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short communication

First report of the occurrence of *Ophiocordyceps melolonthae* (Ascomycota: Hypocreales: Ophiocordycipitaceae) in larvae of *Diloboderus abderus* Sturm (Coleoptera: Melolonthidae) in Brazil

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SALGADO-NETO, G., VALMORBIDA, I., GUEDES, J.V.C., BLUME, E. **First report of the occurrence of *Ophiocordyceps melolonthae* (Ascomycota: Hypocreales: Ophiocordycipitaceae) in larvae of *Diloboderus abderus* Sturm (Coleoptera: Melolonthidae) in Brazil.** Biota Neotropica. 15(2): e20140108. http://dx.doi.org/10.1590/1676-06032015010814

Abstract: This note is the first report on the infection of *Diloboderus abderus* Sturm (Coleoptera: Melolonthidae) larvae by the fungus *Ophiocordyceps melolonthae* (Hypocreales: Ophiocordycipitaceae) in subtropical Brazil. Identification was made possible by extraction and sequencing of the fungal DNA that was covering the larvae's mouthparts, prothorax, cuticle, and digestive tract (alimentary canal). Amplification, sequencing and comparison of the ITS region of the ribosomal DNA with voucher sequences of GenBank were performed and were 95% similar to *Ophiocordyceps melolonthae*. The fungus is an entomopathogen which attacks Melolonthidae larvae, having scientific and economic importance because of the need for increased knowledge on its distribution and on alternatives for biological control of white grubs.

Keywords: *Biological control, dissemination, entomopathogen, entomopathogenic fungi, natural infection.*

SALGADO-NETO, G., VALMORBIDA, I., GUEDES, J.V.C., BLUME, E. **Primeiro registro da ocorrência de Ophiocordyceps melolonthae (Ascomycota: Hypocreales: Ophiocordycipitaceae) em larvas de Diloboderus abderus Sturm (Coleoptera: Melolonthidae) no Brasil.** Biota Neotropica. 15(2): e20140108. http://dx.doi.org/10.1590/1676-06032015010814

Resumo: *Esta* nota é o primeiro registro da infecção de larvas de *Diloboderus abderus* Sturm pelo fungo *Ophiocordyceps melolonthae* na região subtropical do Brasil. A identificação foi possível graças à extração e sequenciamento do DNA do fungo que cobria o aparelho bucal, protórax, cutícula e aparelho digestivo (canal alimentar) das larvas. Amplificação, sequenciamento e comparação da região ITS com sequências voucher do GenBank foram realizados, mostrando 95% de similaridade com *Ophiocordyceps melolonthae*. O fungo é um entomopatógeno que ataca larvas Melolonthidae, tendo importância científica e econômica devido à necessidade de aumento do conhecimento sobre sua distribuição e de alternativas de controle biológico de corós.

Palavras-chave: *Controle biológico, disseminação, entomopatógeno, fungos entomopatogênicos, infecção natural.*

Entomopathogenic fungi have broad host range (DeFaria & Wraight 2007), geographical range and potential to control white grubs. For these reasons, it is important to collect, purify and conserve germplasm of the wide variety of species as they may be used in a selection of strains to perform a biological control program. The conservation of strains in reference collections should be priority for some genotypes that may be lost due to local environmental changes (Hernandez-Velazquez et al. 2011).

In Brazil, previous records have shown that natural epizooties caused by the fungus *Cordyceps unilateralis* (Euascomycetes: Hypocreales) were found in adults of the ants *Camponotus* sp. and *Atta cephalotes* (Hymenoptera: Formicidae) in the Amazon Forest (Andrade 1980). Recently, in Minas Gerais, *Ophiocordyceps unilateralis* (Hypocreales: Clavicipitaceae) was discovered as a specific fungal pathogen of the ant species *Camponotus rufipes*, *C. balzani*, *C. melanoticus* and *C. novogranadensis* (Formicidae: Camponotini) (Evans et al. 2011). Moreover, epizooties caused by fungi in the "Planalto Region" of the state of Rio Grande do Sul have been the main cause of white grubs collapse in wheat. The fungi *Metarhizium anisopliae* (Metchnikoff) Sorokin, *Beauveria bassiana* (Bálsamo) Vuillemin and *Cordyceps* sp. are the most common fungi found infecting Melolonthidae larvae (Gassen 1992, Salvadori 2000, Salvadori & Pereira 2006).

Figure 1. *Ophiocordyceps melolonthae* infecting *Diloboderus abderus* larva.
Foto: Salgado-Neto, 2014.

The *Cordyceps* genus was established as an ascomycete, fungal pathogen of arthropods bearing the ascospore producing structures on stromata arising from the host cadaver. *Cordyceps unilateralis,* originally characterizing species with non-fragmenting ascospores, was reorganized in the genus *Ophiocordyceps* (Hypocreales: Ophiocordycipitacae), which currently comprises around 160 species (Sung et al. 2007, Evans et al. 2011). These parasites infect many different insects with a wide ecological range. The orders infected are Coleoptera, Blattaria, Dermaptera, Diptera, Hymenoptera, Hemiptera, Isoptera, Lepidoptera, Mantodea, Orthoptera and Odonata (Evans et al. 2011, Araújo & Hughes, 2014).

Here, we report the infection of *Ophiocordyceps melolonthae* in the third instar larvae of the white grub *Diloboderus abderus* in subtropical Brazil. Beside increasing the information about its geographical distribution, our finding is also important to biological control due to the increase of white grubs occurrence in cultivate and uncultivated fields in Brazil.

Trenches (50 cm long x 25 cm wide x 30 cm deep) were opened in a native grassland and 35 samples spaced 64 m apart were taken in approximately 15 hectares, at the district of Umbú, Rosário do Sul – Rio Grande do Sul, Brazil (30°35′S and 54°46′W). Both in 2011 and 2012, larvae of *D. abderus* with soil were collected individually in 60 mL plastic containers and transported to the Laboratory of Integrated Pest Management of Universidade Federal de Santa Maria (UFSM) to confirm the white grub species. The larvae presented a whitish cover and a horn like structure attached to it (Figures 1 and 2). In the Laboratory of Phytopathology of UFSM the larvae were superficially disinfected and rinsed in sterile distilled water. Subsequently, some were frozen and others were dissected and separated into the following parts: mouthparts, prothorax, cuticle, and digestive tract (alimentary canal), which were then placed in Eppendorf tubes containing 100 mL of 0.85% saline solution.

Afterwards, the parts were added to Petri dishes with PDA (Potato Dextrose Agar) media and incubated in a growth chamber with a temperature of 25.6 °C and a photoperiod of 12h for seven days. Since there was no growth on PDA, frozen specimens with the whitish structure resembling a stroma of *Ophiocordyceps* spp. (Evans et al. 1999) were sent to the Biological Institut of São Paulo for molecular identification.

Extraction of the isolated DNA was performed according to the method employing the reagent C.T.A.B. (cetyltrimethylammonium bromide) described by Doyle & Doyle (1987). The stroma was triturated in micro tubes with the aid of a plastic pistil and the extracted genomic DNA was subjected to polymerase chain reaction (PCR) for amplification of the ITS region (Internal Transcribed Spacer) located between the genes encoding the 18S and 28S ribosomal RNAs. The primers for the ITS region were ITS1 (5′-TCCGTAGGTGAACCTGCGG-3′) and ITS4 (5′-TCCTCCGCTTATTGATATGC-3′) (White et al. 1990). The amplified products were purified by precipitation with polyethylene glycol (Schmitz & Riesner 2006), subjected to sequencing by the chain termination reaction method employing the reagent Big Dye 3.1 (Applied Biosystems) and analyzed by automated capillary sequencer 3500 L (Applied Biosystems). The sequence obtained was deposited (GenBank access code KR082313) and compared to voucher sequences present in the GenBank of the

Figure 2. *Ophiocordyceps melolonthae* infecting *Diloboderus abderus* larva.
Foto: Salgado-Neto, 2014.

National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov), using the Blastn program (Altschul et al. 1990). The ITS sequenced is the following: AACCGCGGCGCCCGCCGGAGGACCCCACGACTCTCTTCCGCCCCAGCGGCATCTTCCGGGTGAGCCATCACGAATGAGTCAAAACTTTCAACAACGGATCTCTTGGTTCTGGCATCGATGAAGAACGCAGCGAAATGCGATAAGTAATGTGAATTGCAGAATTCAGTGAATCATCGAATCTTTGAACGCACATTGCGCCCGCCAGCACTCTGGCGGGCATGCCTGTCCGAGCGTCATTTCAGCCCTCGAGCCCCCCCCGGGGCTCGGCGTTGGGGCCCGGCCCGCCGCGGCCGCCCCCCAAATCCAGTGGCGACCCCGCCGCGGCCTCCCCTGCGCAGTAGCACACGCCTCGCACCGGAGCCCCGGCGGCGGTCCTCGCCGTGAAACGCGACCAGCCTCCCAGGAGAGTTGACCTCGGATCAGGTAGGGGTACCCGCTGAACTTAAGCATATCAATAAGCGGAGGAA. The fungus was identifies as *Ophiocordyceps melolonthae* (Spatafora et al. 2007), being the probable cause of larval death.

The species *Ophiocordyceps melolonthae* (= *Cordyceps melolonthae*) were studied in the United States of America (Mains 1958) and Mexico (Pérez-Silva 1977, Guzmán et al. 2001). Evans et al. (1999) showed the fungus being parasitic to *Cochliotus melolonthoides* (Gerst.), a Scarabaeidae from Tanzania, and on a melolonthid larva buried in Amazonian Ecuador forest soil that agrees well with the specimens studied here. Lloyd (1920) described subspecies of *C. melolonthae* from Brazil as "growing from the head of some larva" with subcylindric or globose stromata, about 20 mm long. From the macromorphology of stromata present in 10 collected larvae it was determined that the specimens collected represented a species of *C. melolonthae.* This fungus is considerad one of the strongest pathogen to scarabaeid insects, and there have been many attempts to use it as an agent for biological control of Melolonthidae larvae (Mains 1958, Ferron 1981, Sung et al. 2007).

Morphological investigations are necessary to characterize these teleomorphs and to determine whether they are synonyms as previously described *Cordyceps* species, such as *C. staphylinidicola* (Kobayasi & Shimizu 1982), *C. sulfurea* (Kobayasi & Shimizu 1983) and *C. scarabaeicola* (Kobayasi & Shimizu 1976). Progress in methods for in vitro fruiting of *Cordyceps* species with *Beauveria* anamorphs are promising for developmental studies of *Beauveria* and its *Cordyceps* teleomorphs through integrated phylogenetics, developmental and mating studies (Sung et al. 2006, Lee et al. 2010, Rehner et al. 2011).

The natural occurrence in Melolonthidae larvae suggests that this fungus may play an important role in the control of white grubs and it must encourage more extensive studies on the possibility of utilizing this fungus in biological control programs.

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Decadal persistence of frugivorous birds in tropical forest fragments of northern Paraná

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Abstract: Forest fragmentation is a major cause of loss of species. We evaluated the local extinction of medium-large frugivorous bird species in six forest fragments of northern Paraná: the Parque Estadual Mata dos Godoy (PEMG), the largest and most preserved forest fragment in the region, and five other fragments. Fixed-width point counts and line transects were conducted along trails in the PEMG for 10 days: from September 2010 to March 2011, and from August 2011 to November 2011. Avian surveys in each of the other forest fragments were made over four days from October to December 2011. We compared data with a previous census carried out 10 years earlier. No extinction events were recorded from the PEMG. However, the relative abundance of species significantly changed during the ten years between surveys. In all the other forest fragments at least two frugivorous bird species disappeared, and in some as many as seven. Protecting the PEMG is crucial for the maintenance of frugivorous bird populations in our studied landscape.

Keywords: *forest fragmentation, large frugivorous birds, extinction debit.*

ZAIDEN, T., MARQUES, F.C., MEDEIROS, H.R., ANJOS, L. **Persistência de aves frugívoras após uma década em fragmentos florestais do norte do Paraná.** Biota Neotropica. 15(2): e20140084. http://dx.doi.org/10.1590/1676-06032015008414

Resumo: A fragmentação florestal é uma das principais causas da perda de espécies. Avaliamos a extinção local de aves frugívoras de médio e grande porte em seis fragmentos do norte do Paraná: o Parque Estadual Mata dos Godoy (PEMG), maior e mais preservado remanescente florestal da região, e outros cinco fragmentos. Foram realizadas amostragens por pontos de escuta de distância limitada e por transecções no PEMG ao longo de 10 dias: entre setembro de 2010 e março de 2011, e entre agosto e novembro de 2011. Os outros cinco fragmentos foram amostrados ao longo de quatro dias entre outubro e dezembro de 2011. Os dados foram comparados com um levantamento prévio realizado há 10 anos. Não foram observadas extinções no PEMG. No entanto, foram observadas alterações significativas na abundância relativa das espécies em dez anos (Wilcoxon Signed-Rank). Nos outros fragmentos florestais verificou-se o desaparecimento de pelo menos duas espécies, sendo que a variação foi de duas a sete espécies. A proteção do PEMG parece ser crucial para a manutenção das populações de aves frugívoras na paisagem estudada.

Palavras-chave: *fragmentação florestal, aves frugívoras de grande porte, débito de extinção.*

Introduction

Large frugivorous birds that inhabit forests are often among the first species to disappear in fragmented landscapes (e.g. Willis 1979, Aleixo & Vielliard 1995, Galetti & Aleixo 1998, Anjos 2006, Lees & Peres 2008). Ecological traits and requirements such as low density, low fecundity, spatio-temporal variability of food resources, matrix avoidance and area sensitivity increase their vulnerability in fragmented landscapes (Franklin 1980, Strahl & Grajal 1991, Galetti & Pizo 1996, Lynch & Lande 1998, Ragusa-Netto 2010). However, a recent review indicated that when forest fragments differ little the impact of forest fragmentation on frugivorous birds is lower than expected (Bregman et al. 2014). Declines in populations of frugivorous birds may have implications for the biotic integrity of forest fragments due to their ecological function as seed dispersers (Schupp et al. 2002, Terborgh et al. 2002, Galetti et al. 2013). Indeed, if the persistence of frugivorous populations is higher than expected, their role as seed dispersers is crucial for certain plant species (those which depend on birds for dispersal) occupying isolated forest fragments.

