi encontrado em vegetação associada a rochas nos campos rupestres.

As espécies de lagartos registradas na Reserva Biológica Unilavras-Boqueirão correspondem a 17,5% das 57 espécies conhecidas para o Cerrado de Minas Gerais, segundo Bérnils et al. (2009). Com base na curva de rarefação de espécies, pode-se afirmar que os dados obtidos da fauna de lagartos da RBUB são representativos localmente, considerando que a curva de rarefação estimada indica uma riqueza potencial de 11 espécies. Em Minas Gerais, Recorder & Nogueira (2007) registraram 25 espécies de lagartos em uma área de Cerrado do Parque Nacional Grande Sertão Veredas, na divisa dos Estados de Minas Gerais e Bahia e Sousa et al. (2010), em uma amostragem mais recente em fragmentos de Cerrado e Mata Atlântica no Campo das Vertentes, no município de Ritápolis, Minas Gerais, registraram a ocorrência de nove espécies de lagartos. Essas desigualdades podem estar relacionadas com os diferentes métodos de amostragem, tempo e diferentes esforços amostrais empregados na captura de lagartos. Com base nos números, sabe-se que o Cerrado abriga maior diversidade da fauna de lagartos quando comparada com a Mata Atlântica. Sabe-se também que prováveis diferenças na riqueza da fauna de lagartos no Cerrado podem estar mais associadas com os diferentes processos regionais, do que

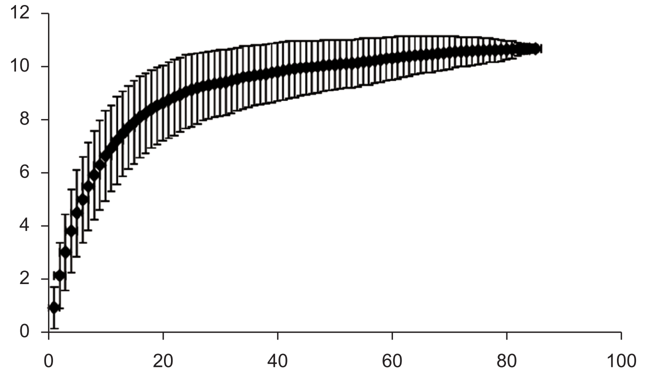

Figura 4. Curva de rarefação das espécies de lagartos amostradas na Reserva Biológica do Unilavras – Boqueirão, Ingaí, Minas Gerais.

Figure 4. Rarefaction curve of lizard species sampled in Reserva Biológica do Unilavras – Boqueirão, Ingaí, Minas Gerais.

propriamente dentro das fitofisionomias que caracterizam uma única localidade (Nogueira et al. 2009).

A escassez de estudos que caracterizam a composição da fauna de lagartos do estado de Minas Gerais pode ser apontada como uma das causas da presença de um grande número de espécies de répteis na categoria "Dados Deficientes" na Lista de Espécies Ameaçadas de Extinção da Fauna do estado (Conselho... 2008). Os registros provenientes da RBUB indicam a necessidade de ampliar os estudos para demais áreas do estado de Minas Gerais, avaliando o potencial para a ocorrência de espécies ou a ampliação da ocorrência de espécies de lagartos então desconhecidas no Cerrado, servindo como ferramentas que irão ajudar na escolha de áreas prioritárias e a criação de Unidades de Conservação neste *hotspot* de biodiversidade.

Agradecimentos

Ao Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA/SISBIO) pela permissão de coleta e transporte dos espécimes (Registros 1971350 e 1971350). À Fundação de Amparo à Pesquisa do Estado de Minas Gerais (PROBIC/FAPEMIG) pelo financiamento do projeto do qual esse estudo faz parte. Ao Dr. Fernando Antônio Frieiro-Costa pela ajuda na escolha e estabelecimento das áreas de coleta. Ao Sr. Fabiano B. Silva pela ajuda nos trabalhos de campo.

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Recebido em 23/12/2010
Versão reformulada recebida em 04/07/2012
Publicado em 06/07/2012

Diversity and habitat use by snakes and lizards in coastal environments of southernmost Brazil

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SANTOS, M.B., OLIVEIRA, M.C.L.M. & TOZETTI, A.M. **Diversity and habitat use by snakes and lizards in coastal environments of southernmost Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn01812032012

Abstract: This study examined species composition differences among snake and lizard assemblages from coastal dunes and restinga habitats in southernmost Brazil. Animals were collected between April 2009 and March 2010 using pitfall traps, artificial shelters, and time-constrained searches in grasslands areas susceptible to flooding. Species richness was higher in the restinga, but lower than the observed in other Brazilian biomes, possibly associated with more unstable microclimate conditions and low habitat complexity (vertical and horizontal distribution of the vegetation) in this habitat. This hypothesis is supported by the fact that the most abundant species of both snakes and lizards have fossorial habits. The assemblage of snakes is apparently mainly determined by abiotic characteristics of the habitat, while the assemblage of lizards, by vegetation cover.
Keywords: *diversity, lizards, restinga, sand dunes, snakes.*

SANTOS, M.B., OLIVEIRA, M.C.L.M. & TOZETTI, A.M. **Diversidade e uso do ambiente por serpentes e lagartos em ambientes costeiros do extremo sul brasileiro**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn01812032012

Resumo: O estudo teve como objetivo avaliar a composição de espécies de serpentes e lagartos em ambientes costeiros no extremo sul brasileiro. Foram feitas amostragens sistematizadas em hábitats de dunas e restingas entre abril de 2009 e março de 2010 por meio de armadilhas de interceptação e queda, abrigos artificiais e procuras visuais. O ambiente de restinga revelou uma maior riqueza de espécies do que as dunas. As taxocenoses revelaram uma menor riqueza do que a observada em outros biomas brasileiros, o que parece estar associado às condições microclimáticas menos estáveis e à baixa complexidade estrutural desses habitats (distribuição vertical e horizontal da vegetação). Essa hipótese parece ser reforçada pelo fato de tanto para serpentes quanto para lagartos as espécies mais abundantes apresentam hábitos fossoriais. Aparentemente a taxocenose de serpentes é determinada predominantemente pelas características abióticas (microclima) do habitat enquanto que a de lagartos pelo padrão de cobertura vegetal.
Palavras-chave: *diversidade, dunas, lagartos, restinga, serpentes.*

Introduction

In the last decades, several studies on assemblages of snakes and lizards have been conducted in the Neotropics, broadening the understanding of the diversity patterns of these groups (Di-Bernardo et al. 2007). However, the number of studies is still low when compared to those in Europe, North America, and Australia (Seigel & Collins 1993). This also occurs in Brazil, which houses a large diversity of Squamata (Di-Bernardo et al. 2007). Currently, 241 Brazilian species of lizard and 371 species of snakes have been described (Bérnils 2010). Unfortunately, generalizations on the patterns of regional diversity of Squamata in Brazil are limited, as most studies available focus on forest habitats (*e.g.* Marques & Sazima 2004, Bernarde & Abe 2006, Sawaya et al. 2008) and most recently in Cerrado (*e.g.* Colli et al. 2002, Costa et al. 2007, Sawaya et al. 2008). In Rio Grande do Sul state, samplings have been concentrated in the Pampa, Araucaria forest, central depression, and northern coastal region (Maciel et al. 2003, Santos et al. 2005, Zanella & Cechin 2006, Winck et al. 2007).

Southern Brazil, especially the southernmost region of Rio Grande do Sul state houses 21 species of lizards and 75 species of snakes (Brasil 2004, 2008, Quintela et al. 2006, Quintela & Loebmann 2009) and most of them are poorly studied. The municipality of Rio Grande, in Rio Grande do Sul state, harbors one of the largest continuous and relatively well-preserved areas of coastal grasslands, which are characterized by a mosaic of sand dunes and restingas. These two habitats differ, regarding patterns of plant cover and daily temperature variation (Cordazzo & Seeliger 1987, Calliari & Klein 1993). Despite the physical proximity between dunes and restinga, their characteristics might impose different limits for their use by snakes and lizards (Rocha & Sluys 2005). Thus, the present study was aimed at examining differences in species composition and relative abundance in assemblages of snakes and lizards in areas of dunes and restinga in southernmost Brazil.