Local extinction often occur after a time lag, which makes the evaluation of population persistence more difficult. In several studies, populations may persist on the brink of extinction for long periods before finally becoming extinct (Brooks et al. 1999, Helm et al. 2006, Vellend et al. 2006). This time lag in extinction is called relaxation time (Diamond 1972). Isolated patches of habitat in fragmented or degraded habitats are said to owe an extinction debt for the species for which future extinctions are inevitable (Tilman et al. 1994, Kuussaari et al. 2009). Thus, the mere presence of frugivorous bird species in a forest fragment is no guarantee that the populations will remain in the long-term (Metzger et al. 2009). In this study, we made a preliminary evaluation of the population persistence of large frugivorous birds in forest fragments based on a temporal data series.

Herein we evaluated if large frugivorous birds persisted in six forest fragments in southern Brazil over a period of 10 years. In this case we evaluated only the persistence of the species, not variations in population size. In the largest of those forest fragments, we effectively evaluated variations in the population sizes of the frugivorous birds over the period of 10 years.

Material and Methods

1. Study area

The study was carried out in the Parque Estadual Mata dos Godoy (PEMG) and five other forest fragments (FA, FB, FC, FH and FI) in the north of Paraná State, southern Brazil (Fig. 1). The region is characterized by a humid subtropical climate (Köppen Cfa) with rainfall concentrated in the summer months and annual average temperature and precipitation of 20.8 – 21.6 °C and of 1100 – 1200 mm, respectively (Maack 1981). The soils have the same parent material (basalt), resulting in fertile reddish clay soils such as eutropherric red latosols (Maack 1981).

The fragmentation process occurred in the studied region about 50 years ago and reduced the forest to small and isolated fragments immersed in a matrix mainly composed by agriculture. In such a scenario of habitat loss, PEMG remains relatively undisturbed and is considered the largest and best preserved area of semideciduous forest in northern Paraná State with a high biological integrity (Anjos et al. 2009). The other fragments vary in size and isolation levels (Table 1). In a recent study assessing the ecological integrity of Atlantic forest remnants, Medeiros & Torezan (2013) evaluated two of the six areas sampled in this study. According to the authors, the vegetation of the PEMG is of “excellent” integrity category and the vegetation of the fragment FI was classified as “regular”. Furthermore, hunting and selective tree logging are forbidden in the region, in particular in the PEMG and in the five forest fragments located in private areas.

Figure 1. Location of studied areas in Londrina, Parana, Southern Brazil. Studied fragments are presented in dark grey, fragments in light grey and agricultural areas in white. Geographical coordinates are presented in Table 01.

Table 1. Characterization of forest fragments (FF) analyzed by their geographic coordinates, area (ha), connectivity, distance to the PEMG, and proximity index, a proxy for functional connectivity.

FF	Geographic coordinates	Area (ha)	Connectivity	Distance	Proximity index
PEMG	23°27′9,39″S 51°15′17,77″W	656	Referential	0	125.96
FA	23°28′8,14″S 51°14′19,85″W	56	FC	500 m	166.12
FB	23°28′6,31″S 51°15′17,10″W	25	PEMG	400 m	133.89
FC	23°28′31,27″S 51°15′22,17″W	11	FB	1100 m	199.17
FH	23°29′17,95″S 51°11′38,35″W	72	-	2400 m	8.39
FI	23°30′11,35″S 51°4′34,74″W	184	-	14500 m	499.1

Proximity index used a search radius of 1000 meters.

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We calculated the proximity index (Uezu et al. 2008) based on a binary forest vs. matrix map obtained from SOS Mata Atlântica (2008) and used by Ribeiro et al. (2009). This index was calculated for the search radius of 1000 meters around a centroid defined within the patches by using ArcGIS (ERSI 2005) and V-LATE extension (LARG 2005). The six forest fragments vary greatly in size and functional connectivity represented by the proximity index (Table 1).

2. *Field work*

2.1 Previous data. Data from two different studies (Anjos 2001, Anjos et al. 2004) conducted in the six forest fragments were used to evaluate the extinction debt of medium and large frugivorous bird species. Data from both studies were obtained using point counts of unlimited distance (Blondel et al. 1970, Vielliard & Silva 1990). In these studies, the points were 100 m apart and at least 50 m from the edge of forest; the sampling time at each point was 20 minutes.

Data presented in Anjos (2001) were collected monthly from January to December 1996 in the PEMG and fragments FA, FB and FC, totaling 12 samples for each fragment. Data presented in Anjos et al. (2004) were collected monthly between September and December 1997 in the PEMG, FA, FB, and FC, and over the same months in 2000 in FH and FI, totaling four samples for each fragment.

2.2 Recent data. The field data were obtained using the methods described in Anjos et al. (2007). Point counts of fixed radius and distance sampling-line transects were sampled along four 1000 m long trails (TA, TB, TC and TD) in PEMG. For data collected using point counts of limited distance, nine points were established every 100 m on each trail in the PEMG. Thus, 36 sampling points were sampled over 10 days beginning at sunrise, from September 2010 to March 2011 and from August to November 2011. The detection radius at each point was 50 m and the starting point for each transect sample alternated each day, offering the same odds of detection for all species. The sampling period at each point was 15 minutes, thus the total sampling on each day lasted for about four hours. Point counts do not consider differences in detectability or make it possible to calculate the current densities of each species; however, this method can be used as an index to detect significant differences in the abundance of populations of a particular species (Bibby et al. 1992). At each sampling point, each pair or flock of each species was counted once, and precautions were taken not to count the same individual or group more than once (Anjos et al. 2011), making it possible to calculate the Index of Point Abundance (IPA) of each species.

For the distance sampling-line transects, the trails in PEMG were traveled at a constant speed of 2 km/h, allowing the observer to record species through auditory or visual contact at a distance of 50 m. The distance of the bird relative to the observer and the detection angle in relation to the track were measured for subsequent calculation of the relative density for each species. Ten samples per transect from September 2010 to March 2011 were collected, and from August to November 2011, beginning at sunrise to coincide with the beginning of vocal activities of diurnal birds (Gilardi & Munn 1998). In the case of the Psittacidae family, whenever a flock was sighted, the number of individuals was counted visually. Based on the monitored flocks, an average number of individuals per flock of each Psittacidae species was measured giving an estimation of the number of individuals in the PEMG.

In the five forest fragments (FA, FB, FC, FH and FI) we exclusively used the distance sampling-technique with line transects along 1000 m long trails. Each fragment was sampled over a period of 4 days between October and December 2011, to verify the presence or absence of frugivorous birds. Thus, the sampling effort was similar to the lower sampling effort of previous studies carried out 10 years ago, allowing the comparison of the occurrence data in each fragment.

3. *Data analysis*

Only medium (40-80 g) and large (greater than 80 g) non-passerines frugivorous birds were considered for this study (Pizo 2001). According to Anjos (2001), 24 medium and large non-passerines frugivorous bird species occur in the PEMG. In this study, these species has been treated as large frugivorous birds.

The population density per hectare in the PEMG was estimated by entering data collected in the sampling-line transect into the software DISTANCE 6.0 (Thomas et al. 2010). We also calculated IPA of each species in the PEMG (according to Anjos et al. 2010) and this value was used to analyze the persistence of these populations after 10 years. The IPA was estimated by dividing the total number of species observed by the total number of points sampled in the PEMG. Wilcoxon Signed-Rank analysis was used to compare the IPA values of the species obtained in the present study with those presented for the same species a decade earlier by Anjos et al. (2004). This analysis was carried out using the function wilcox with the R software version 3.0.2 (R Development Core Team 2013).

Results

Twenty-four species of medium and large frugivorous birds were recorded in the PEMG. Of the 20 species of frugivorous birds recorded by Anjos (2001) and Anjos et al. (2004) in the remaining fragments, 11 species disappeared in some of the forest fragments. However, the rate of species that persisted was different in the forest fragments: 87% in FA; 75% in FB; 81% in FC; 72% in FH and 59% in FI (Table 2). There were also some species that had not been recorded in the survey 10 years ago: one species in FA and FC (*Aratinga auricapillus*) and three species in FB (*Aratinga auricapillus*, *Psittacara leucophthalmus* and *Amazona aestiva*; see Table 2).

The Wilcoxon Signed-Rank analysis revealed that the IPA values of the analyzed large frugivorous birds changed over 10 years ($V = 285$; $p = 0.0001$). This difference was also found for the 11 species which disappeared from the fragments, but persisted in the PEMG ($V = 56$; $p = 0.0453$), and for the remaining 13 species that persisted in the fragments, beside PEMG ($V = 90$; $p = 0.0004$). In fact, we found that the mean IPA values in 2004 were higher for all those three groups of species than in the present study. When considering all species, the mean IPA in 2004 was 0.3833 while the present mean IPA was 0.0689. When considering the 11 species that disappeared from the fragments, but persisted in the PEMG, the mean IPA in 2004 was 0.1409 while the present mean IPA was only 0.0116. Finally, when considering the remaining 13 species that persisted in the fragments, the mean IPA in 2004 was 0.5885 while the present mean IPA was only 0.1173.

Table 2. Presence/absence of medium and large frugivorous birds species in fragments analyzed (PEMG, FA, FC, FB, FH and FI) in the present study and 10 years ago (Anjos 2001, Anjos et al. 2004) (X: present species; -: absent species). Species are in systematic and phylogenetic position following nomenclature of the South American Classification Committee of the American Ornithologists' Union (Remsen et al. 2015).

	Present study						**Previous study**					
Species	**PEMG**	**FA**	**FB**	**FC**	**FH**	**FI**	**PEMG**	**FA**	**FB**	**FC**	**FH**	**FI**
Cracidae												
Penelope superciliaris Temminck, 1815	X	-	X	X	X	-	X	X	X	X	X	X
Columbidae												
Claravis pretiosa (Ferrari-Pérez, 1886)	X	-	-	-	-	-	X	-	-	-	X	X
Patagioenas picazuro Temminck, 1813	X	X	X	X	X	X	X	X	X	X	X	X
Patagioenas cayennensis Bonnaterre, 1792	X	X	X	X	X	X	X	X	X	X	X	X
Patagioenas plumbea Vieillot, 1818	X	-	-	-	-	-	X	-	-	-	-	-
Leptotila verreauxi Bonaparte, 1855	X	X	X	X	X	X	X	X	X	X	X	X
Leptotila rufaxilla (Richard & Bernard, 1792)	X	X	X	X	X	-	X	X	X	X	X	X
Geotrygon montana (Linnaeus, 1758)	X	X	X	X	X	-	X	X	X	X	X	X
Trogonidae												
Trogon surrucura Vieillot, 1817	X	X	X	X	X	X	X	X	X	X	X	X
Trogon rufus Gmelin, 1788	X	-	-	-	-	-	X	-	-	-	-	X
Momotidae												
Baryphthengus ruficapillus (Vieillot, 1818)	X	X	X	X	X	X	X	X	X	X	X	X
Ramphastidae												
Ramphastos dicolorus Linnaeus, 1766	X	-	-	-	-	-	X	X	X	X	X	-
Selenidera maculirostris (Lichtenstein, 1823)	X	X	X	X	X	X	X	X	X	X	X	X
Pteroglossus bailloni (Vieillot, 1819)	X	-	-	-	-	-	X	-	-	-	-	X
Pteroglossus aracari (Linnaeus, 1758)	X	-	-	-	-	-	X	-	-	-	-	-
Psittacidae												
Primolius maracana (Vieillot, 1816)	X	-	-	-	-	-	X	-	-	X	-	-
Psittacara leucophthalmus (Müller, 1776)	X	X	X	-	X	X	X	-	X	-	X	X
Aratinga auricapillus (Kuhl, 1820)	X	X	X	-	X	-	X	-	-	-	-	-
Pyrrhura frontalis (Vieillot, 1818)	X	-	X	-	-	-	X	X	X	X	X	X
Brotogeris tirica (Gmelin, 1788)	X	-	-	-	-	-	X	-	-	X	-	-
Pionopsitta pileata (Scopoli, 1769)	X	-	-	-	-	X	X	-	-	-	-	X
Pionus maximiliani (Kuhl, 1820)	X	X	X	X	X	X	X	X	X	X	X	X
Amazona aestiva (Linnaeus, 1758)	X	X	-	-	X	-	X	-	X	-	X	-
Triclaria malachitacea (Spix, 1824)	X	-	-	-	-	-	X	-	-	-	-	-

It was possible to calculate the population density for nine of the 24 sampled species (Table 3; 4). The species with the highest density was *Aratinga auricapillus*, with 1.04 ind/ha, while the lowest was *Patagioenas cayennensis*, with 0.231 ind/ha.

Discussion

The differences found between the values of IPA comparing our recent data with those from ten years ago in the PEMG demonstrates that the effects of forest fragmentation could still have an impact on large frugivorous birds, even in a relatively large forest fragment. Our data suggest that populations of large frugivorous birds could be declining over time in the PEMG. Therefore, the large frugivorous birds in the PEMG may have been paying an extinction debt over the last ten years (Diamond 1972, Tilman et al. 1994, Kuussaari et al. 2009).

Some studies have demonstrated that forest species with large population size in fragmented landscapes tend to persist longer in forest fragments (*e.g.* Purvis et al. 2000, Manne & Pimm 2001, Henle et al. 2004), probably due to the rescue effect, which increase the chances to colonize empty fragments (Brown & Kodric-Brown 1977, Anjos et al. 2011). This argument is consistent with our data on the 11 species that were not recorded in at least one of the closer fragments; those species reached the lowest IPA values in the PEMG. Therefore, low population size seems to reduce the potential of the rescue effect of large frugivorous birds from surrounding forest fragments. If it is true, those 11 species could be considered as members of the "undead" *sensu* Sodhi et al. (2011), even in the PEMG. Interestingly, the FI fragment that presented the highest proximity index (499.1), also lost the highest number of species. This unexpected result could be explained by the fact that FI is the farthest studied fragment from the PEMG which probably acts as an important source for rescue effects in that landscape. Furthermore, all the forest fragments located within 2400 meters radius from PEMG lost fewer species (two to four species), while FI, which is located 14.500 meters far from PEMG, lost seven species.

Some studies have demonstrated the negative effect of the extinction of large frugivorous birds in forest dynamics (e.g. Silva & Tabarelli 2000, Lord et al. 2002, Schupp et al. 2002, Terborgh et al. 2002, Galetti et al. 2013). Galetti et al. (2013), in a recent study conducted in the Brazilian Atlantic forest showed that functional extinction of large frugivorous birds is associated with the consistent reduction of *Euterpe edulis*' seed size resulting in several negative consequences for plant recruitment

Table 3. Index of Point Abundance (IPA) of medium and large frugivorous bird species from PEMG in the present study and 10 years ago (Anjos et al. 2004). Species are in systematic and phylogenetic position following nomenclature of the South American Classification Committee of the American Ornithologists' Union (Remsen et al. 2015).

	IPA	
	Present study	**Previous study**
Cracidae		
Penelope superciliaris Temminck, 1815	0.006	0.200
Columbidae		
Claravis pretiosa (Ferrari-Pérez, 1886)	0.003	0.000
Patagioenas picazuro Temminck, 1813	0.264	1.850
Patagioenas cayennensis Bonnaterre, 1792	0.086	0.450
Patagioenas plumbea Vieillot, 1818	0.003	0.000
Leptotila verreauxi Bonaparte, 1855	0.247	0.950
Leptotila rufaxilla (Richard & Bernard, 1792)	0.008	0.050
Geotrygon montana (Linnaeus, 1758)	0.031	0.200
Trogonidae		
Trogon surrucura Vieillot, 1817	0.194	0.900
Trogon rufus Gmelin, 1788	0.014	0.000
Momotidae		
Baryphthengus ruficapillus (Vieillot, 1818)	0.142	0.550
Ramphastidae		
Ramphastos dicolorus Linnaeus, 1766	0.008	0.350
Selenidera maculirostris (Lichtenstein, 1823)	0.236	0.900
Pteroglossus bailloni (Vieillot, 1819)	0.017	0.000
Pteroglossus aracari (Linnaeus, 1758)	0.006	0.050
Psittacidae		
Primolius maracana (Vieillot, 1816)	0.008	0.200
Psittacara leucophthalmus (Müller, 1776)	0.114	0.200
Aratinga auricapillus (Kuhl, 1820)	0.131	0.750
Pyrrhura frontalis (Vieillot, 1818)	0.003	0.450
Brotogeris tirica (Gmelin, 1788)	0.014	0.000
Pionopsitta pileata (Scopoli, 1769)	0.014	0.150
Pionus maximiliani (Kuhl, 1820)	0.086	0.750
Amazona aestiva (Linnaeus, 1758)	0.017	0.100
Triclaria malachitacea (Spix, 1824)	0.003	0.150

Table 4. Population density per hectare (D) of nine species recorded in PEMG. For the families Columbidae, Trogonidae, Momotidae and Ramphastidae, values are number of pairs per ha, while for Psittacidae values are number of individuals per ha. Species are in systematic and phylogenetic position following nomenclature of the South American Classification Committee of the American Ornithologists' Union (Remsen et al. 2015).

Species	**D**	**Individual/band**
Columbidae		
Patagioenas picazuro (Temminck, 1813)	0.928	
Patagioenas cayennensis (Bonnaterre, 1792)	0.231	
Leptotila verreauxi Bonaparte, 1855	0.439	
Trogonidae		
Trogon surrucura Vieillot, 1817	0.341	
Momotidae		
Baryphthengus ruficapillus (Vieillot, 1818)	0.415	
Ramphastidae		
Selenidera maculirostris (Lichtenstein, 1823)	0.781	
Psittacidae		
Psittacara leucophthalmus (Statius Müller, 1776)	0.976	4,67 ± 3,18 (n = 33)
Aratinga auricapillus (Kuhl, 1820)	1.040	4,28 ± 2,01 (n = 40)
Pionus maximiliani (Kuhl, 1820)	0.528	3,00 ± 1,24 (n = 27)

and population dynamics. *Penelope superciliaris*, the frugivorous bird species with the largest body mass recorded in PEMG and a major disperser of *E. edulis* was not found either in the smallest (FB) or in the most isolated (FI) fragments. The level of isolation and the size of the fragments, which among other factors are related to the population decline or local extinction of large frugivorous birds, may be associated with functional loss of these species and its consequences to the ecosystem.

It is important to mention, however, that time difference between the two studies are relatively short (a decade) and such fluctuations could be expected in the seasonal semidecidous forest. Indeed, we do not know about the natural fluctuations of those frugivorous populations over time. For example, if resources were scarce in those particular fragments due to climatic variations in recent years, the occurrence and abundance of the studied birds could be affected. Another aspect that could affect time lag studies is the potential alterations of the matrix habitat due to anthropogenic action. Although the landscape appeared similar during the studied period, it is unclear whether some disturbance, in particular in the matrix habitat, could have affected our data. Therefore, our results should be viewed as a preliminary investigation of the effects of fragmentation over time. Only a long term monitoring campaign over a higher number of forest fragments could uncover bird population trends in the studied landscape.

We also recorded three species of Psittacidae, *Aratinga auricapillus*, *Psittacara leucophthalmus* and *Amazona aestiva* in three fragments of the five analyzed fragments (FA, FB and FC) in the latest survey. Unlike the remaining frugivores, Psittacidae have a high capacity for dispersal across open spaces, using a wide area throughout the day (Gilardi & Munn 1998, Lees & Peres 2009). It is important to mention that *A. auricapillus* is Near Threatened according to BirdLife International (2013), which could highlight the importance of the PEMG for conservation of this particular species.

In conclusion, our study indicates that forest fragmentation could be negatively influencing the persistence of the remaining populations of large frugivorous birds in the studied fragmented landscapes. Therefore, protecting the PEMG with buffer zones for restoration, as well as increasing connectivity with surrounding forest fragments with forest corridors is crucial for maintenance of frugivorous populations in the studied landscape.

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Diversity, community structure and conservation status of an Atlantic Forest fragment in Rio de Janeiro State, Brazil

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Abstract: The State of Rio de Janeiro still holds unknown portions of the Atlantic Forest, which represent gaps in the knowledge of this ecosystem. Paracambi and neighbor municipal districts comprise a vast stretch of virtually unknown forest that makes up part of the Serra do Mar biodiversity corridor. The following study describes the tree community structure in a stretch of the ombrophilous Atlantic Forest, in the *Parque Natural Municipal do Curió* (Curio MNP), Paracambi, Rio de Janeiro, which serves as the basis to evaluate species diversity and conservation status. The altitudes in the area ranges from 100 to 690 m and the climate varies from mild subtropical to tropical hot and humid. Forty plots (10x10m) were randomly placed along the area, where all the stems equal to or greater than five centimeters (5 cm) diameter at breast high from ground level were measured. A total of 749 individuals, pertaining to 128 genera and 210 species were recorded, eight of which are listed as threatened of extinction in the Brazilian flora. The Shannon-Weaver diversity index (H′) was 4.7 nat.ind.$^{-1}$ and the species with greater importance value was *Pseudopiptadenia contorta* (1.6460 m^2; 18 individuals) while the most common species were *Senefeldera vertcilata* (48) and *Actinostemon verticilatus* (47 individuals). Despite the sample area being a little smaller than that commonly adopted in tropical studies, data pointed to a richness hitherto not registered in any other study for the State of Rio de Janeiro, no matter the inclusion criteria used, and also confirmed by the two estimator indices used, which have revealed very similar results. The vertical forest structure, the values associated to the successional stage of the species and other aspects of community structure indicate that the Curio MNP encompasses forest stretches in advanced stages of ecological succession. Besides its key location for the connectivity of forest fragments in the region, the results emphasize the ecological importance of this forest remnant and the need for its conservation.

Keywords: *tropical rain forest, phytosociology, ecological succession, Serra do Mar biodiversity corridor, Curio Municipal Natural Park- Paracambi.*

CYSNEIROS, V.C., MENDONÇA-JUNIOR, J.O., GAUI, T.D., BRAZ, D.M. **Diversidade, estrutura e estado de conservação de um fragmento da Floresta Atlântica no Estado do Rio de Janeiro.** Biota Neotropica. 15(2): e20140132. http://dx.doi.org/10.1590/1676-06032015013214

Resumo: O estado do Rio de Janeiro ainda detém porções desconhecidas da Floresta Atlântica, apontadas como lacunas no conhecimento desse ecossistema. Paracambi e municípios vizinhos contêm um extenso trecho florestado praticamente desconhecido que compõe o corredor ecológico da Serra do Mar. Este estudo descreve a estrutura do componente arbóreo da Floresta Atlântica ombrófila em uma porção desse contínuo florestal, no Parque Natural Municipal do Curió (PNM Curió), Paracambi, Rio de Janeiro, que serviu de base para avaliar a riqueza específica e seu estado de conservação. A altitude atinge de 100 a 690 m.s.n.m na área estudada e o clima varia de subtropical brando a tropical quente e úmido. Foram alocadas 40 parcelas de 10x10m (100m^2) distribuídas arbitrariamente ao longo do Parque, onde todos os indivíduos com diâmetro à altura do peito maior ou igual a cinco centímetros ($\geq$ 5cm) foram mensurados. Foram amostrados 749 indivíduos, somando 128 gêneros e 210 espécies, oito das quais listadas como ameaçadas de extinção na flora brasileira. O índice de diversidade de Shannon-Weaver (H′) foi 4.7 nat.ind.$^{-1}$ e a espécie com maior valor de importância foi *Pseudopiptadenia contorta* (1.6460 m^2; 18 indivíduos) enquanto que as espécies mais comuns foram *Senefeldera vertcilata* (48) e *Actinostemon verticilatus* (47). Apesar da área de estudo menor que a comumente adotada em estudos semelhantes, os dados apontaram para uma riqueza até então não registrada em nenhum outro estudo para o estado do Rio de Janeiro, independente do critério de inclusão adotado, o que também foi confirmado pelos dois estimadores de riqueza utilizados, que apresentaram resultados muito semelhantes.

A estrutura vertical da floresta, a associação dos valores obtidos ao estágio sucessional das espécies e outros aspectos da estrutura da comunidade, indicam que o PNM Curió engloba trechos de floresta em estágio avançado de sucessão ecológica. Além da localização chave na conectividade de fragmentos florestais na região, os resultados enfatizam a importância ecológica desse remanescente e da necessidade de sua conservação.

Keywords: *floresta ombrófila, fitossociologia, sucessão ecológica, corredor ecológico da Serra do Mar, Parque Natural Municipal do Curió- Paracambi.*

Introduction

Due to its high levels of endemism and biodiversity, the Atlantic Forest is considered a biome of unique biological complexity (Peixoto 1991, Stehmann et al. 2009). This feature, combined with its history of degradation, makes it one of the most threatened ecosystems in the world (Myers et al. 2000). Extensive areas have been devastated without any knowledge and many species have become extinct before they were even described by science (Guedes-Bruni et al. 2002, Borém & Oliveira-Filho 2002). Currently, the Atlantic Forest is reduced to fragments, mostly concentrated in the Brazilian Southeast and South, in areas of rugged topography inappropriate for agricultural activities and within conservation units (Martins 1991, Leitão-Filho et al. 1993, Kurtz & Araújo 2000, Ribeiro et al. 2009). Although fragmented, high rates of endemism found in this large forest block, with its different formations (Oliveira-Filho & Fontes 2000, Stehmann et al. 2009), make the remaining forest fragments singular relics.

Floristic studies are essential to the understanding and conservation of tropical forests (Silva & Leitão-Filho 1982, Guedes-Bruni et al. 1997). Along with this, structural surveys, which include quantitative traits, are among the best tools for characterization of the vegetation and the identification of the ecosystem successional status (Guedes-Bruni et al. 1997). Floristic and structural surveys make it possible to identify the potential for sustainable use of forest resources, as well as develop strategies to preserve and recover degraded areas and to quantify the richness, abundance and diversity of plant communities (Fonseca & Sá 1997, Scarano 1998).

The State of Rio de Janeiro still encompasses preserved portions of the Atlantic Forest, especially in the state interior and in mountain regions. Strategies for biodiversity conservation in the state (Bergalho 2009) call attention to the lack of knowledge especially in much of the Middle Paraíba River region, in the South of the state, and virtually the entire Northwest Region. These regions are still home to remaining forest fragments and efforts to fill these gaps are essential for understanding the flora of Rio de Janeiro and the Atlantic Forest as a whole. In the poorly known southern portion of the state, the *Parque Natural Municipal do Curió* (Municipal Natural Park of Curió) (Curio MNP) makes up part of the biodiversity corridor of the Serra do Mar, between the mountain ranges of Tinguá and Bocaina. Investigations of the flora, microorganisms and soil (Fraga et al. 2012) have indicated high rates of diversity in the area and its good conservation condition.

The importance of connectivity between forest fragments in the region makes the Curio MNP a strategic area for the maintenance of plant diversity in the state, which can serve as germoplasm stock and as a reference for measuring floristic restoration, especially in nearby areas. For these reasons, the present study aimed to elucidate the structure and floristic composition of the tree component within a forest fragment of the Curio MNP, including comparison of its richness to other forested areas in the State of Rio de Janeiro, and characterization of its horizontal and vertical structures to evaluate the conservation status of this vegetation.

Material and Methods

Study area – The area is located in the municipality of Paracambi, Rio de Janeiro, between the geographical coordinates 22°36′39" S to 43°42′33" W (Figure 1), covering an area of approximately 900 ha (Fraga et al. 2012). Paracambi is located at the southern limit of the metropolitan region of the state, and the area of the Curio MNP lies at the limits of the municipality, bordering the Middle Paraíba River and South-Central regions of the state (Bergalho 2009). The topography in Curio MNP is distinctly hilly, with altitudes ranging from 100 to 690 m.a.s.l.; the climate ranges from mild subtropical in most mountain areas with a dry winter and hot and rainy summer, and tropical hot and humid in other areas, classified as *Aw* according to Köppen-Geiger; the average annual temperature is 23.4° C (Fraga et al. 2012). Rich in water resources, the park is part of the Guandu River basin and sub-basin of the *Macacos* and *Cascata* streams, with springs that run along almost its entire length. The fragment is mostly woody and covered by the lowland and submontane Atlantic rain forest (IBGE 2012, Oliveita-Filho & Fontes, 2000). The area of the Curio MNP is inserted in the Southern Atlantic Forest Corridor, or the Serra do Mar Corridor, linking the forests of Rio de Janeiro and São Paulo States (Tabarelli et al. 2005).