Materials and Methods

1. *Study area*

Samplings were conducted in a continuous area of coastal grasslands of approximately 14700 ha, located at sea level (Figure 1a), known as Balneário Cassino (32° 07’ 54.65” S and 52° 20’ 53.36” O), municipality of Rio Grande, Rio Grande do Sul, Brazil. The climate is humid subtemperate with an average annual temperature of 18.1 °C (Maluf 2000). Seasons are well defined, with occasional dry periods in the spring and average annual rainfall of 1162 mm (Maluf 2000). During this study, between April 2009 and March 2010, the hottest months were January and February (average air temperature = 25.4 °C) and the coldest months were June and July (average air temperature = 11.2 °C). In the study period total rainfall was 1371 mm, with November and February being the wettest ($\sum = 527.9$ mm) and July and March the driest months ($\sum = 63.3$ mm; Figure 2). Climate data were obtained from weather station #83995 of Rio Grande (EM 83995-INMET).

Two distinct habitats were sampled: (1) coastal grasslands associated with coastal dunes (hence termed “dune habitat”; Figure 1b) and (2) coastal grasslands associated with restinga (termed “restinga habitat”; Figure 1c).

The vegetation in the dune habitat consists of grasses and shrubs [e.g. *Panicum racemosum* (P. Beauv.) and *Senecio crassiflorus* (Poir.), Calliari & Klein (1993)]. Because of the ground cover and sandy soil, daily temperatures in the dunes vary widely (0-40 °C, Calliari & Klein 1993). The vegetation in the restinga habitat is composed of predominantly shrubs and trees [e.g. *Lithraea brasiliensis* Marchand and *Chrysophyllum marginatum* (Hook. & Arn.), which provide significant amounts of leaf litter (Dorneles & Waechter 2004). The higher density and taller vegetation in the restinga provide more micro-climatic stability, and therefore the daily temperature variation is not as wide as in the dunes (Rocha & Sluys 2005).

2. *Field work*

The study was carried out between April 2009 and March 2010. The following methods were used to capture snakes and lizards:

a) Pitfall traps with drift fence (PDF) – consisted of 40 m lines with four buckets connected by a 50 cm high nylon drift fence (for details see Sawaya et al. 2008). Three groups were set up at least 600 m apart in each examined habitat (dunes and restingas). Each group consisted of two lines of buckets, totaling 12 lines, 480 m of drift fence and 48 buckets (24 in each examined habitat). To minimize the effects of plant cover heterogeneity among groups, we selected visually similar areas regarding density and structure of the vegetation. Uncovered buckets were inspected during a period of five consecutive days, repeated every 15 days, totaling 120 sampling days. After 12 months of collection, 5.760 pitfall traps were monitored;

b) Artificial shelters (AS) – We installed three shelters for each line of traps, two located at the opposite sides of the line and one in the center (approximately 5 m from buckets), totaling 36 artificial shelters. Each AS consisted of a wood board of 1 m^2 and approximately 6 mm thick, placed on the ground after clearing the vegetation (Parmelee & Fitch 1995). The inspection of shelters was carried out simultaneously to PDF, totaling 5.184 inspections throughout the study;

c) Time constrained visual searches (TCVS) – we conducted 20 hours/man of search per month equally distributed between dune and restinga habitats, totaling 240 hours/man (Martins & Oliveira 1998); and

d) Incidental encounters (IC) – This method was used exclusively to complement the list of species and included animals found during activities other than those previously described.

The identification of specimens was based on available identification keys (Quintela & Loebmann 2009, Achaval & Olmos 2003), as well as consultation of materials from collections of other institutions. Nomenclature followed the Brazilian List of Reptiles of the Sociedade Brasileira de Herpetologia (Bérnils 2010).

3. *Data analysis*

Catches taken by TCVS and IC were used only for making the list of local species. To evaluate the efficiency of PDF and AS (the only methods that allow controlled sampling effort), an average curve of species accumulations (collector’s curve) was calculated with the software Estimates 8.2.0 (Colwell 2009), adjusted for 1000 iterations. The final average curve represented the average values of its points. The data obtained for each group of traps and their corresponding shelters, during a period of five days were considered one sample, with a total of 138 samples (6 groups and 23 sample periods).

Five richness estimators were tested for precision: Chao 1 and 2, Jacknife 1 and 2 and ACE. Chao 1 was chosen for stabilizing quickly and constancy of the extrapolated value for 1000 random iterations calculated with the software Estimates 8.2.0 (Colwell 2009). To examine the participation of each species in the assemblage composition, we also calculated dominance with the rarefaction method using the software Ecosim (Gotelli & Entsminger 2001), adjusted for 1000 iterations. Number of captures obtained for the two habitats were compared with the Mann-Withney test (exclusively for species with more than 10 captures, sensu Zar 1999).

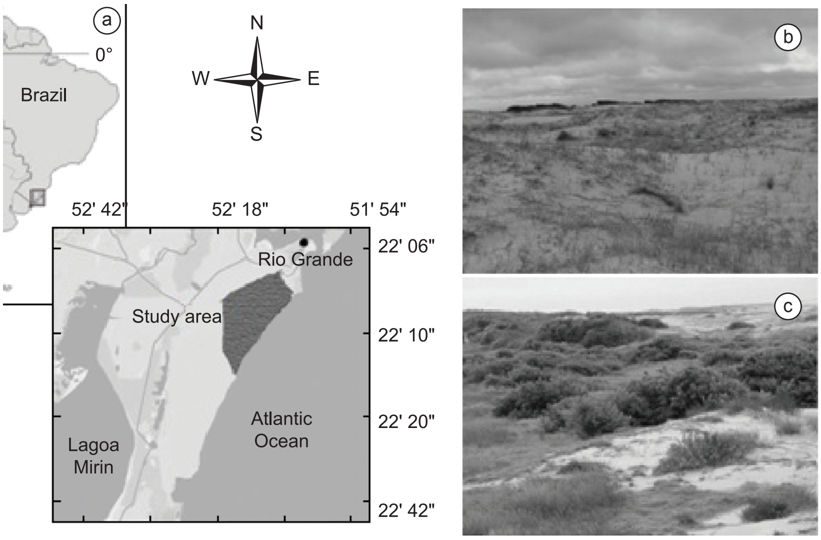

Figure 1. a) Geographic location of the study area; samplings were carried out in the area highlighted in the map. b) General aspect of the dune habitat. c) General aspect of the restinga habitat.

Figura 1. a) Localização geográfica da área de estudos; as amostragens foram realizadas na área destacada no mapa. b) Aspectos gerais do habitat de dunas. c) Aspectos gerais do habitat de restinga.

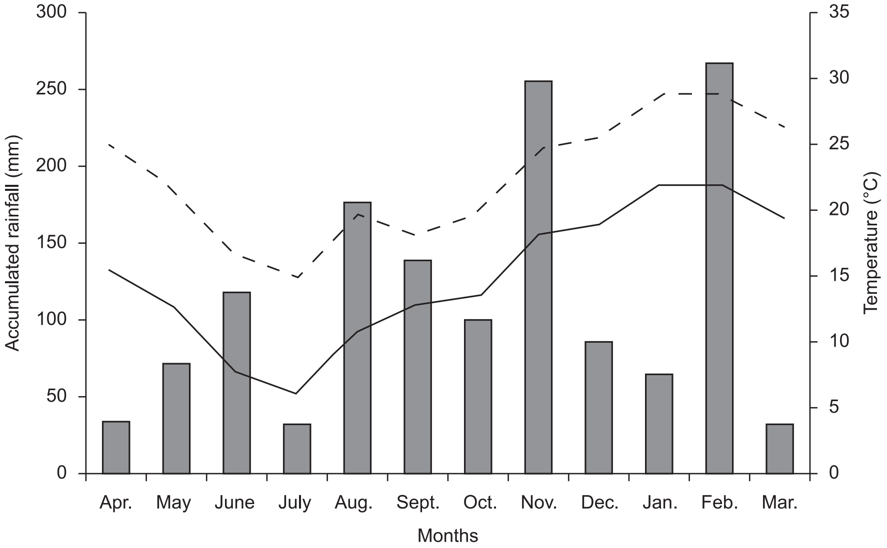

Figure 2. Accumulated rainfall variation (bars), maximum (dashed lines) and minimum temperatures (line), between April 2009 and March 2010 in the study area, in the municipality of Rio Grande, RS. Source: EM 83995-INMET.