Sampling and analysis – Data were collected between February 2009 and March 2010 by means of simple random sampling (Scolforo & Mello 2006) using the plot method (Mueller-Dombois & Ellenberg 1974). Aiming to include the largest possible area of the local vegetation, the sample was distributed over the entire area of the park, between 150-524 m.a.s.l. altitude, excluding the areas of access and of edge effect. Forty sampling units with dimensions of 10x10m (100m^2) were allocated, in which all individuals with diameter of at least five cm at breast height (DBH, 1.30 m above the ground) were measured using a measure tape and a 2 m rod to estimate total height. Fertile and sterile botanical material was collected and treated under usual herbarium techniques (Guedes-Bruni et al. 2002) for posterior inclusion in the collection of the Herbarium RBR of the Department of Botany/IB, *Universidade Federal Rural do Rio de Janeiro* (UFRRJ). The identification was based on consultation of the collections of RBR and RB (*Instituto de Pesquisa Jardim Botânico do Rio de Janeiro*) Herbaria, specialized bibliographies and, when possible, by consulting taxonomic specialists. The sources used for current taxonomic nomenclature were the *Lista das Espécies da Flora do Brasil* (2014), Tropicos (2013) and the International Index of Plant Names (IPNI, 2013) databases. The classification system

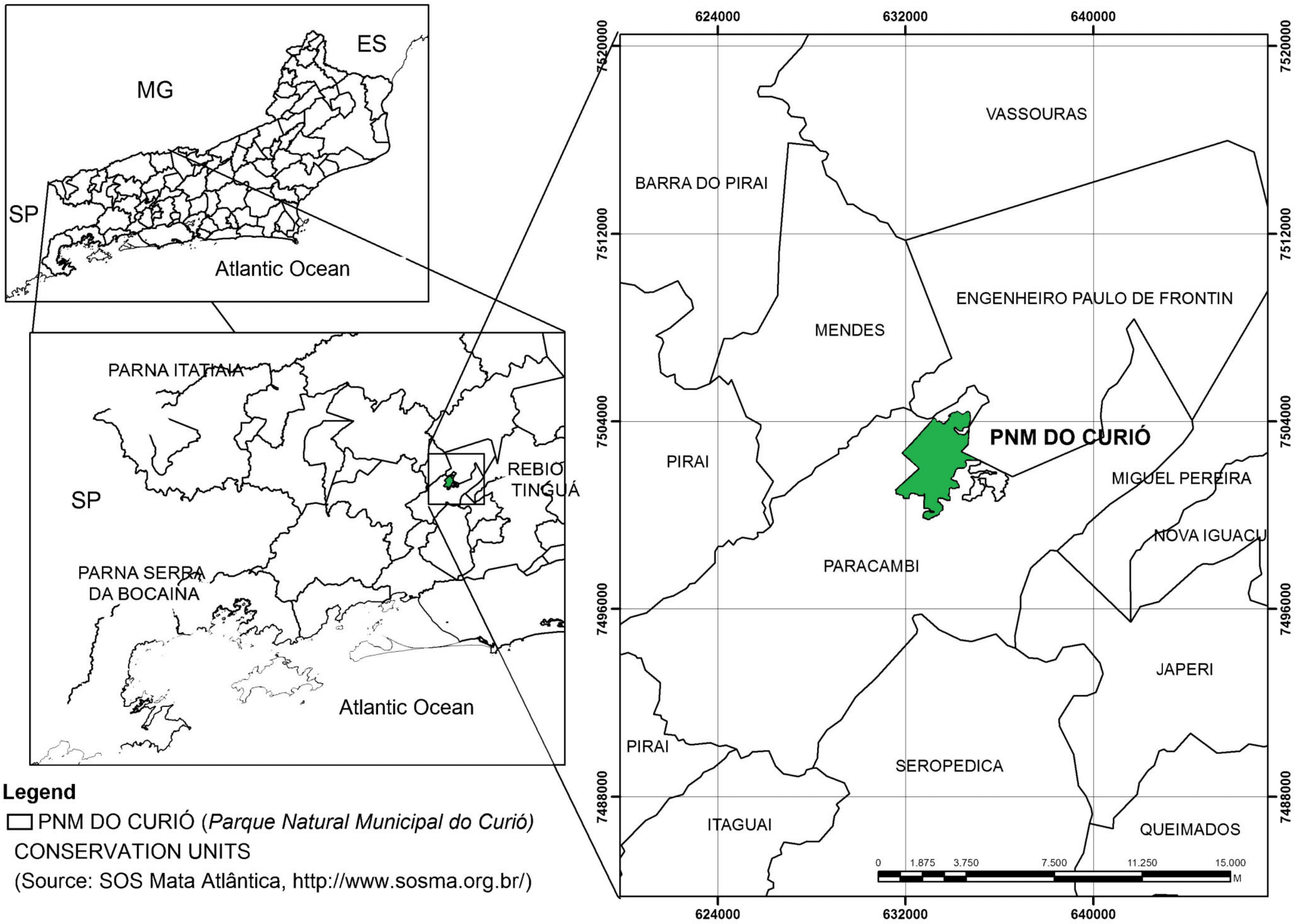

Figure 1. Geographic location of the *Parque Natural Municipal do Curió* (Municipal Natural Park of Curió) (Curio MNP), Municipal District of Paracambi, State of Rio de Janeiro, Brazil.

adopted followed the APG III (APG, 2009). Unidentified species were named (sp.) and numbered as "morpho-species", which allowed for their inclusion in the estimation of phytosociological and diversity indexes.

For all analysis, only living, individual trees were considered. The species accumulation curve was constructed using the software EstimateS 8:20, with the support of Microsoft Excel® spreadsheets. This curve minimizes the problems caused by the collector curve, because it is an average curve, generated from several distinct and random orderings (Magurran 2011, Schilling & Batista 2008). For its construction, 1000 simulations were performed with the goal of changing the sample unit entry order and assess the degree of stability of the sample (Pillar 2004 Apud Schilling & Batista 2008) on the basis of the central limit theorem (Ferreira 2009). From the average accumulation of number of species as a function of the area sampled, species richness was estimated through the estimators Chao 1 and Jackknife 1 (Magurran 2011). The floristic diversity of the area and the distribution of the individuals per species were estimated through the Shannon-Weaver (H′) and Pielou (J) diversity indexes (Magurran 2011). To characterize the horizontal structure, the phytosociological parameters commonly used were estimated, as follows: relative density (Rd), relative dominance (Ro), relative frequency (Rf), coverage index (CV) and importance value (IV), widely discussed and exemplified in Felfili et al. (2011). Vertical structure was analyzed considering lower, middle and upper strata. These limits were defined based on the total average height (Ht) of the trees and on the standard deviation of the height (^{S}Ht), according to the criteria of Souza (1999): lower stratum, includes trees with total height less than the average height least one unit of the standard deviation of the total height; middle stratum, the trees with average height equal or least one unit of the standard deviation up to those with average height plus one unit of the standard deviation; upper stratum, the trees with average height equal or plus one unit of the standard deviation. The diametric structure of the species that had the highest importance values was obtained considering the number and range of classes, as shown and described by Felfili & Rezende (2003). For each species, the Meyer model (Paula et al. 2004) was adjusted to obtain the estimated frequency per diameter class and allow for the application of the balanced forest concept. Diameter distribution of the community was calculated with exponential fit by the Meyer equation and their statistical coefficients determined by regression (determination coefficient R^2).

Results

The sample included 749 individuals of 210 tree species from 128 genera and 51 botanical families (Table 1). Among the

Table 1. Phytosociological parameters analyzed for the tree species sampled in a stretch of rainforest in Curio MNP, Paracambi, RJ, Brazil, in descending order of importance value. N = number of individuals sampled; Ba= basal area (m^2/ha); Rd= relative density (%); Ro= relative dominance (%); Rf= relative frequency (%); CV= coverage value (%); IV= importance value (%).

Specie	N°	Ba (m^2)	Rd (%)	Ro (%)	Rf (%)	CV (%)	IV (%)
Pseudopiptadenia contorta (DC.) G.P.Lewis e M.P.Lima	18	1.6460	2.40	8.49	2.25	5.45	4.38
Senefeldera verticilata (Vell.) Croizat	47	0.4618	6.28	2.38	2.25	4.33	3.64
Actinostemon verticillatus (Klotzsch) Baill.	48	0.2936	6.41	1.51	1.84	3.96	3.26
Cupania racemosa (Vell.) Radlk.	30	0.3614	4.01	1.86	3.89	2.93	3.25
Virola gardneri (A.DC.) Warb.	18	1.0350	2.40	5.34	1.84	3.87	3.20
Myrcia splendens (Sw.) DC.	33	0.5221	4.41	2.69	2.05	3.55	3.05
Piptadenia gonoacantha (Mart.) J.F.Macbr.	5	1.0699	0.67	5.52	0.82	3.09	2.34
Miconia cinnamomifolia (DC.) Naudin	8	0.9105	1.07	4.70	1.23	2.88	2.33
Cariniana legalis (Mart.) Kuntze	1	0.9972	0.13	5.14	0.20	2.64	1.83
Lacistema pubescens Mart.	14	0.1104	1.87	0.57	2.05	1.22	1.50
Tachigali pilgeriana (Harms) Oliveira-Filho	6	0.4519	0.80	2.33	1.23	1.57	1.45
Erythroxylum pulchrum A.St.-Hil.	10	0.3421	1.34	1.76	1.23	1.55	1.44
Astronium graveolens Jacq.	8	0.2991	1.07	1.54	1.23	1.31	1.28
Apuleia leiocarpa (Vogel) J.F.Macbr.	8	0.2917	1.07	1.50	1.23	1.29	1.27
Ocotea sp.1	10	0.1195	1.34	0.62	1.64	0.98	1.20
Siparuna guianensis Aubl.	13	0.0589	1.74	0.30	1.43	1.02	1.16
Cariniana estrellensis (Raddi) Kuntze	6	0.2419	0.80	1.25	1.23	1.02	1.09
Pera glabrata (Schott) Baill.	7	0.2198	0.93	1.13	1.02	1.03	1.03
Licania octandra (Hoffmanns. ex Roem. & Schult.) Kuntze	7	0.1605	0.93	0.83	1.23	0.88	1.00
Corymbia citriodora (Hook.) K.D.Hill e L.A.S. Johnson	1	0.4974	0.13	2.56	0.20	1.35	0.97
Sorocea bonplandii (Baill.) W.C.Burger et al.	8	0.0602	1.07	0.31	1.43	0.69	0.94
Eugenia brasiliensis Mart.	8	0.2095	1.07	1.08	0.61	1.07	0.92
Astrocarium aculeatissimum (Schott) Burret	7	0.0738	0.93	0.38	1.43	0.66	0.92
Cupania concolor Radlk.	8	0.1170	1.07	0.60	1.02	0.84	0.90
Micropholis crassipedicellata (Mart. & Eichler ex Miq.) Pierre	5	0.1855	0.67	0.96	1.02	0.81	0.88
Casearia sylvestris Sw.	7	0.0924	0.93	0.48	1.23	0.71	0.88
Bathysa gymnocarpa K.Schum.	7	0.0903	0.93	0.47	1.23	0.70	0.88
Dalbergia frutescens (Vell.) Britton	9	0.1565	1.20	0.81	0.61	1.00	0.87
Chamaecrista aspleniifolia (H.S.Irwin e Barneby) H.S.Irwin e Barneby	7	0.1951	0.93	1.01	0.61	0.97	0.85
Brosimum guianense (Aubl.) Huber	7	0.0680	0.93	0.35	1.23	0.64	0.84
Ocotea dispersa (Nees e Mart. ex Nees) Mez	7	0.0659	0.93	0.34	1.23	0.64	0.83
Ocotea glaziovii Mez	6	0.0804	0.80	0.41	1.23	0.61	0.82
Virola bicuhyba (Schott ex Spreng.) Warb.	1	0.3922	0.13	2.02	0.20	1.08	0.79
Casearia arborea (L.C.Rich.) Urb.	9	0.0535	1.20	0.28	0.82	0.74	0.77
Trichilia lepidota Mart.	6	0.0847	0.80	0.44	1.02	0.62	0.75
Matayba guianensis Aubl.	9	0.0846	1.20	0.44	0.61	0.82	0.75
Aioueia saligna Meisn.	9	0.0806	1.20	0.42	0.61	0.81	0.74
Cryptocaria moschata Nees e Mart. ex Nees	2	0.2982	0.27	1.54	0.41	0.90	0.74
Beilschmiedia sp.	7	0.0921	0.93	0.48	0.61	0.70	0.67
Mabea fistulifera Mart.	6	0.1555	0.80	0.80	0.41	0.80	0.67

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Table 1. Continued.

Specie	**N°**	**Ba (m^2)**	**Rd (%)**	**Ro (%)**	**Rf (%)**	**CV (%)**	**IV (%)**
Pseudolmedia laevigata Trécul	6	0.0760	0.80	0.39	0.82	0.60	0.67
Licania kunthiana Hook.f.	4	0.1565	0.53	0.81	0.61	0.67	0.65
Annona cacans Warm.	4	0.1536	0.53	0.79	0.61	0.66	0.65
Aniba firmula (Nees e Mart. ex Nees) Mez	6	0.0536	0.80	0.28	0.82	0.54	0.63
Buchenavia kleinii Exell	1	0.2934	0.13	1.51	0.20	0.82	0.62
Geissospermum laeve (Vell.) Miers	2	0.2035	0.27	1.05	0.41	0.66	0.58
Xylopia sericea A.St.-Hil.	4	0.1071	0.53	0.55	0.61	0.54	0.57
Ficus gomelleira Kunth e C.D.Bouché	3	0.2046	0.40	1.06	0.20	0.73	0.55
Guarea guidonia (L.) Sleumer	5	0.1126	0.67	0.58	0.41	0.62	0.55
Rinorea guianensis Aubl.	4	0.0461	0.53	0.24	0.82	0.39	0.53
Ecclinusa ramiflora Mart.	5	0.0573	0.67	0.30	0.61	0.48	0.53
Pradosia kulhmanii Toledo	1	0.2327	0.13	1.20	0.20	0.67	0.51
Amaioua guianensis Aubl.	4	0.0356	0.53	0.18	0.82	0.36	0.51
Stryphnodendron polyphyllum Mart.	2	0.2063	0.27	1.06	0.20	0.67	0.51
Byrsonima oblanceolata Nied	2	0.1662	0.27	0.86	0.41	0.56	0.51
Euterpe edulis Mart.	6	0.0508	0.80	0.26	0.41	0.53	0.49
Coussarea meridionalis (Vell.) Müll.Arg.	4	0.0543	0.53	0.28	0.61	0.41	0.48
Trichilia elegans A.Juss.	4	0.0528	0.53	0.27	0.61	0.40	0.47
Diatenopteryx sorbifolia Radlk.	5	0.1003	0.67	0.52	0.20	0.59	0.46
Guatteria sellowiana Schltdl.	3	0.0724	0.40	0.37	0.61	0.39	0.46
Pouteria caimito (Ruiz e Pav.) Radlk.	3	0.0716	0.40	0.37	0.61	0.38	0.46
Tapirira guianensis Aubl.	1	0.2012	0.13	1.04	0.20	0.59	0.46
Cecropia pachystachya Trécul	1	0.1987	0.13	1.02	0.20	0.58	0.45
Guatteria australis A.St.-Hil.	3	0.0664	0.40	0.34	0.61	0.37	0.45
Aspidosperma spruceanum Benth. ex Müll.Arg	3	0.0620	0.40	0.32	0.61	0.36	0.45
Carpotroche brasiliensis Endl.	3	0.0489	0.40	0.25	0.61	0.33	0.42
Sparattosperma leucanthum (Vell.) K.Schum.	3	0.0485	0.40	0.25	0.61	0.33	0.42
Protium warmingianum Marchand	3	0.0453	0.40	0.23	0.61	0.32	0.42
Ficus adhatodifolia Schott ex Spreng.	3	0.1246	0.40	0.64	0.20	0.52	0.42
Chamaecrista ensiformis (Vell.) H.S.Irwin e Barneby	3	0.0404	0.40	0.21	0.61	0.30	0.41
Licaria armeniaca (Nees) Kosterm.	4	0.0510	0.53	0.26	0.41	0.40	0.40
Tachigali paratyensis (Vell.) H.C.Lima	3	0.1164	0.40	0.60	0.20	0.50	0.40
Kielmeyera lanthrophyton Saddi	3	0.0367	0.40	0.19	0.61	0.29	0.40
Hieronyma alchorneoides Allemão	2	0.1378	0.27	0.71	0.20	0.49	0.39
Sloanea hirsuta (Schott.) Planch. ex Benth.	2	0.0973	0.27	0.50	0.41	0.38	0.39
Jacaranda micrantha Mart.	2	0.0970	0.27	0.50	0.41	0.38	0.39
Chrysophyllum flexuosum Mart.	3	0.0296	0.40	0.15	0.61	0.28	0.39
Coussarea nodosa (Benth.) Müll.Arg	5	0.0166	0.67	0.09	0.41	0.38	0.39
Neoraputia alba (Nees e Mart.) Emmerich	4	0.0739	0.53	0.38	0.20	0.46	0.37
Urbanodendron bahiense (Meisn.) Rohwer	4	0.0280	0.53	0.14	0.41	0.34	0.36

Continued on next page

Table 1. Continued.