Figura 2. Variação da pluviosidade acumulada (barras), temperaturas máxima (linha pontilhada) e mínima (linha contínua), entre abril de 2009 e março de 2010 na área de estudo, município do Rio Grande, RS. Fonte: EM 83995-INMET.

Were used a cluster analysis using the Sorensen's index of similarity to compare the species composition of the study area with those of other habitats. In the comparison, only species with genus and species epithets were included. Assemblages of snakes and lizards were analyzed separately due to ecological differences and to facilitate comparisons with other studies. The species composition was compared with those of other localities and biomes according to the classification by IBGE (Instituto... 2011). For snakes, the following studies were compared: Amazon rainforest - Martins (1991); Atlantic rainforest - Zanella & Cechin (2006), Hartmann et al. (2009) and Borges-Martins et al. (2007); Cerrado – Sawaya et al. (2008) and Souza et al. (2010); Caatinga - Loebmann & Hadaad (2010); Pantanal - Strüssmann & Sazima (1993); Coastal environment of Uruguay - Carreira et al. (2005); Argentine Chaco - Leynaud & Bucher (1999); Pampa - Santos et al. (2005), Quintela & Loebmann (2009) and this study. For lizards, we selected: Amazon rainforest - Ilha & Dixo (2010) and Silva et al. (2011); Atlantic rainforest - Carvalho et al. (2007), Costa et al. (2009), Silva-Soares et al. (2011), Freire (1996) and Teixeira (2001); Cerrado - Valdujo et al. (2009) and Cintra et al. (2009); Chaco region in Argentina - Cabrera (2009) and Álvarez et al. (2009); Coastal environment of Uruguay - Carreira et al. (2005); Pampa - Santos et al. (2005), Quintela & Loebmann (2009) and this study.

Results

1. Snakes

1.1. Richness and dominance

Thirteen species from two families, Dipsadidae (12 species and 98.1% of captures) and Viperidae (one species, 1.79% of captures; Table 1), were captured. The three most abundant genera were *Liophis* (three species, 56.3% of captures), *Xenodon* (one species, 18.75% of captures) and *Phalotris* (one species, 98.21% of captures; Table 1).

For the analysis of species richness, we only included captures obtained using PDF and AS. The species accumulation curve did not stabilize (Figure 3), indicating that new samplings would increase the number of snake species. Species richness was higher in the restinga (nine species) than in the dune habitat (six species). Additionally, the estimated richness (Chao1) of snakes was higher for the restinga (9.68 ± 3.04) than for dunes (5.93 ± 1.15).

The dominance observed for the dune habitat was lower (0.40) than that of the restinga (0.43). Although the number of captures in the dunes (n = 181) was higher than that of the restinga (n = 79), this difference was not significant (U = 2248.5, p = 0.574, n = 138). The same occurred when species were examined individually. In the dunes, the most abundant species were *Liophis poecilogyrus* (40.62% of captures), *Xenodon dorbignyi* (26.56% of captures) and *Liophis jaegeri* (12.6% of captures; Table 1). In the restinga, the three most abundant species were *L. poecilogyrus* (43.75% of captures), *Phalotris lemniscatus* (16.66% of captures) and *L. jaegeri* (12.5% of captures; Table 1). The snakes *Boiruna maculata* and *Helicops infrataeniatus* were observed only in the dunes, while *Oxyrhopus rhombifer*, *Philodryas aestiva* and *Rhinocerophis alternatus*, only in the restinga (Table 1).

1.2. Comparison of snake assemblages from other localities

The number of species found in this study (n = 13) was less than the total species in all areas compared (Table 2). The cluster analysis revealed that the snake assemblage described in the present study is most similar to those of the Coastal environment of Uruguay (Careira et al. 2005), Atlantic rainforest from south of Brazil and Pampa habitats (Table 2; Figure 4). Similarity was lowest when compared to assemblages of the Atlantic Rainforest in southeastern Brazil (Hartmann et al. 2009) and other open habitats (e.g. Cerrado, Pantanal and Chaco; Figure 4).

2. Lizards

2.1. Richness and dominance

We captured two hundred lizards from five species distributed in five families, Liolaemidae (64.5% of captures), Gymnophtalmidae (30% of captures), Scincidae (3% of captures), Teiidae (1.5% of captures) and Anguidae (1% of captures; Table 3). Specimens of the latter family represent a new species that is currently being described (M. Borges Martins, personal comment.).

Table 1. Snake species captured in dune and restinga habitats in the municipality of Rio Grande, RS.

Tabela 1. Espécies de serpents capturadas nso habitats de dunas e restinga no município do Rio Grande, RS.

Family	Species	Dunes						Restinga						Total	
		AS	PDF	IO	TCVS	T	A%	AS	PDF	IO	TCVS	T	A%	TG	T%
Dipsadidae															
	Boiruna maculata (Boulenger, 1896)	0	0	1	0	1	1.56	0	0	0	0	0	0	1	0.9
	Helicops infrataeniatus (Jan, 1865)	0	0	1	0	1	1.56	0	0	0	0	0	0	1	0.9
	Liophis jaegeri (Günther, 1858)	3	0	1	4	8	12.6	2	3	0	1	6	12.5	14	12.5
	Liophis semiaurius (Cope, 1862)	0	0	1	0	1	1.56	0	1	0	0	1	2.09	2	1.78
	Liophis poecilogyrus (Wied, 1824)	13	3	1	9	26	40.62	6	4	4	7	21	43.75	47	41.97
	Oxyrhopus rhombifer Duméril, Bibron & Duméril, 1854	0	0	0	0	0	0	0	1	0	0	1	2.09	1	0.9
	Phalotris lemniscatus (Duméril, Bibron & Duméril, 1854)	0	1	0	1	2	3.13	0	4	4	0	8	16.66	10	8.92
	Philodryas aestiva (Duméril, Bibron & Duméril, 1854)	0	0	0	0	0	0	0	2	0	0	2	4.16	2	1.78
	Philodryas patagoniensis (Girard, 1857)	2	1	0	0	3	4.68	0	0	1	0	1	2.08	4	3.58
	Psomophis obtusus (Cope, 1984)	0	0	0	1	1	1.56	0	1	0	0	1	2.09	2	1.78
	Thamnodynastes hypoconia (Cope, 1860)	0	3	0	1	4	6.26	0	1	0	0	1	2.09	5	4.46
	Xenodon dorbignyi (Duméril, Bibron & Duméril, 1854)	0	8	1	8	17	26.56	0	2	2	0	4	8.33	21	18.75
Viperidae															
	Rhinocerophis alternatus (Duméril, Bibron & Duméril, 1854)	0	0	0	0	0	0	0	0	2	0	2	4.16	2	1.78
Total of captures		18	16	6	24	64	100	8	19	13	8	48		112	100

AS = captures in artificial shelters; PDF = captures with pitfall traps with drift fence; IO = incidental encounters; TCVS = captures during time constrained visual searches; T = number of individuals captured per habitat; TG = total capture in dunes and restinga; A% = percentage in relation to the total of individuals captured per habitat and T% = percentage in relation to the total of individuals captured in the two habitats combined.

AS = capturas em abrigos artificiais; PDF = capturas em armadilhas de interceptação e queda; IO = encontros ocasionais; TCVS = capturas por procura visual limitada por tempo; T = número de indivíduos capturados por habitat; TG = total de capturas em dunas e restinga; A% = porcentagem em relação ao total de indivíduos capturados por habitat e T% = porcentagem em relação ao total de indivíduos capturados nos dois habitats.