Specie	**N°**	**Ba (m^2)**	**Rd (%)**	**Ro (%)**	**Rf (%)**	**CV (%)**	**IV (%)**
Cabralea canjerana (Vell.) Mart.	4	0.0267	0.53	0.14	0.41	0.34	0.36
Hesteria silvanii Schwacke	2	0.0779	0.27	0.40	0.41	0.33	0.36
Guapira opposita (Vell.) Reitz	3	0.0116	0.40	0.06	0.61	0.23	0.36
Pseudobombax gradiflorum (Cav.) A.Robyns	2	0.1151	0.27	0.59	0.20	0.43	0.36
Eryotheca candolleana (K.Schum.) A.Robyns	2	0.0656	0.27	0.34	0.41	0.30	0.34
Bathysa australis (A.St.-Hil.) K.Schum.	2	0.0644	0.27	0.33	0.41	0.30	0.34
Miconia chartacea Triana	1	0.1243	0.13	0.64	0.20	0.39	0.33
Pterocarpus rohrii Vahl.	2	0.0519	0.27	0.27	0.41	0.27	0.31
Plinia cauliflora (Mart.) Kausel	1	0.1134	0.13	0.58	0.20	0.36	0.31
Ocotea teleiandra (Meisn.) Mez	2	0.0434	0.27	0.22	0.41	0.25	0.30
Miconia brasiliensis (Spreng.) Triana	3	0.0156	0.40	0.08	0.41	0.24	0.30
Abarema cochliacarpos (Gomes) Barneby e J.W.Grimes	3	0.0151	0.40	0.08	0.41	0.24	0.30
Enterolobium glaziovii (Benth.) Mesquita	2	0.0409	0.27	0.21	0.41	0.24	0.30
Eugenia aff. *fusca* O.Berg.	3	0.0139	0.40	0.07	0.41	0.24	0.29
Zollernia glabra (Spreng.) Yakovlev	3	0.0121	0.40	0.06	0.41	0.23	0.29
Protium heptaphyllum (Aubl.) Marchand	1	0.1016	0.13	0.52	0.20	0.33	0.29
Tabernaemontana laeta Mart.	2	0.0341	0.27	0.18	0.41	0.22	0.28
Sorocea guilleminiana Gaudich.	2	0.0338	0.27	0.17	0.41	0.22	0.28
Psychotria vellosiana Benth.	3	0.0069	0.40	0.04	0.41	0.22	0.28
Handroanthus umbellatus (Sond.) Mattos	1	0.0945	0.13	0.49	0.20	0.31	0.28
Aparisthimum cordatum (A.Juss.) Baill.	3	0.0392	0.40	0.20	0.20	0.30	0.27
Matayba elaeagnoides Radlk.	2	0.0236	0.27	0.12	0.41	0.19	0.27
Sapium glandulosum (L.) Morong	2	0.0229	0.27	0.12	0.41	0.19	0.26
Eugenia sp.	2	0.0223	0.27	0.11	0.41	0.19	0.26
Ormosia arborea (Vell.) Harms	2	0.0210	0.27	0.11	0.41	0.19	0.26
Nectandra membranacea (Sw.) Griseb.	2	0.0190	0.27	0.10	0.41	0.18	0.26
Jacaratia spinosa (Aubl.) A.DC.	1	0.0844	0.13	0.44	0.20	0.28	0.26
Cecropia glaziovii Snethl.	2	0.0186	0.27	0.10	0.41	0.18	0.26
Eugenia pisiformis Cambess	2	0.0163	0.27	0.08	0.41	0.18	0.25
Ocotea sp.5	2	0.0555	0.27	0.29	0.20	0.28	0.25
Malouetia cestroides (Nees ex Mart.) Müll.Arg.	2	0.0155	0.27	0.08	0.41	0.17	0.25
Martiodendron mediteraneum (Mart. ex Benth.) Koeppen	1	0.0780	0.13	0.40	0.20	0.27	0.25
Allophyllus edulis (A.St.-Hil. et al.) Radlk.	2	0.0102	0.27	0.05	0.41	0.16	0.24
Urbanodendron verrucosum (Nees) Mez	2	0.0092	0.27	0.05	0.41	0.16	0.24
Roupala longepetiolata Pohl	2	0.0077	0.27	0.04	0.41	0.15	0.24
Eugenia oblongata O.Berg	2	0.0064	0.27	0.03	0.41	0.15	0.24
Pseudolmedia hirtula Kuhlm.	3	0.0202	0.40	0.10	0.20	0.25	0.24
Pouteria filipes Eyma	2	0.0058	0.27	0.03	0.41	0.15	0.24
Ocotea laxa (Nees) Mez	2	0.0052	0.27	0.03	0.41	0.15	0.23
Siparuna bifida (Poepp. & Endl.) A.DC.	2	0.0046	0.27	0.02	0.41	0.15	0.23

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Table 1. Continued.

Specie	**N°**	**Ba (m^2)**	**Rd (%)**	**Ro (%)**	**Rf (%)**	**CV (%)**	**IV (%)**
Pseudopiptadenia inaequalis (Benth.) Rauschert	2	0.0043	0.27	0.02	0.41	0.14	0.23
Aspidosperma ramiflorum Müll.Arg.	1	0.0645	0.13	0.33	0.20	0.23	0.22
Pouteria aff. *englerii* Eyma	1	0.0627	0.13	0.32	0.20	0.23	0.22
Annona dolabripetala Raddi	1	0.0497	0.13	0.26	0.20	0.19	0.20
Casearia sp.	2	0.0166	0.27	0.09	0.20	0.18	0.19
Myrcia richardiana (O.Berg) Kiaersk.	2	0.0150	0.27	0.08	0.20	0.17	0.18
Lamanonia ternata Vell.	2	0.0140	0.27	0.07	0.20	0.17	0.18
Marlierea excoriata Mart.	2	0.0138	0.27	0.07	0.20	0.17	0.18
Annona neolaurifolia H. Rainer	1	0.0390	0.13	0.20	0.20	0.17	0.18
Moldenhawera floribunda Schrad.	1	0.0390	0.13	0.20	0.20	0.17	0.18
Inga sp.	2	0.0115	0.27	0.06	0.20	0.16	0.18
Zanthoxylum sp.	2	0.0112	0.27	0.06	0.20	0.16	0.18
Algernonia leandrii (Baill.) G.L.Webster	2	0.0097	0.27	0.05	0.20	0.16	0.17
Alseis floribunda Schott	1	0.0347	0.13	0.18	0.20	0.16	0.17
Copaifera langsdorfii Desf.	2	0.0069	0.27	0.04	0.20	0.15	0.17
Pouteria sp.1	1	0.0326	0.13	0.17	0.20	0.15	0.17
Ocotea sp.3	1	0.0296	0.13	0.15	0.20	0.14	0.16
Inga capitata Desv.	1	0.0270	0.13	0.14	0.20	0.14	0.16
Cordia sellowiana Cham.	1	0.0268	0.13	0.14	0.20	0.14	0.16
Schizolobium parahyba (Vell.) Blake	1	0.0259	0.13	0.13	0.20	0.13	0.16
Swartzia acutifolia Vogel.	1	0.0256	0.13	0.13	0.20	0.13	0.16
Ocotea aniboides (Meisn.) Mez	1	0.0241	0.13	0.12	0.20	0.13	0.15
Indeterminate 2	1	0.0230	0.13	0.12	0.20	0.13	0.15
Aspidosperma sp.	1	0.0224	0.13	0.12	0.20	0.12	0.15
Dalbergia foliolosa Benth	1	0.0199	0.13	0.10	0.20	0.12	0.15
Tibouchina granulosa (Desr.) Cogn.	1	0.0199	0.13	0.10	0.20	0.12	0.15
Joannesia princeps Vell.	1	0.0191	0.13	0.10	0.20	0.12	0.15
Pourouma guianensis Aubl.	1	0.0183	0.13	0.09	0.20	0.11	0.14
Guazuma crinita Mart.	1	0.0183	0.13	0.09	0.20	0.11	0.14
Cyathea corcovadensis (Raddi) Domin	1	0.0176	0.13	0.09	0.20	0.11	0.14
Vochysia laurifolia Warm.	1	0.0161	0.13	0.08	0.20	0.11	0.14
Cryptocaria micrantha Meisn.	1	0.0154	0.13	0.08	0.20	0.11	0.14
Maprounea guianensis Aubl.	1	0.0147	0.13	0.08	0.20	0.10	0.14
Ocotea elegans Mez.	1	0.0140	0.13	0.07	0.20	0.10	0.14
Sapotaceae sp.	1	0.0127	0.13	0.07	0.20	0.10	0.13
Vernonanthura discolor (Spreng.) H.Rob.	1	0.0121	0.13	0.06	0.20	0.10	0.13
Pouteria beaurepairei (Glaz. & Raunk.) Baehni	1	0.0115	0.13	0.06	0.20	0.10	0.13
Ocotea sp.2	1	0.0109	0.13	0.06	0.20	0.09	0.13
Piptocarpha axillaris (Less.) Baker	1	0.0109	0.13	0.06	0.20	0.09	0.13
Sloanea guianensis (Aubl.) Benth.	1	0.0109	0.13	0.06	0.20	0.09	0.13

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Table 1. Continued.

Specie	N°	Ba (m^2)	Rd (%)	Ro (%)	Rf (%)	CV (%)	IV (%)
Schoepfia brasiliensis A.DC.	1	0.0092	0.13	0.05	0.20	0.09	0.13
Fabaceae sp.	1	0.0087	0.13	0.04	0.20	0.09	0.13
Ficus maxima Mill.	1	0.0081	0.13	0.04	0.20	0.09	0.13
Syagrus romanzoffiana (Cham.) Glassman	1	0.0081	0.13	0.04	0.20	0.09	0.13
Guazuma ulmifolia Lam.	1	0.0078	0.13	0.04	0.20	0.09	0.13
Miconia budlejoides Triana	1	0.0076	0.13	0.04	0.20	0.09	0.13
Indeterminate 1	1	0.0072	0.13	0.04	0.20	0.09	0.13
Parinari excelsa Sabine	1	0.0072	0.13	0.04	0.20	0.09	0.13
Coussarea contracta (Walp.) Benth. & Hook.f. ex Müll.Arg	1	0.0067	0.13	0.03	0.20	0.08	0.12
Cupania furfuracea Radlk.	1	0.0067	0.13	0.03	0.20	0.08	0.12
Citronela megaphylla (Miers) R.A.Howard	1	0.0062	0.13	0.03	0.20	0.08	0.12
Psychotria appendiculata Müll.Arg.	1	0.0058	0.13	0.03	0.20	0.08	0.12
Gallesia integrifolia (Spreng.) Harms	1	0.0054	0.13	0.03	0.20	0.08	0.12
Zollernia glaziovii Yakovlev	1	0.0054	0.13	0.03	0.20	0.08	0.12
Andira fraxinifolia Benth.	1	0.0050	0.13	0.03	0.20	0.08	0.12
Ocotea diospyrifolia (Meisn.) Mez	1	0.0050	0.13	0.03	0.20	0.08	0.12
Pouteria sp 2	1	0.0050	0.13	0.03	0.20	0.08	0.12
Casearia obliqua Spreng.	1	0.0046	0.13	0.02	0.20	0.08	0.12
Ocotea aciphylla (Nees e Mart. ex Nees) Mez	1	0.0046	0.13	0.02	0.20	0.08	0.12
Qualea gestasiana A.St.-Hil.	1	0.0046	0.13	0.02	0.20	0.08	0.12
Swartzia myrtifolia Sm.	1	0.0046	0.13	0.02	0.20	0.08	0.12
Myrtaceae sp.1	1	0.0042	0.13	0.02	0.20	0.08	0.12
Eugenia rostrata O.Berg	1	0.0039	0.13	0.02	0.20	0.08	0.12
Myrsine umbellata Mart.	1	0.0039	0.13	0.02	0.20	0.08	0.12
Pouteria gardneri (Mart. & Miq.) Baehni	1	0.0039	0.13	0.02	0.20	0.08	0.12
Terminalia januariensis DC.	1	0.0039	0.13	0.02	0.20	0.08	0.12
Calyptranthes aff. *concinna* DC.	1	0.0035	0.13	0.02	0.20	0.08	0.12
Tripterodendron filicifolium (Linden) Radlk.	1	0.0035	0.13	0.02	0.20	0.08	0.12
Calyptranthes lucida Mart. ex DC.	1	0.0032	0.13	0.02	0.20	0.07	0.12
Marlierea suaveolens Cambess.	1	0.0032	0.13	0.02	0.20	0.07	0.12
Solanum leucodendron Sendtn.	1	0.0032	0.13	0.02	0.20	0.07	0.12
Trichilia pallens C.DC.	1	0.0032	0.13	0.02	0.20	0.07	0.12
Ampelocera glabra Kuhlm.	1	0.0029	0.13	0.01	0.20	0.07	0.12
Hirtella hebeclada Moric. ex DC.	1	0.0029	0.13	0.01	0.20	0.07	0.12
Licaria sp.	1	0.0029	0.13	0.01	0.20	0.07	0.12
Mollinedia corcovadensis Perkins	1	0.0029	0.13	0.01	0.20	0.07	0.12
Cocolloba acuminata Kunth.	1	0.0026	0.13	0.01	0.20	0.07	0.12
Helicostyles tomentosa (Poepp. & Endl.) Rusby	1	0.0026	0.13	0.01	0.20	0.07	0.12
Lauraceae sp.	1	0.0026	0.13	0.01	0.20	0.07	0.12
Ocotea sp.4	1	0.0026	0.13	0.01	0.20	0.07	0.12

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Table 1. Continued.