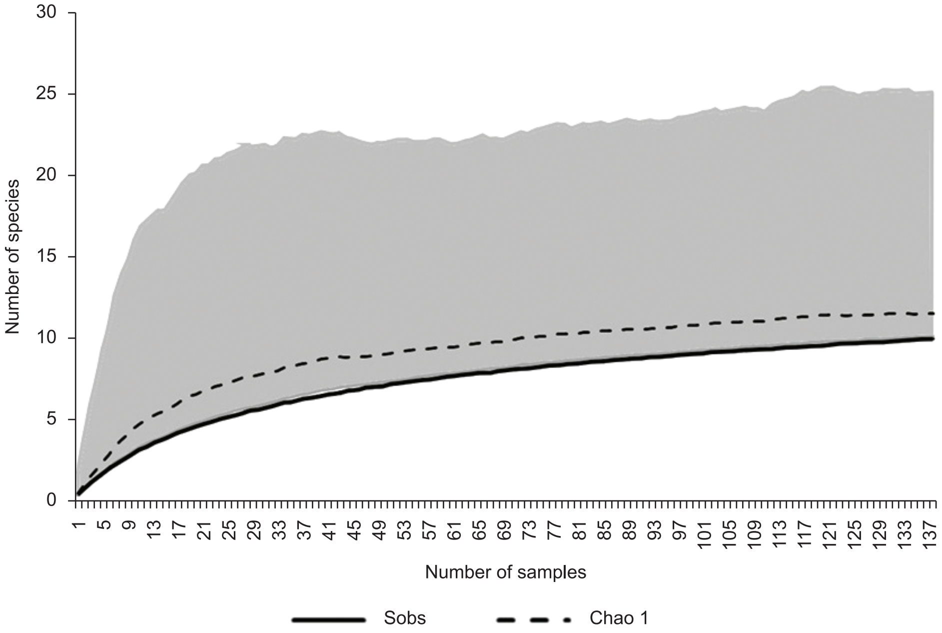

Figure 3. Accumulation curve of snake species captured between April 2009 and March 2010 in dune and restinga habitats in southernmost Brazil. The curves represent the number of species observed (Sobs) and the number generated by the richness estimator Chao1. The points represent the average of 1000 curves generated with a random order of samples. The gray area represents the standard deviation associated with the mean of 1000 curves generated by the random order of samples.

Figura 3. Curva de acumulação de espécies de serpentes capturadas entre abril de 2009 e março de 2010 nos habitats de dunas e restinga no extremo sul do Brasil. As curvas representam o número de espécies capturadas (Sobs) e o número gerado pelo estimador de riqueza Chao 1. Os pontos representam a média de 1000 curvas geradas com uma ordem aleatória de amostras. A área cinza representa o desvio padrão associado à média de 1000 curvas geradas pela ordem aleatória de amostras.

Table 2. Number of snake species found in 14 different areas of Brazil, Argentina and Uruguay.

Tabela 2. Número de espécies de serpentes encontradas em 14 áreas diferentes no Brasil, Argentina e Uruguai.

Authors	Country	Biome	Richness
Martins (1991)	Brazil	Amazon rainforest	64
Leynaud & Bucher (1999)	Argentina	Eastern Chaco	47
Leynaud & Bucher (1999)	Argentina	Western Chaco	38
Loebmann & Haddad (2010)	Brazil	Caatinga	37
Sawaya et al. (2008)	Brazil	Cerrado	36
Hartmann et al. (2009)	Brazil	Atlantic rainforest	36
Strüssmann & Sazima (1993)	Brazil	Pantanal	32
Santos et al. (2005)	Brazil	Non coastal Pampa	24
Borges-Martins et al. (2007)	Brazil	Atlantic rainforest	23
Quintela & Loebmann (2009)	Brazil	Coastal Pampa	19
Zanella & Cechin (2006)	Brazil	Atlantic rainforest	19
Souza et al. (2010)	Brazil	Cerrado	18
Carreira et al. (2005)*	Uruguay[1]	Coastal environment	16
Present study	Brazil	Coastal Pampa	13

[1] Department of Rocha (Uruguay); *List of species obtained based on the compilation of several studies conducted in Uruguay.

[1] Departamento de Rocha (Uruguai); *Lista de espécies obtida através da compilação de diversos estudos realizados no Uruguai.

The species accumulation curve (captures in AS and PDF) approached stability (Figure 5). The observed richness in the restinga habitat (five species) was higher than that of dunes (four species). Also, the estimated richness (Chao 1) of lizards was higher for the restinga (4.74 ± 1.08) than for the dune habitat (3.58 ± 0.61).

The dominance observed for the dunes was higher (0.66) than that of that of the restinga (0.57). The number of captures of lizards was significantly different between habitats ($U = 1822$, $p = 0.001$, $n = 138$), higher in the dunes ($n = 147$) than that in restinga ($n = 52$; Table 3). In both habitats, *Liolaemus occipitalis* was the most abundant species with 90 captures for the dunes and 30 for the restinga (41.34% of the total of captures), followed by *Cercosaura schreibersii*, with 45 captures in the dunes and 15 in the restinga (19.23% of the total of captures; Table 3).

For *L. occipitalis* ($U = 1789.5$, $p = 0.011$, $n = 138$) and *C. schreibersii* ($U = 1894.5$, $p = 0.038$, $n = 138$), the number of captures was higher in the dunes ($n = 98$ and 45, respectively) than in the restinga ($n = 30$ and 15; Table 3). The lizard *L. occipitalis*

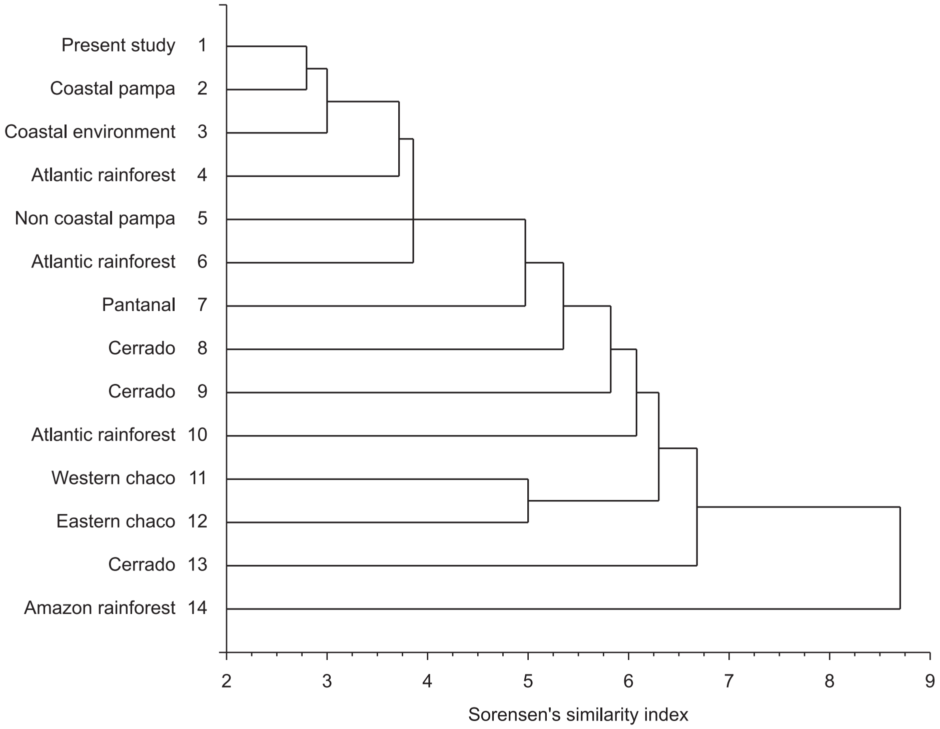

Figure 4. Dendrogram of the grouping analysis based on the composition (presence and absence) of 189 snake species distributed in 14 assemblages. 1) Present study; 2) Quintela & Loebmann (2009); 3) Carreira et al. (2005); 4) Borges-Martins et al. 2007; 5) Santos et al. (2005); 6) Zanella & Cechin (2006); 7) Strüssmann & Sazima (1993); 8) Souza et al. (2010); 9) Sawaya et al. (2008); 10) Hartmann et al. (2009); 11) Leynaud & Bucher (1999); 12) Leynaud & Bucher (1999); 13) Loebmann & Hadaad (2010); 14) Martins (1991).

Figura 4. Dendrograma de análise de agrupamento baseada na composição (porcentagem e abundância) de 189 espécies de serpentes distribuídas em 14 assembléias. 1) Presente estudo; 2) Quintela & Loebmann (2009); 3) Carreira et al. (2005); 4) Borges-Martins et al. 2007; 5) Santos et al. (2005); 6) Zanella & Cechin (2006); 7) Strüssmann & Sazima (1993); 8) Souza et al. (2010); 9) Sawaya et al. (2008); 10) Hartmann et al. (2009); 11) Leynaud & Bucher (1999); 12) Leynaud & Bucher (1999); 13) Loebmann & Hadaad (2010); 14) Martins (1991).

Table 3. Lizard species captured in dune and restinga habitats in the municipality of Rio Grande, RS.

Tabela 3. Espécies de lagartos capturadas em habitats de dunas e restinga no município do Rio Grande, RS.

Family	Species	Dunes						Restinga						Total	
		AS	PDF	IO	TCVS	T	A%	AS	PDF	IO	TCVS	T	A%	TG	T%
Anguidae															
	Ophiodes sp.	0	1	0	-	1	0.68	0	1	0	-	1	1.92	2	1
Gymnophthalmidae															
	Cercosaura schreibersii Wiegmann, 1834	43	2	0	-	45	30.4	15	0	0	-	15	28.84	60	30
Scincidae															
	Mabuya dorsivittata Cope, 1862	3	0	0	-	3	2.03	3	0	0	-	3	5.77	6	3
Teiidae															
	Tupinambis merianae (Duméril & Bibron, 1839)	0	0	0	-	0	0	1	2	0	-	3	5.77	3	1.5
Liolaemidae															
	Liolaemus occipitalis Boulenger, 1885	0	98	1	-	99	66.89	0	30	0	-	30	57.7	129	64.5
Total		46	101	1	-	148	100	19	33	0	0	52	100	200	100

AS = captures in artificial shelters; PDF = capture with pitfalls with drift fence; IE = captures during incidental encounters; TCVS = captures during time-constrained visual searches; T = number of individuals captured for the habitat; TG = total captures in dunes and restinga; A% = percentage in relation to the total number of individuals captured per habitat and T% = percentage in relation to the total number of individuals captured in the two habitats combined.

AS = capturas em abrigos artificiais; PDF = capturas em armadilhas de interceptação e queda; IO = encontros ocasionais; TCVS = capturas por procura visual limitada por tempo; T = número de indivíduos capturados por habitat; TG = total de capturas em dunas e restinga; A% = porcentagem em relação ao total de indivíduos capturados por habitat e T% = porcentagem em relação ao total de indivíduos capturados nos dois habitats.

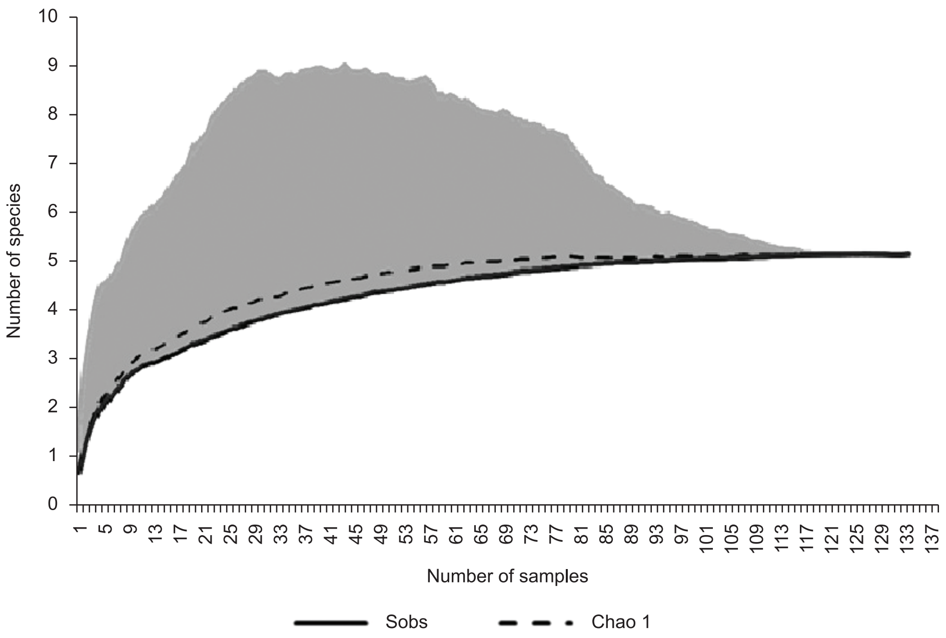

Figure 5. Species accumulation curve of lizards captured between April 2009 and March 2010 in dune and restinga habitats in the municipality of Rio Grande, RS. The curves represent the number of species observed (Sobs) and the number generated by the richness estimator Chao 1. The points represent the average of 1,000 curves generated with a random order of samples. The gray area represents the standard deviation associated with the mean of 1000 curves generated by the random order of samples.

Figura 5. Curva de acumulação de espécies de lagartos capturados entre abril de 2009 e março de 2010 nos habitats de dunas e restinga no município do Rio Grande, RS. As curvas representam o número de espécies observadas (Sobs) e o número gerado pelo estimador de riqueza Chao 1. Os pontos representam a média de 1000 curvas geradas com uma ordem aleatória de amostras. A área cinza representa o desvio padrão associado à média de 1000 curvas geradas pela ordem aleatória de amostras.

was only captured by PDF and *Mabuya dorsivittata*, only by AS. *Cercosaura schreibersii* had only two captures by PDF. All species of lizards were observed in both habitats, except for *Tupinambis merianae*, captured only in the restinga (Table 3).

2.2. Comparison with lizard assemblages from other localities

The number of species of lizards found in this study (n = 5) was lower than those found in compared studies (Table 4).

Cluster analysis revealed that the assemblage of lizards studied has greater similarity with areas of Pampa, Coastal environment of Uruguay and Eastern Chaco in Argentina (Table 4; Figure 6). The dendrogram revealed a distinction between open and forested habitats. Similarity was lowest between assemblages of forest and that of the present study.

Discussion

Despite the intense sampling effort and the combination of capture methods, the non-stabilization of the collector's curve suggests that the species richness of snakes in the study area is still higher than that recorded. The numbers of species found in this study represents 68% of the snake species and 62% of the lizard species previously recorded in the municipality (Quintela et al. 2006). This indicates the importance of dune and restinga habitats for the region. The relatively low species richness compared to other Brazilian assemblages might be due to historical factors (Seeliger 1997), an abiotic filter created by the wide daily temperature variation, as well as the harsh winter for tropical standards (Maluf 2000). These factors associated to strong coastal winds (Calliari & Klein 1993), make these habitats less susceptible for the colonization by ectotherms. Consequently, the lower richness observed in dunes compared to restinga (for snakes as well as lizards) might be associated to more severe microclimatic conditions in dunes (e.g. insolation and wide daily temperature variation) and also the lower heterogeneity in plant cover.. On the other hand this configuration should be driven by historical factors. A biogeographic approach should be helpful for subsequent studies in similar habitats.

Interestingly, two fossorial snakes were the dominant species in dunes (*X. dorbignyi*) as well as restinga (*P. lemniscatus*). The ability to bury might increase the adaptability to dune and restinga habitats, both subjected to abrupt temperature variations at the ground surface (Tozetti et al. 2009, Oliveira et al. 2001). The dominance of semi-fossorial (*L. occipitalis*) and cryptic (*C. schreibersii*) species was also observed for lizards. The sandy substrate possible favors *L. occipitalis*, which buries itself in the sand and builds shelters (Santos et al. 2010, Bujes & Verrastro 1998). In contrast, *C. schreibersii*, instead of burying itself, uses logs and stones as shelter (Doan 2003, pers. obs.). Although this behavior could increase its affinity for the restinga, where the leaf litter and additional accumulated plant material provide more shelters, this was not observed. The use of artificial shelters might have increased the capture of individuals of these species in the dunes (where the availability of natural shelters is low), masking differences in abundance between habitats.

The cluster analysis suggests that the type of vegetation has a secondary role in the structure of snake assemblages examined. This is supported by the higher similarity of the study area to some assemblages from forests than to those from open habitats such as Pampa or Pantanal. However, the similarity with other Coastal environments suggest a stronger abiotic influence in the structure of

Table 4. Number of species of lizards found in 14 areas of different states, habitats and biomes of Brazil, Argentina and Uruguay, with their corresponding references.

Tabela 4. Número de espécies de lagartos encontradas em 14 áreas em diferentes estados, habitats e biomas do Brasil, Argentina e Uruguai, com suas referencias correspondentes.