Specie	N°	Ba (m^2)	Rd (%)	Ro (%)	Rf (%)	CV (%)	IV (%)
Erythroxylum citrifolium A.St.-Hil.	1	0.0023	0.13	0.01	0.20	0.07	0.12
Eugenia aff. *umbelliflora* O.Berg	1	0.0023	0.13	0.01	0.20	0.07	0.12
Ocotea divaricata (Nees) Mez	1	0.0023	0.13	0.01	0.20	0.07	0.12
Sorocea hillarii Gaudich.	1	0.0023	0.13	0.01	0.20	0.07	0.12
Casearia commersoniana Cambess.	1	0.0020	0.13	0.01	0.20	0.07	0.12
Hymenaea courbaril L.	1	0.0020	0.13	0.01	0.20	0.07	0.12
Myrtaceae sp.2	1	0.0020	0.13	0.01	0.20	0.07	0.12
Ormosia fastigiata Tul.	1	0.0020	0.13	0.01	0.20	0.07	0.12
Psychotria nuda (Cham. & Schltdl.) Wawra	1	0.0020	0.13	0.01	0.20	0.07	0.12
Strychnos trinervis (Vell.) Mart.	1	0.0020	0.13	0.01	0.20	0.07	0.12
TOTAL	**749**	**19.3904**	**100**	**100**	**100**	**100**	**100**

surveyed species, 13 were identified only to the genus level, five at family level and two species remained unidentified. Of the species found, *Apuleia leiocarpa*, *Cariniana legalis*, *Cupania concolor*, *Cupania furfuracea*, *Euterpe edulis*, *Pradosia kulhmanii*, *Urbanodendron bahiense* and *Virola bicuhyba* are listed as threatened in Brazilian flora in the endangered or vunerable categories (CNCFLORA 2014). According to the Chao 1 and Jackknife 1 richness estimators, the number of expected species for the community is 323 and 325, respectively. Thus, the observed richness (n = 210) corresponds to 65.7 % of the total estimated richness for the community. The floristic diversity index of Shannon-Weaver (H′) was 4.7, and the evenness index (J) was 0.88. The species accumulation curve showed a smooth curvature (Figure 2), but did not reach the asymptotic value.

A total of 15 dead standing trees were found. The estimated total basal area was 48.48 m^2/hectare (ha) (Table 1). *Pseudopiptadenia contorta* had the highest importance value (IV), mainly due to its high value of dominance. *Senefeldera verticilata*, even with low values of relative dominance, had the second highest density value for the community, being second in IV. The species with the third highest IV was *Actinostemon verticilatus*, which despite having the highest density, showed reduced values of frequency and dominance, due to its clustered pattern of occurrence and small individual size. *Cupania racemosa*, which ranked fourth in IV, was the most frequent species in the sample and the fourth in density, evenly distributed throughout the study area. *Virola gardnerii*, the fifth species in IV, had lower density and frequency values, however it held this position due to the large size of its individuals, which generated high levels of dominance (3rd position). The sixth highest IV was held by *Myrcia splendens*, the third in density, being represented only by individuals of small and medium size. These first six species accounted for 20.77% of the importance value and 24.1% of the coverage value (CV), highlighting the importance of these taxa in the forest structure of the Curio MNP. *Piptadenia gonoacantha* and *Miconia cinnamomifolia* (7th and 8th IV), which were represented by few individuals, showed high importance values however due to the large size of their individuals. The ninth ranked IV species was *Cariniana legalis*, which despite being represented by only one individual, had the fourth highest dominance value of the community due to its large diameter (112 cm).

The individual distribution by diameter class (R^2) was 0.875 (Figure 3), with an exponential distribution in the form of an "inverted- J" and higher frequency of individuals in the smaller classes. The diameter distribution of the six species of highest importance value (IV) revealed that the majority showed a balanced pattern of distribution. *Pseudopiptadenia contorta* (R^2 = 0.6) and *Cupania racemosa* (R^2 = 0.57) were exceptions, showing a distinct pattern with interruptions between the classes.

The lower stratum included individuals up to 5.1 meters high, the middle, individuals from 5.1 to 15.6 meters, and the higher, with individuals taller than 15.6 meters. The middle stratum was the most abundant in number of individuals (73.5%) and species (179). This layer assembles the understory species of medium height and those in the growth phase to the canopy, with greater richness and density. The most common species of the lower stratum were *Senefeldera verticilata*, *Actinostemon verticilatus*, *Cupania racemosa* and *Siparuna guianensis*. In the upper stratum, *Virola gardnerii*, *Pseudopiptadenia contorta*

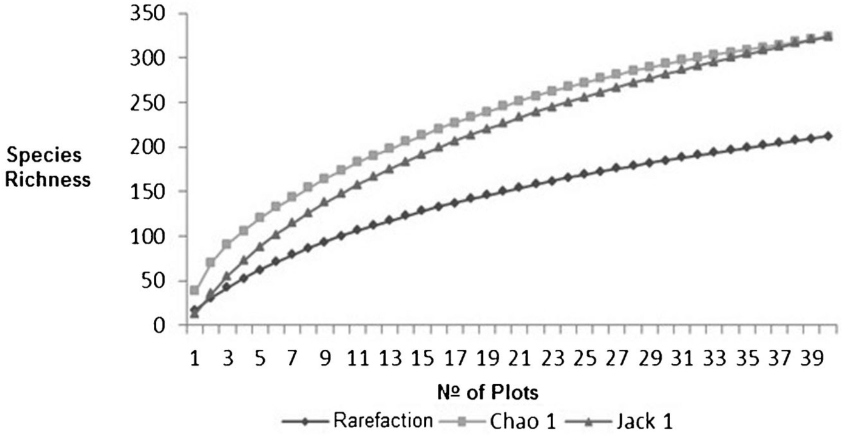

Figure 2. Species accumulation curve and Chao 1 and Jackknife 1 richness estimators for the rainforest in the Curio MNP, Paracambi, RJ, Brazil.

and *Myrcia splendens* were the most abundant. In addition, many emergent trees above 30 meters high were recorded, such as *Pseudopiptadenia contorta*, *Martiodendron mediterraneum*, *Apuleia leiocarpa*, *Cariniana legalis*, *Miconia cinnamomifolia* and *Virola gardnerii*.

Main parameters used for comparing species richness, diversity and structure with other Atlantic Forest areas studied in the State of Rio de Janeiro are presented in Table 2.

Discussion

The diversity index registered in the survey was high when compared to values found in other studied areas of Atlantic Rain Forest in Rio de Janeiro. Martins (1991) asserted that, in general, the diversity values obtained for the Atlantic Forest vary from 3.61 to 4.07. For Rio de Janeiro State, Kurtz & Araújo (2000) suggested a variation from 1.69 to 4.4, depending on the study area. Comparisons should be made with caution, because when considering species equitability in the diversity calculation, these scores may end up assigning lower values for areas with high abundance of some species, which commonly occurs in Atlantic Forest fragments. However, the index of species equitability (J) in the study area (0.88) indicated that the individuals are uniformly distributed among the species. Although higher richness was registered to the Atlantic Forest as a whole, with the highest number recorded by Thomaz & Monteiro (1997) and Saiter et al (2011) to the state of Espirito Santo, among the studies conducted for this vegetation in the state of Rio de Janeiro, including equal or larger sample areas, the Curio MNP was the one with the greater species richness. The lack of stabilization of the species accumulation curve is, in fact, a pattern to be expected for tropical forests (Schilling & Batista 2008, Schilling et al. 2012), as well as the high number of species, which also reaffirm the richness and importance for conservation of this forest area. Similarly, the index of species estimation for the study area and the occurrence of threatened species of the national flora also show the importance of the Curio MNP for the maintenance of genetic resources and protection of their habitats. By the other side, this high richness in species may be due to the high altitudinal gradient of the sampled area. The impracticality of identifying some studied species (10% of total) reveals that there is still a lack of knowledge of some Atlantic Forest representatives.

Among the studied tree communities in the State, a greater value for basal area than that found in this survey was only found by Kurtz & Araújo (2000) in the *Estação Ecológica Paraiso* (57.28 m^2 /ha), mainly due to the presence of large remaining individuals. Although broader inclusion criteria may lead to an increase in this variable (Nettesheim et al., 2010), these two studies with the highest values used the same criteria, not as restrictive as other studies in Rio de Janeiro. The total density was 1872 individuals/ha, a relatively high value when compared to that found in other studies in the State of Rio de Janeiro, but lower than those found by Gandra et al. (2011) in *PRNP Porangaba* (1886 ind/ha) and by Kurtz et al. (2009) on a sandbank of Buzios (2386 ind/ha). Reduced basal area and density may reflect anthropogenic disturbances such as the presence of selective wood extraction (Silva & Nascimento 2001) or natural factors such as drought and land slope (Guedes-Bruni et al. 2006). Indeed, Borém & Oliveira-Filho (2002), studying an amended topo-sequence, obtained increasing values of these variables with the reduction of the disturbance gradient. These variables have been shown to be effective indicators of the degree of preservation of an area (Moreno et al. 2003), as long as they are carefully analyzed. In the study area, anthropogenic disturbance is the result of the proximity of the urban area, old abandoned plantations and on-going plant extraction.

Regarding the species with the highest importance values (IV), Borém & Oliveira -Filho (2002) also found *Pseudopiptadenia contorta* to be one of the most important in the upper third of a topo-sequence in Silva Jardim, RJ, and attributed this position to the species' high basal area. Guedes-Bruni et al. (2006) found *Senefeldera vertcilata* to be the most important species (IV) in three fragments analyzed and explained its position due to its high density values, as was also detected in this study. This was due to the clustered pattern and small size of the individuals. Moreno et al. (2003) also found high levels of coverage and importance for *Actinostemon verticilatus* at two different altitudes, reflecting its high density in both. Similarly to observations in the present study, a high number of species represented by few individuals (1-2) is a typical factor of forest communities, especially in Brazilian rainforests (Martins 1991, Kurtz & Araújo 2000, Silva & Nascimento 2001, Borém & Oliveira-Filho 2002, Moreno et al. 2003, Carvalho et al. 2007). In general, the occupation strategy

Table 2. Main parameters used for comparing species richness, diversity and structure with other Atlantic Forest areas studied in the State of Rio de Janeiro. N= number of individuals; S= species; G= genus; F= Family; H'= Shannon-Weaver index of diversity; Ba basal area (m^2/ha); and Dens= density of individuals (ind/ha).

Studied area	N	S	G	F	H'	Ba (m^2/ha)	Dens (ind/ha)	Method	Criteria	Amostral area	Reference
Área de Proteção Ambiental do Pau-brasil	1193	98		36	3.6	23.6	2386	Plot	Dbh>5	0.5 ha	Kurtz et al. (2009)
Estação Ecológica do Paraiso	592	138	83	42	4.2	57.28	1369	Quadrant	Dbh>5	150 pt	Kurtz & Araujo (2000)
Fazenda Biovert, Silva Jardim	579	129	95	43	4.1	23.15	1608	Plot	Dbh>3.18	0.36 ha	Borém & Oliveira-Filho (2002)
Mata do Bom Jesus, Campos dos Goytacazes	336	105		35	4.02	17.3		Quadrant	Dbh>3.2	84 pt	Carvalho et al. (2006)
Mata do Carvão, Campos dos Goytacazes	564	83		34	3.21	15	564	Plot	Dbh>10	1.0 ha	Silva & Nascimento (2001)
Parque Estadual do Desengano, Imbé (250m)	480	145		39	4.3	34.6	800	Plot	Dbh>10	0.6 ha	Moreno et al. (2003)
Parque Estadual do Desengano, Imbé (50m)	460	125		31	4.2	41.9	766	Plot	Dbh>10	0.6 ha	Moreno et al. (2003)
REBIO Poço das Antas	580	174		45	4.57	26.85	580	Plot	Dbh>5	1.0 ha	Guedes-Bruni et al. (2006)
Rio Bonito	698	106	77	32	3.9	29	1745	Plot	Dbh>5	0.4 ha	Carvalho et al.(2007)
RPPN Porangaba, Itaguaí	943	105	66	36	3.8	20.71	1886	Plot	Dbh>5	0.5 ha	Gandra et al. (2011)
S.F. de Itabapoana	564	83		34	3.21	15	564	Plot	Dbh>10	1.0 ha	Silva & Nascimento (2001)
Parque Natural Municipal do Curió	749	210	128	51	4.7	48.48	1872	Plot	Dbh>5	0.4 ha	present study