Authors	Country	Biome	Richness
Cabrera (2009)	Argentina	Gran Chaco	28
Valdujo et al. (2009)	Brazil	Cerrado	26
Ilha & Dixo (2010)	Brazil	Amazon Rainforest	19
Silva et al. (2011)	Brazil	Amazon Rainforest	17
Freire (1996)	Brazil	Atlantic Rainforest	13
Cintra et al. (2009)	Brazil	Cerrado	13
Álvarez et al. (2009)	Argentina	Eastern Chaco	13
Carvalho et al. (2007)	Brazil	Atlantic Rainforest	12
Costa et al. (2009)	Brazil	Atlantic Rainforest	12
Silva-Soares et al. (2011)	Brazil	Atlantic Rainforest	11
Teixeira (2001)	Brazil	Atlantic Rainforest	8
Carreira et al. (2005)*	Uruguai[1]	Coastal environment	8
Santos et al. (2005)	Brazil	Non coastal Pampa	7
Quintela & Loebmann (2009)	Brazil	Coastal Pampa	7
Present study	Brazil	Coastal Pampa	5

[1]Department of Rocha (Uruguay); *List of species based on the compilation of several studies.

[1]Departamento de Rocha (Uruguai); *Lista de espécies baseada na compilação de diversos estudos.

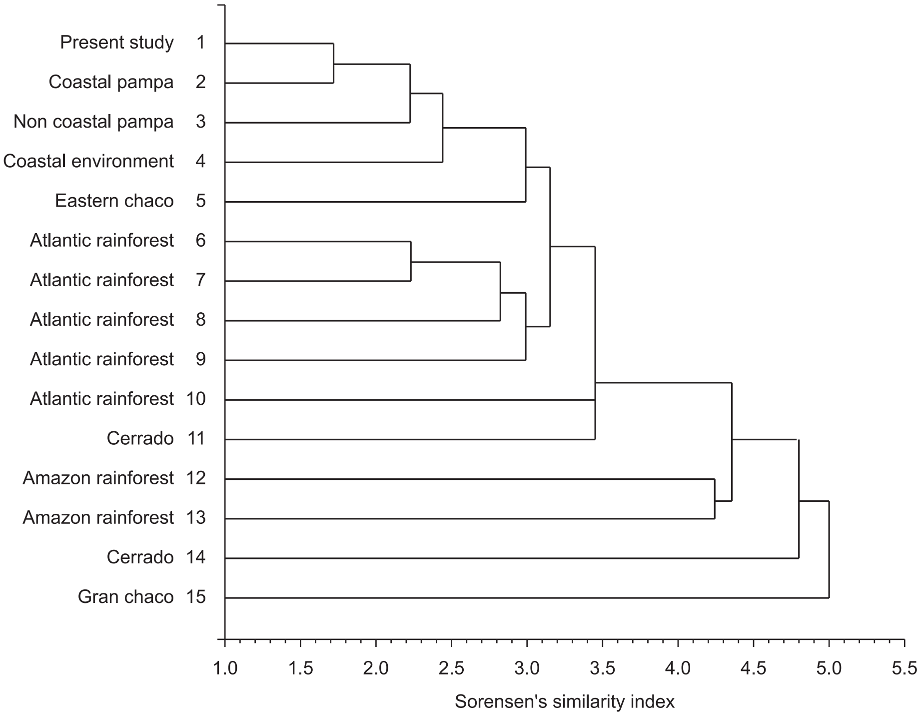

Figure 6. Dendrogram of the grouping analysis of the species composition of lizards (presence and absence of 98 species) of eight assemblages. 1) Present study; 2) Quintela & Loebmann (2009); 3) Santos et al. (2005); 4) Carreira et al. (2005); 5) Álvarez et al. 2009; 6) Teixeira (2001); 7) Silva-Soares et al. (2011); 8) Carvalho et al. (2007); 9) Costa et al. (2009); 10) Freire (2006); 11) Cintra et al. (2009); 12) Silva et al. (2011); 13) Ilha & Dixo (2010); 14) Valdujo et al. (2009); 15) Cabrera (2009).

Figura 6. Dendrograma de análise de agrupamento baseada na composição (porcentagem e abundância) de 189 espécies de serpentes distribuídas em 14 assembléias. 1) Presente estudo; 2) Quintela & Loebmann (2009); 3) Santos et al. (2005); 4) Carreira et al. (2005); 5) Álvarez et al. 2009; 6) Teixeira (2001); 7) Silva-Soares et al. (2011); 8) Carvalho et al. (2007); 9) Costa et al. (2009); 10) Freire (2006); 11) Cintra et al. (2009); 12) Silva et al. 2011; 13) Ilha & Dixo (2010); 14) Valdujo et al. (2009); 15) Cabrera (2009).

communities, which is supported by the similarity observed between the study area and the Coastal environment of Uruguay (Carreira et al. 2005). In both areas, the climatic conditions and the marine influence are similar. This abiotic filter, less favorable to ectotherms, might also be responsible for the relatively low species richness compared to other Brazilian assemblages.

Conversely, lizard assemblages showed a stronger association with plant cover. Similarity was higher with the Pampa, where climatic conditions are distinct from those of the Coastal environments (Maluf 2000, Santos et al. 2005). Additionally, despite the coastal influence in areas of the Atlantic Forest, the assemblages from this biome were different from that of the study area. Although the Atlantic Forests included restinga habitats, plant cover consists of an arboreal component more developed than that of the study area (Freire 1996, Teixeira 2001, Carvalho et al. 2007). This divergence suggests that plant cover pattern represent a primary filter, wich overlaps the abiotic factors in the structure of the lizard assemblages compared.

Our findings also revealed an intrinsic heterogeneity of the communities of some groups of Squamata in habitats that comprise the Brazilian coastal grasslands. Despite low endemic rates, the coastal grasslands of southernmost Brazil contain biotic and abiotic characteristics that act as important filters in the structure of snakes and lizards communities.

Acknowledgements

The authors are thankful to the researchers Alexandre Hartmann and Lucas Ott Tavaves for field work assistance, and to CNPq, FAPERGS, and Capes for financial support to conduct this study and a Master's fellowship.

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Received 20/09/2011
Revised 24/06/2012
Accepted 10/08/2012

First record of the exotic channel catfish *Ictalurus punctatus* (Rafinesque 1818) (Siluriformes: Ictaluridae) in the Rio dos Sinos basin, RS, Brazil

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CRUZ-SPINDLER, S., LEAL, M.E., LEHMANN, P.A. & SCHULZ, U.H. **First record of the exotic channel catfish *Ictalurus punctatus* (Rafinesque 1818) (Siluriformes: Ictaluridae) in the Rio dos Sinos basin, RS, Brazil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/en/abstract?article+bn01212032012

Abstract: The introduction of non-native species in inland waters is one of the main threats for aquatic biodiversity. Introduced species may compete for resources, prey on native fauna, spread diseases and parasites. The channel catfish *Ictalurus punctatus* (Siluriformes, Ictaluridae) was first described by Rafinesque 1818 in the United States and is widely distributed in North America, south Canada and north-east Mexico. This species adapts easily to new environmental conditions, is tolerant to different habitats, and is grown easily in aquaculture, which turns it into a potential invader of natural aquatic environments. The introduction of *I. punctatus* occurs in Brazil since 1980, and this is the first record of its occurrence in the Rio dos Sinos basin, Brazil. A female adult catfish was captured during a survey in the main channel of the Rio dos Sinos (29° 44' 14.04" S and 51° 05' 11.08" W). Most probably the captured individual is an escapee from nearby aquaculture facilities.
Keywords: *introduction, exotic species, aquaculture, catfish, environmental laws.*

CRUZ-SPINDLER, S., LEAL, M.E., LEHMANN, P.A. & SCHULZ, U.H. **Primeira ocorrência do exótico bagre do canal, *Ictalurus punctatus* (Rafinesque 1818), (Siluriformes, Ictaluridae) na Bacia do Rio dos Sinos, RS, Brasil**. Biota Neotrop. 12(3): http://www.biotaneotropica.org.br/v12n3/pt/abstract?article+bn01212032012

Resumo: A introdução de peixes não nativos em águas interiores é uma das principais ameaças à biodiversidade. Espécies introduzidas podem competir por recursos, predar a fauna nativa, transmitir doenças e parasitas. O bagre americano, *Ictalurus punctatus* (Siluriformes, Ictaluridae), foi descrito por Rafinesque em 1818 nos Estados Unidos. Possui ampla distribuição na América do Norte, Sul do Canadá, e Nordeste do México. A espécie apresenta alto valor comercial devido ao fato de adaptar-se facilmente a novos ambientes, tolerar variações ambientais, e ser de fácil cultivo. Como todas as espécies exóticas ou alóctones criadas na aqüicultura, é um potencial invasor aos ambientes aquáticos naturais. No Brasil, sua introdução ocorre desde o ano 1980. Este é o primeiro registro de ocorrência de *I. punctatus*, para a bacia do Rio dos Sinos, São Leopoldo, Brasil. A captura de uma fêmea adulta foi realizada durante um levantamento ictiofaunístico na calha principal do Rio dos Sinos (29° 44' 14.04" S e 51° 05' 11.08" W). O individuo capturado provavelmente representa o resultado de escape de uma estação de piscicultura.
Palavras-chave: *introdução, espécies exóticas, aquicultura, bagre, legislação ambiental.*

Introduction

The deliberate or accidental introduction of species in freshwater systems is an increasing global problem that affects the aquatic biota (Lintermans 2004). Of approximately 1,678 documented introductory events of 280 species of freshwater fish in the world, 70.9% resulted in the establishment of the species in the new environment (Bomford et al. 2010). The introduction or transference of exotic and/or allochthonous species can result in the decline or extinction of native species (Rahel 2000). Introduced species can be vectors for pathogens and parasites, and usually are competitors for resources and areas for reproduction and may alter the aquatic environment (Welcomme 1988, Agostinho et al. 2000).

Some species are cited in lists or databases like the national database for non-native invasive species, established by the *Instituto Hórus* and The Nature Conservancy in cooperation with the Ministry of Environment and associated members from all over Brazil. These non-native species are generally introduced for aquaculture, biological control, sport fishing, released by aquarists, by accident (Ligas 2007). The introduction of nonnative species can be used to compensate the decline of natural fish stocks or to occupy a "vacant niche" in newly created artificial ecosystems like reservoirs (Elvira & Almodóvar 2001).

The Brazilian Federal Law 9605-98 determines punishement of up to three years of reclusion for unauthorized introductions of exotic especies. Nevertheless, as in a completely contradictory way, the polycultural farming of commercial species such as tilapia (*Oreochromis niloticus niloticus* and *Tilapia rendalli*; Cichlidae) and grass carp (*Ctenopharyngodon idella*; Cyprinidae) is encouraged, even by state agencies. As recorded by FEPAGRO (Mardini et al. 1997) more than 90% of the established commercial cultivations of the Rio Grande do Sul state are of exotic species, several of which are frequently recorded in inventories of fish assemblages in southern Brazil (Mardini et al. 1997, Schulz & Leal 2005, Leal et al. 2009, Winckler-Sosinski et al. 2009, Leal et al. 2010).

The Ictaluridae belong to the Siluriformes and contain nine species, including *Ictalurus punctatus* Rafinesque (1818). The channel catfish is one of the most important freshwater species commercialized in the United States (FISHBASE http://fishbase.org; accessed 05/2010). Its natural distribution includes the states around the Gulf of Mexico and the Mississippi Valley/USA (Nelson 1994). Today it is introduced in provinces of Canada and other parts of the United States, as well as in many other countries in the world (Wellborn 1988).

Ictalurus punctatus lives in lotic and lentic environments and reaches sexual maturity at two years of age. The species spawns naturally in lentic systems, mainly in structurally complex environments containing rocks and logs, where it takes care of the offspring (Wellborn 1988). Juveniles are omnivorous, feeding on insects, mollusks, algae and fish. Adults feed predominantly on fish and occasionally on small birds (Wellborn 1988, Goldstein & Simon 1999). Fast growth, high fecundity, euryphagy, resistance against extreme environmental conditions, as well as advances in artificial reproduction, rearing and fattening, are factors that boost its commercial exploitation (Ligas 2007).

Brazil seems to be highly vulnerable to the invasion and proliferation of the channel catfish (Orsi & Agostinho 1999, Vitule et al. 2006, 2009). The occasional captures of *I. punctatus* in south Brazilian inland waters have been occurring frequently since the year 2008, although these events are underrepresented in scientific literature. In the state of Rio Grande do Sul, Brazil, there are two records of this species in the ichthyological collection of the Museum of Science and Technology, Catholic University of Rio Grande do Sul (PUCRS), originated from the Taquari River at the mouth of the Rio Guaporé, Taquari-Antas river basin (MCP 43066 and 43352).

Considering the characteristics of fast adaptation to new environments and its potential as predator, the channel catfish could possibly change the equilibrium of the aquatic biocenosis of natural systems. Therefore, the present study aims to report the first record of *I. punctatus* in a natural environment in the Rio dos Sinos basin, Rio Grande do Sul, Brazil.

Materials and Methods

The study was conducted in the Rio dos Sinos basin, which is part of the Laguna dos Patos system (Fundação... 2009). The specimen was captured with a gillnet (25 mm mesh size between adjacent knots). The net was set in the main channel of the river in the city São Leopoldo (29° 44' 14.04" S and 51° 05' 11.08" W) (Figure 1).

The collected catfish was anesthetized with Eugenol and preserved in 10% formalin. In the Laboratory of Ichthyology – UNISINOS the fish was identified based on material provided by Britski et al. (1999) and Graça & Pavanelli (2007). The specimen was deposited in the fish collection of the Museum of Science and Technology of the Catholic University of Rio Grande do Sul (MCP 46292).

Results

A mature female specimen of *I. punctatus* (36.5 cm SL and 419.9 g; Figure 2) was captured on October 21, 2009 in 3.5 m water depth. The stomach content of the specimen was analyzed and contained four partly digested insects (Hymenoptera) and remains of plant material. Together with *I. punctatus* two other species considered as invasive (allochthonous) were captured: *Pachyurus bonariensis* (Sciaenidae), commonly known as La Plata croaker, and *Acestrorhynchus pantaneiro* a piscivcorous characin (Acestrorhynchidae).

Discussion

The channel catfish is often confounded with the native silver catfish jundiá (*Rhamdia quelen*, Heptapteridae). The more obvious morphological difference between both species is the number and distribution of the barbels. The native silver catfish has three pairs of barbels (two mentonian and one maxillary), whereas the exotic channel catfish has four (two mentonian, one maxillary, and one nasal) (Wellborn 1988). Another important characteristic of the exotic species is the first ray of the dorsal fin, which is transformed in a rigid spine, whereas in the silver catfish it is soft.

The collected specimen was a mature female, which indicates that the reproduction of this species in the Rio dos Sinos is plausible. The spawning season of the channel catfish under natural conditions in North America occurs during the summer at elevated water temperatures (Wellborn 1988). A similiar range of conditions occurs in the Rio dos Sinos.

Invasive species can compete for food resources with native species (Welcomme 1988, Agostinho et al. 2000). Piedras et al. (2006) reported strong similarities comparing the digestive systems of the invasive *I. punctatus* and the two native siluriforms, *R. quelen* and *Pimelodus maculatus*, which indicates a strong overlap in the food niches of these three species. In this sense, the sympatric occurrence of the channel catfish with the native species may result in interspecific competition for the same food resources.