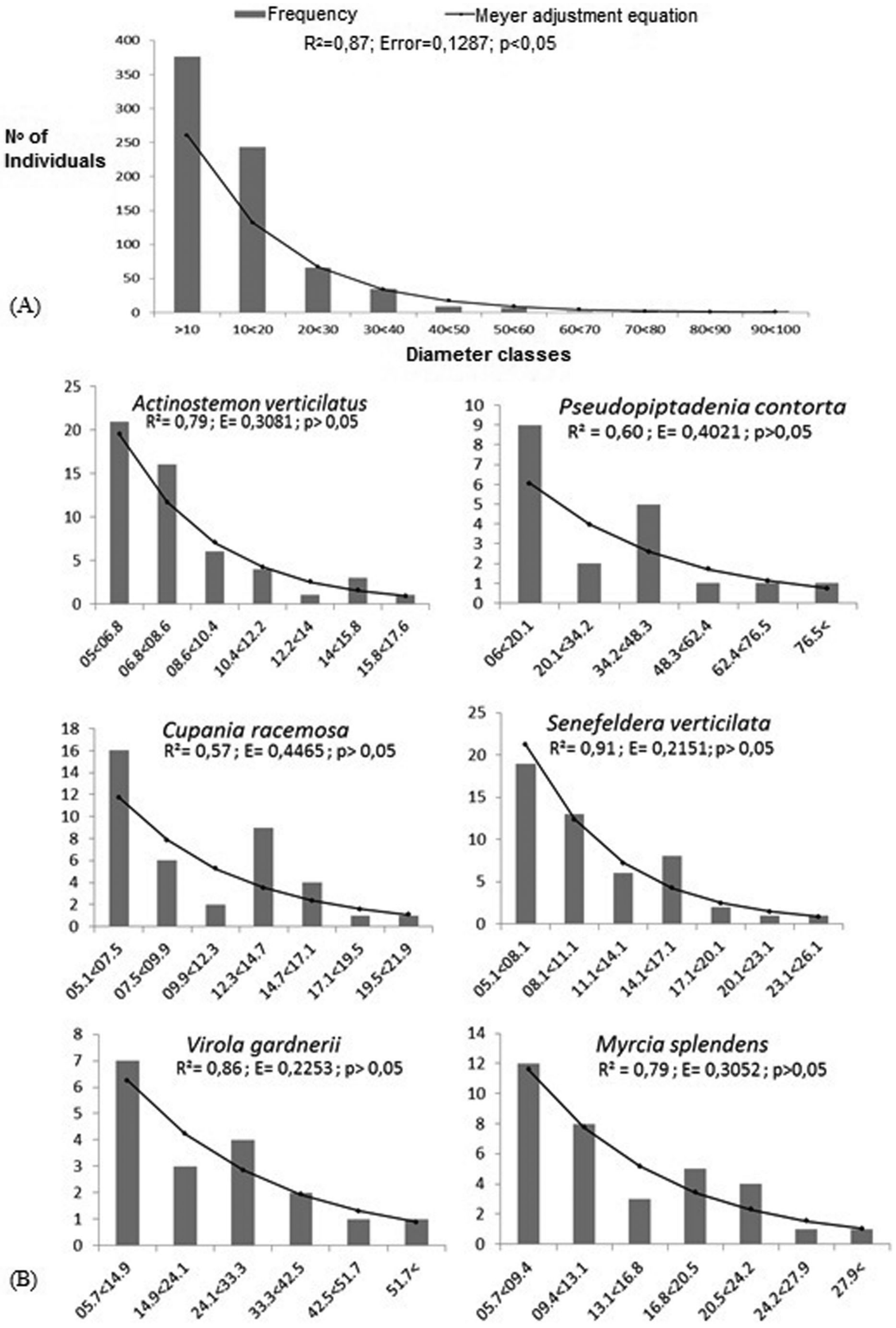

Figure 3. Diameter distribution of the community and of the six tree species with the highest dominance values in a fragment of the rainforest in Curio MNP, Paracambi, RJ, with exponential fit by the Meyer equation and their statistical coefficients.

of most species is many individuals with reduced size, while a minority has a few individuals of large size (Borém & Oliveira-Filho 2002, Guedes-Bruni et al. 2006). Species with large individuals in the study area, such as *Piptadenia gonoacantha* and *Miconia cinnamomifolia*, were cited by Borém & Oliveira-Filho (2002) as ecologically dominant, namely, species that occupy significant positions in IV, albeit at low density. Both are considered pioneers species and indicators of disturbance (Araújo et al. 2006). As these species are represented by a few and large individuals, it is likely declining in the community, indicating that succession is progressing to more advanced stages. In the study area, the only individual of *Cariniana legalis* (9th in IV) is probably a relic from a primary forest, suggesting maturity in some patches of this forest. Dan et al. (2010) also found species of the same genus with low density in a municipality of northwestern Rio de Janeiro State and, pointing out its abundance in the past, attributed the finding to exploitation of this highly valuable timber species. For many species, however, the low density can also be indicative of very peculiar spatial distribution. The low frequency of *C. legalis* in the area may result from its exploitation or also be caused by a small sample, what suggests the need for further investigations.

The number of dead standing trees (15; 1.96%) can be considered low when compared to other forests from Rio de Janeiro State. Moreno et al. (2003) mentioned a mortality rate of 1.5% for a well preserved forest, while Carvalho et al. (2007) found 10.1% in an area affected by human disturbance. Silva & Nascimento (2001) also found a 9.76 % mortality rate in a *tabuleiro* forest and related this to problems caused by fragmentation and the edge effect. The reduced mortality found in the Curio MNP can be another factor that reinforces the maturity and good level of preservation of the studied fragment.

The individual distribution by diameter class (R^2= 0.875) followed the typical pattern pointed out by Soares et al. (2007), which may indicate the capacity for self-regeneration and replacement of individuals on a short time-scale (Felfili 1997). According to Parrota (1993), the occurrence of a greater number of individuals in the lower- diameter classes is a pattern expected for secondary forests, favoring succession and buffering disturbances. The evaluation of the diameter distribution at the community level has been shown to be an important tool for understanding vertical structure in forests. On the other hand, it may be insufficient to assess the condition of the tree component, and therefore analyses at the population level are needed (Martins 1991, Felfili 1997, Paula et al. 2004, Carvalho & Nascimento 2009). Kurtz & Araújo (2000) postulated that equilibrated populations have nearly balanced diameter distributions, tending to produce an inverted-J curve, which is typical of species with abundant regeneration and a stable population structure. Carvalho & Nascimento (2009), when studying the diameter structure of the principal tree populations in a forest remnant in Silva Jardim, RJ, also found balanced patterns for most species, indicating temporal stability in floristic composition and the absence of problems in the regeneration of these populations. In the present study, the large number of individuals of *Pseudopiptadenia contorta* and *Cupania racemosa* in the smaller classes suggests their persistence in the forest fragment.

In the Curio MNP, the middle stratum includes understory species of medium height and canopy species in the growth phase, thus showing greater richness and density, as found by Kurtz & Araujo (2000) at the *Estação Ecológica do Paraíso*, where 65.2% of the richness and 48% of the individuals were in the middle strata. Dan et al. (2010) also found a greater number of species in the middle of three strata when studying the structure of a tree community in the Santo Domingo River basin of São José de Ubá, RJ. Although using different methodology, Guilherme et al. (2004) detected three well-defined strata for an Atlantic forest area preserved in São Paulo and likewise had greater richness in the middle stratum, although the greater density was found in the lower stratum. By the other side, in the present study the upper stratum showed the highest coverage values, with 55.9% of the total basal area found, which reflects the large size of the species. Puig (2008) suggested high structural heterogeneity in tropical moist forests, both in their vertical organization and in their horizontal arrangement. It should be emphasized, however, that the vertical structure of tropical forests is still little studied, especially because of the difficulty in precise measurement of this variable in native forests and in its analysis (Guilherme et al. 2004; Machado & Figueiredo-Filho, 2006). The most frequent species in the lower stratum (*Senefeldera verticillata*, *Actinostemon verticilatu*s, *Cupania racemosa* and *Siparuna guianensis*) are classified as initial secondary or pioneer species, with low shade tolerance and of medium size (Silva et al. 2003, Carvalho et al. 2007). Carvalho et al. (2007), refer to the same species as typical of the understory in secondary forests, highlighting disturbed areas in the Curio MNP. In the upper stratum, *Virola gardnerii* is mentioned by Carvalho et al. (2007) as a late canopy species, while *Pseudopiptadenia contorta* is indicated as a long-lived pioneer (Carvalho et al. 2007), related to an intermediate stage of regeneration (Gandolfi et al. 1995). Emergent species (*Pseudopiptadenia contorta*, *Martiodendron mediterraneum*, *Apuleia leiocarpa*, *Cariniana legalis*, *Miconia cinnamomifolia* and *Virola gardnerii*) represent the oldest individuals in the community, being indicative of maturity or an advanced stage of forest succession.

The high diversity and species richness registered, despite the small sample area, is a strong indication of the good condition of the vegetation of the Curio MNP. The high diversity index (H′) is probably associated with the uniformity found in the distribution of individuals by species. The diameter distributions of the six species with the greatest importance values suggest temporal stability of these populations. The high species richness, high basal area, the presence of large emergent individuals and the low number of dead trees indicate that the forests, even being secondary, can be considered mature, with the prevalence of advanced stages in a successional forest mosaic. Since approximately 30% of the species are still unknown and the already high number of species found may be due to the high altitudinal gradient of the park area, besides evaluate the richness in different altitudinal quotas further research may reveal other ecologically important species for this vegetation and/or little known. The occurrence of endangered species listed for the Brazilian flora reiterates the importance of the area as a relic fragment of Rio de Janeiro Atlantic Forest still in good environmental condition. Added to this, the lack of floristic knowledge of the region reinforces the need for conservation of this forest to maintain and restore native vegetation, especially in nearby areas. These features taken together point out to the need for constant care and a possible expansion of the boundaries of the park, with the elevation of this conservation area to a state or federal level, which can ensure greater protection of the local biota.

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Dung beetles of the tribe Phanaeini (Coleoptera: Scarabaeidade: Scarabaeinae) from Roraima state, Northern Brazil: checklist and key to species

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PACHECO, T.L., VAZ-DE-MELLO, F.Z. **Dung beetles of the tribe Phanaeini (Coleoptera: Scarabaeidade: Scarabaeinae) from Roraima state, Northern Brazil: checklist and key to species.** Biota Neotropica. 15(2): e20140145. http://dx.doi.org/10.1590/1676-06032015014514

Abstract: Phanaeini comprises about 160 species in 12 genera restricted to the Americas. Since the diversity of this tribe remains little known in several regions of Brazil, this study presents a guide to its 13 species with presence in the biologically rich and largely unexplored state of Roraima: *Coprophanaeus (Coprophanaeus) abas* (MacLeay, 1819), *C. (C.) dardanus* (MacLeay, 1819), *C. (C.) gamezi* Arnaud, 2002, *C. (C.) jasius* (Olivier, 1789), *C. (Megaphanaeus) lancifer* (Linnaeus, 1767), *Oxysternon (Oxysternon) conspicillatum conspicillatum* Werber, 1801, *O. (O.) durantoni* Arnaud, 1984, *O. (O.) ebeninum* (Nevinson, 1890), *O. (O.) festivum viridanum* (Olsoufieff, 1924), *O. (O.) silenus chicheryi* Arnaud, 2001, *Phanaeus (Notiophanaeus) bispinus* Bates, 1868, *P. (N.) bordoni* Arnaud, 1996 (first record from Brazil), and *Sulcophanaeus faunus* (Fabricius, 1775). The species of *Dendropaemon* were not considered herein because the genus is presently under taxonomic revision.

Keywords: *Inventory, Amazon, Guyana Shield.*

PACHECO, T.L., VAZ-DE-MELLO, F.Z. **Os besouros rola-bostas da tribo Phanaeini (Coleoptera: Scarabaeidae: Scarabaeinae) do estado de Roraima, Norte do Brasil: lista e chave para as espécies.** Biota Neotropica. 15(2): e20140145. http://dx.doi.org/10.1590/1676-06032015014514

Resumo: Phanaeini abrange cerca de 160 espécies pertencentes a 12 gêneros restritos às Américas. Como a diversidade desta tribo permanece pouco conhecida em diversas regiões do Brasil, este estudo apresenta um guia de identificação das 13 espécies com registro de ocorrência no estado biologicamente rico e amplamente inexplorado de Roraima: *Coprophanaeus (Coprophanaeus) abas* (MacLeay, 1819), *C. (C.) dardanus* (MacLeay, 1819), *C. (C.) gamezi* Arnaud, 2002, *C. (C.) jasius* (Olivier, 1789), *C. (Megaphanaeus) lancifer* (Linnaeus, 1767), *Oxysternon (Oxysternon) conspicillatum conspicillatum* Werber, 1801, *O. (O.) durantoni* Arnaud, 1984, *O. (O.) ebeninum* (Nevinson, 1890), *O. (O.) festivum viridanum* (Olsoufieff, 1924), *O. (O.) silenus chicheryi* Arnaud, 2001, *Phanaeus (Notiophanaeus) bispinus* Bates, 1868, *P. (N.) bordoni* Arnaud, 1996 (que aqui é reportado pela primeira vez no Brasil), e *Sulcophanaeus faunus* (Fabricius, 1775). As espécies do gênero *Dendropaemon* não foram incluídas no trabalho por estarem em processo de revisão taxonômica.

Palavras-chave: *Inventário, Amazônia, Escudo das Guianas.*

Introduction

Dung beetles of the subfamily Scarabaeinae are primarily scavengers that feed mostly on carrion, animal excrement and decomposing fruits (Halffter & Matthews 1966). Thus, such insects display a crucial role in the balance of several ecosystems, representing highly informative bioindicators regarding the conservation status of tropical environments (Halffter & Favila 1993). Such a peculiar feeding biology renders to dung beetles enormous ecological importance, acting directly in the fertilization and renewal of the soil, in the biological control of agricultural pests and also as secondary seed dispersal (Nichols *et al.* 2008).

The tribe Phanaeini was introduced by Hope (1838) without further comments, and was defined in more details by Kolbe (1905) who, based on the cup-like shape of the antennal club and lack of protarsi, included in this group the following genera: *Phanaeus* MacLeay, 1819, *Oruscatus* Bates, 1870, *Gromphas* Brullé, 1837, *Bolbites* Harold, 1868, *Dendropaemon* Perty, 1830 and *Megatharsis* Waterhouse, 1891. Gillet (1911) added the genera *Ennearabdus* van Lansberge, 1874a and *Pleronyx* van Lansberge, 1874b (then spelled *Pteronyx*) to Kolbe's (1905) group, formally allocating it as a subtribe of Coprini. Thirteen years later, d'Olsoufieff (1924) removed *Ennearabdus* and *Pteronyx* (*sic*), included *Diabroctis* Gistel, 1857 (as its synonym *Taurocopris* d'Olsoufieff, 1924), *Oxysternon* Castelnau, 1840 and *Tetramereia* Klages, 1907 (then described as new as *Boucomontius* d'Olsoufieff, 1924). In addition, the same author splitted *Phanaeus* into five subgenera: *Phanaeus*, and the new taxa *Sulcophanaeus*, *Coprophanaeus*, *Metallophanaeus* and *Megaphanaeus*. Based on the system proposed by d'Olsoufieff, Edmonds (1972) elevated *Sulcophanaeus* and *Coprophanaeus* to genus level. Furthermore Edmonds (1972) described *Mioxysternon* as a subgenus of *Oxysternon*, and subgenera *Paradendropaemon* and *Coprophanaeoides* for the genus *Dendropaemon*. More recently, Edmonds (1994) described *Notiophanaeus* as a subgenus of *Phanaeus* and Arnaud (2002) described *Pteroxysternon* as a subgenus of *Oxysternon*.