Aquaculture is becoming one of the major vectors for the introduction of exotic species (Welcomme 1988). The proximity and access to water resources are the reasons for the instalation of fish farms in river floodplains, or directly in the river channel or in marginal ponds (fish cages). These areas are highly susceptible to flooding. On these ocasions thousands of juvenile and adult fish may escape (Orsi & Agostinho 1999; Leal et al. 2010). A severe flood

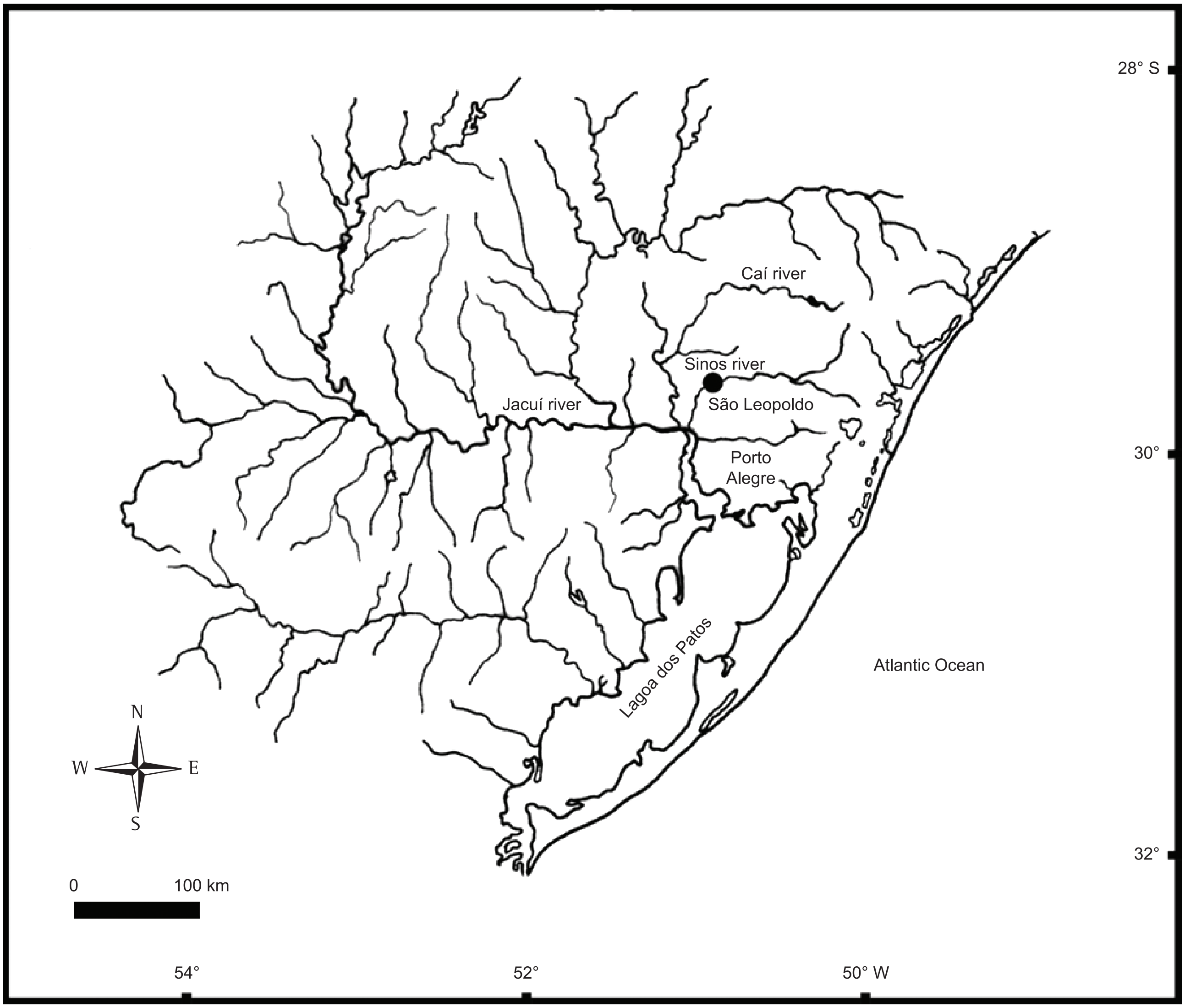

Figure 1. Map of Rio dos Sinos basin; the black dot indicates the capture site of *Ictalurus punctatus* (29° 44' 14.04" S and 51° 05' 11.08" W).

Figura 1. Mapa da Bacia Hidrográfica do Rio dos Sinos; o ponto preto indica a localidade de captura de *Ictalurus punctatus* (29° 44' 14.04" S e 51° 05' 11.08" W).

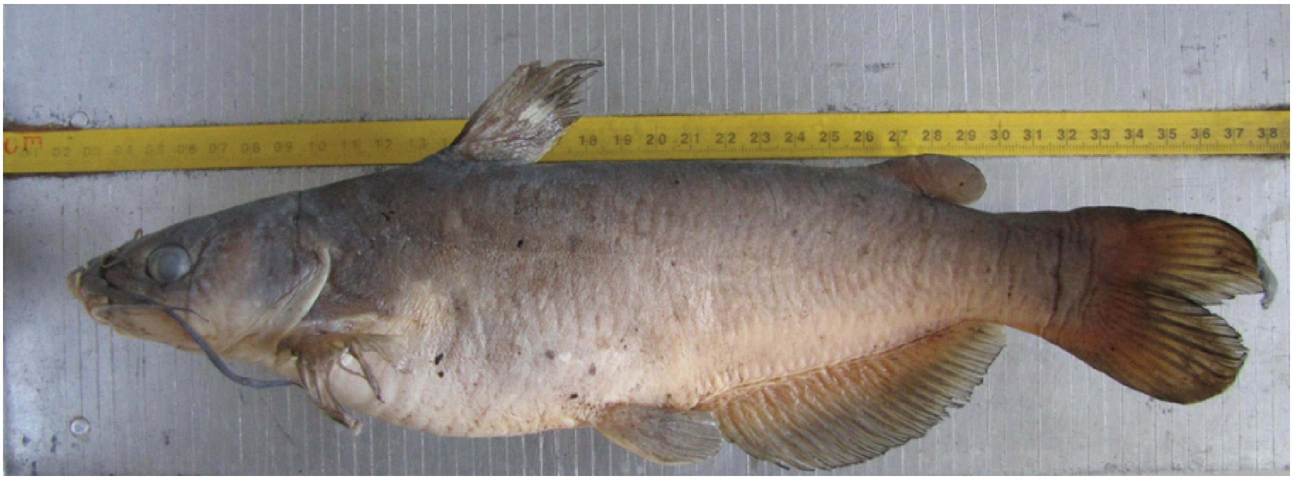

Figure 2. Captured specimen of *Ictalurus punctatus* (MCP 46292).

Figura 2. Exemplar coletado de *Ictalurus punctatus* (MCP 46292).

ocurred in the Rio dos Sinos in May 2008 and may have resulted in an escapee of the captured channel catfish from one of the nearby fishfarms.

Former studies of the fish fauna of Rio dos Sinos have shown the vulnerability to the invasion of the basin by non-native species. Leal et al. (2009) state that of the 102 species currently registered in Rio dos Sinos 10% are non native fishes. The capture of the allochthonous characin *Hoplerythrinus unitaeniatus* (Erythrinidae) infected by the also non-native parasite crustacean *Lernaea cyprinacea* (Copepoda) corroborate the hypothesis of fish farm escapees. In fact, the specimen of *Ictalurus puncatus* was captured in the same location where *H. unitaeniatus* was found (Leal et al. 2010).

The channel catfish is a successfully introduced and cultivated species due to the easy reproduction in captivity and ability to adapt to new environments. According to the FAO (Food... 1997), the channel catfish is one of the most frequently introduced fish in the list of exotic species in Brazil. In the Rio Grande do Sul state the environmental protection agency FEPAM (Fundação Estadual de Proteção Ambiental Henrique Luiz Roessler/RS), based in a Federal law (Portaria 145, 29 October 1998 - IBAMA), imposes legal restrictions to the propagation of exotic species in aquaculture. However, more than one million fingerlings of several exotic species are still grown and commercialized annually by fish farmers in the state (Vermulm Junior & Giamas 2011).

The capture of one individual of *I. punctatus* is not enough evidence to characterize a successful invasion; nevertheless, it should alert managers to the potential impact of fish introductions on the native ichthyofauna. The use of exotic fishes in Brazilian aquaculture is highly questionable, considering the high native fish diversity and its potential for cultivation. Just to mention an example, the native silver catfish *Rhamdia quelen* may substitute the channel catfish in aquaculture, minimizing the risks of ecological problems of eventual escapees.

Acknowledgements

We are grateful to FAPERGS-Probic for the scientific initiation scholarship for Sabrina Spindler and to UNISINOS for encouraging this research. An unknown referee contributed significantly to the final version of the manuscript.

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Received 06/03/2012
Revised 24/07/2012
Accepted 01/08/2012