Geographically restricted to the New World, the tribe Phanaeini includes around 160 species and 12 genera allocated in the subtribes Phanaeina and Gromphadina (Cupello & Vaz-de-Mello 2013). Phanaeini systematics is yet in discussion. In the field of alpha taxonomy, taxa of the group have been the subject of recent taxonomic revisions and of much discussion regarding validity of several species and subspecies (Arnaud 1996, 1996b, 1997, 2000, 2001, 2002, 2002b, 2002c, 2004, Edmonds 1994, Edmonds & Zídek 2004, 2010, 2012, Cupello & Vaz-de-Mello 2013, 2013b, Kohlmann & Solís 2012). Phylogenetic studies are scarce and the debate regarding the identity of the tribe is still open. Zunino (1983, 1985) failed to recover Phanaeini as a clade, allocating its 12 genera to the tribe Onitini (Gromphadina [then spelled Gromphina] + (Onitina + Phanaeina)); in contrast, Philips *et al.* (2004) recovered a monophyletic Phanaeini supported by 14 morphological synapomorphies. One less inclusive approach by Price (2007) based on 67 morphological characters suggests that the genera *Phanaeus* and *Oxysternon* are not reciprocally monophyletic. Based on morphological and molecular data, Price (2009) recovers *Phanaeus* as polyphyletic, with representatives of *Coprophanaeus*, *Sulcophanaeus*, and *Oxysternon* nested within its terminals. Finally Tarasov & Génier (2015) recover Phanaeini as monophyletic with the genus *Ennearabdus* appearing as its sister group forming Neotropical clade.

The Brazilian state of Roraima lies on the Guiana Shield, northern South America. In terms of natural landscapes, Roraima is highly heterogeneous; while dense Amazonian forests predominate in the southern portion of the state, open savannah spots locally referred by 'lavrados' are common in central Roraima. In contrast, mountainous formations characterize the northern area of the state, where there is the Pacaraima range, the geographic divisor of the Amazonas and Orinoco basins. Such a geomorphological plasticity is evidently associated to an enormous complexity of microhabitats, rendering Roraima a high biodiversity of animals and plants (IBGE 1977).

According to Vaz-de-Mello (2000), the diversity of dung beetles of Roraima is poorly known; considering all trustworthy records, there are only 47 Scarabaeinae species documented in the state. Nonetheless, considering the ecological importance of the group, the knowledge on the scarab diversity and the availability of tools allowing precise identification of species are crucial to provide proper support to future studies of conservational concern. Herein we provide a detailed inventory of the Phanaeini species occurring in the limits of the Roraima state, presented as a checklist of species containing detailed geographic data, as well as a key to species and an illustrated guide.

Materials and Methods

We examined specimens from the following entomological collections (acronyms in parentheses): Setor de Entomologia da Coleção Zoológica da Universidade Federal de Mato Grosso, Departamento de Biologia e Zoologia, Cuiabá, Mato Grosso, Brasil (CEMT), Coleção de Invertebrados do Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brasil (INPA), and Patrick and Florent Arnaud private collection, Saintry sur Seine, France (CPFA). In addition, we performed an extensive investigation of the literature approaching South American Scarabaeine (species descriptions, taxonomic revisions and regional inventories) computing all trustworthy records attributed to Roraima localities.

Results and Discussion

We reported 13 species of the tribe Phanaeini from localities within the limits of the state of Roraima (Table 1), since the publication of the most recent studies making reference to

Table 1. Checklist of Phanaeini species known to occur in Roraima.

Species	Record
Coprophanaeus (Coprophanaeus) abas (MacLeay, 1819)*	CEMT
Coprophanaeus (Coprophanaeus) dardanus (MacLeay, 1819)	Edmonds & Zídek, 2010; Cupello & Vaz-de-Mello, 2013b; CEMT
Coprophanaeus (Coprophanaeus) gamezi Arnaud, 2002	Edmonds & Zídek, 2010; CEMT; CPFA
Coprophanaeus (Coprophanaeus) jasius (Olivier, 1789)*	CEMT
Coprophanaeus (Megaphanaeus) lancifer (Linnaeus, 1767)*	CEMT
Oxysternon (Oxysternon) conspicillatum conspicillatum Weber, 1801	Arnaud, 2002; CEMT
Oxysternon (Oxysternon) durantoni Arnaud, 1984	Vaz-de-Mello, 1999; CEMT
Oxysternon (Oxysternon) ebeninum (Nevinson, 1890)	Arnaud, 2002; CEMT; CPFA
Oxysternon (Oxysternon) festivum viridanum (Arnaud, 2002)*	CEMT; INPA; CPFA
Oxysternon (Oxysternon) silenus chicheryi Arnaud, 2001	Arnaud, 2001; CPFA
Phanaeus (Notiophanaeus) bispinus Bates, 1868*	CEMT
Phanaeus (Notiophanaeus) bordoni Arnaud, 1996*	CEMT
Sulcophanaeus faunus (Fabricius, 1775)*	CEMT

*= new state records.

Table 2. New records of species of Phanaeini from Roraima, their localities and examined specimens.

Species	Examined specimens from Roraima
Coprophanaeus (Coprophanaeus) abas (MacLeay, 1819)	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 1♂, 3♀♀).
Coprophanaeus (Coprophanaeus) jasius (Olivier, 1789)	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 6♂♂, 11♀♀); V-2009, Andrade (CEMT: 1♀); Cantá, Serra Negra, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 2♂♂, 1♀). Pacaraima, BV8, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 1♂, 2♀♀). Mucajaí, Rio Apiaú, VII-1997 Vaz-de-Mello (CEMT: 2♀♀).
Coprophanaeus (Megaphanaeus) lancifer (Linnaeus, 1767)	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 16♂♂, 10♀♀); V-2009, Andrade (CEMT: 5♂♂, 11♀♀).
Oxysternon (Oxysternon) festivum viridanum (Arnaud, 2002)	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 7♂♂, 15♀♀); V-2009, Andrade (CEMT: 15♂♂, 62♀♀); Boa Vista, mata, 23-XI-2008, França (CEMT: 2♀♀).
Phanaeus (Notiophanaeus) bispinus Bates, 1868	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 1♀).
Phanaeus (Notiophanaeus) bordoni Arnaud, 1996	**BRASIL: Roraima:** Amajari, Ilha de Maracá, V-2009, Andrade (CEMT: 1♂).
Sulcophanaeus faunus (Fabricius, 1775)	**BRASIL: Roraima:** Amajari, Ilha de Maracá, IX-1996, Ribeiro & Vaz-de-Mello (CEMT: 1♂).

Roraima (Vaz-de-Mello 2000, Arnaud 2002, Edmonds & Zídek 2010, Cupello & Vaz-de-Mello 2013b).

Vaz-de-Mello (1999) mentioned *Oxysternon (O.) durantoni* as the first Phanaeini record to Roraima; two years later, Arnaud (2001) described *O. (O.) silenus chicheryi* from the confluence of the rivers Negro and Branco. Arnaud (2002) added *O. (O.) conspicillatum conspicillatum*, *O. (O.) ebeninum* and *O. (Mioxysternon) spiniferum spiniferum* as state records; however, the latter record is an error due to confusion of the abbreviations of the states Rondônia (RO) and Roraima (RR) (FZVM, personal observation in CPFA). In a taxonomic revision of *Oxysternon*, Edmonds & Zídek (2004) synonymized *O. festivum festivum* and *O. f. viridanum* mentioning one specimen from Roraima. In the same year, Arnaud (2004) resurrected *O. f. viridanum*. After examining specimens from the same localities that based Edmond & Zídek's (2004) decisions, we concluded that their record of Roraima shall be attributed to *O. f. viridanum* (*sensu* Arnaud, 2004). Edmonds & Zídek (2010) added *Coprophanaeus (C.) dardanus* and *C. (C.) gamezi* as state records. Finally Cupello & Vaz-de-Mello (2013) mention again *C. (C.) dardanus*.

In the holdings of CEMT, we recovered specimens of *Coprophanaeus (C.) abas, C. (C.) jasius, C. (Megaphanaeus) lancifer, Oxysternon (Oxysternon.) festivum viridanum, Phanaeus (Notiophanaeus) bispinus, P. (N.) bordoni and Sulcophanaeus faunus*, all representing new state records (Table 2). *Oxysternon (Mioxysternon) spiniferum, Phanaeus chalcomelas, P. cambeforti*, all widespread in Amazonia, were not recorded in our samples; nonetheless, we included these species in our identification key, considering its potential occurrence in Roraima, as well as the Phanaeini genera *Gromphas* and *Dendropaemon*.

Key to the species of Phanaeini from Roraima

1. Basal antennomere of antennal club not concave apically, two apical antennomeres not embraced by basal antennomere and clearly visible… ***Gromphas* Brullé, 1837** (Figure 3GJ)

   Basal antennomere of antennal club concave apically, two apical antennomeres embraced by basal antennomere (Figure 3F) … 2
2. Mesotarsus and metatarsus with two or three tarsomeres (Figure 3M) … ***Dendropaemon* Perty, 1830**

   Mesotarsus and metatarsus with five tarsomeres … 3
3. Clypeus anteriorly without strong emargination; if toothed, teeth external with respect to clypeal margin. Tooth of protibiae rounded … 4

   Clypeus with two acute teeth separated by a strong "V"-shaped emargination, and with external emarginations separating them from adjacent clypeal border, producing the two acute external lobes. Protibiae with four strongly pronounced teeth… ***Coprophanaeus* d'Olsoufieff, 1924** (Figure 1) … 6
4. Metasternum without spiniform process … 5

   Metasternum with curved spiniform process extending between apexes of procoxae… ***Oxysternon* Castelnau, 1840** (Figure 2C) … 10
5. Body very large (superior to 25 mm) and with black color. Anterior margin of pronotum (circumnotal ridge) not interrupted behind each eye … ***Sulcophanaeus faunus* (Fabricius, 1775)** (Figure 3KL)

   Body size less than 25 mm, dorsally with brown color or black with green or blue metallic reflections. Anterior margin of pronotum (circumnotal ridge) interrupted behind each eye … ***Phanaeus (Notiophanaeus)* Edmonds, 1994** … 15
6. Very large, usually longer than 28 mm. Elitral interstriae with strong transverse carinae. Dorsum color metallic, predominantly blue. Cephalic horn long and slightly tapering towards apex … ***Coprophanaeus (Megaphanaeus) lancifer* (Linnaeus, 1767)** (Figure 1IJ)

   Small to medium size, rarely exceeding 28 mm. Elitral interstriae weakly convex, without strong sculpture. Varied

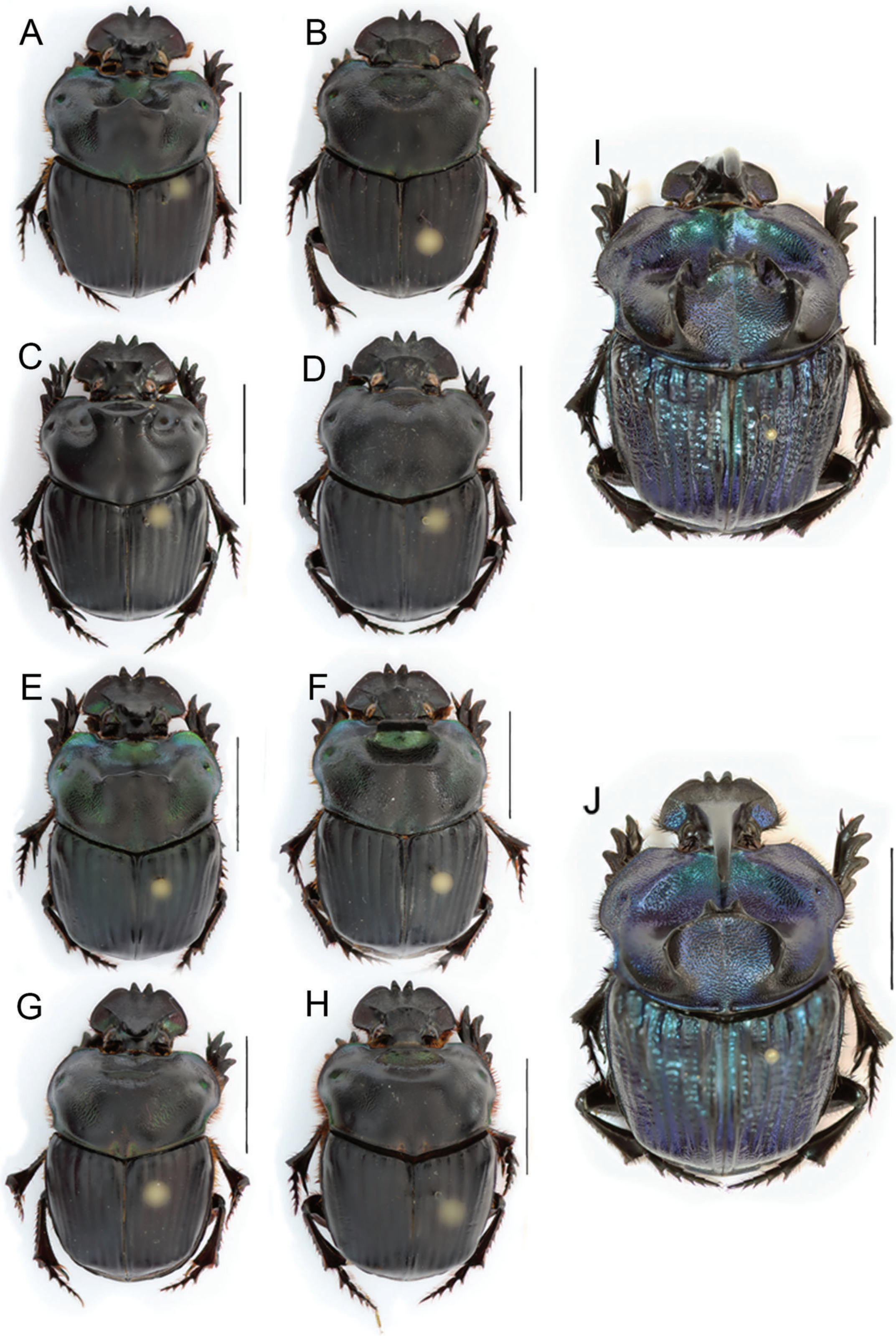

Figure 1. Species of the genus *Coprophanaeus* reported from Roraima: A - *C. abas* (male), B - *C. abas* (female), C - *C. dardanus* (male), D - *C. dardanus* (female), E - *C. gamezi* (male), F - *C. gamezi* (female), G - *C. jasius* (male), H - *C. jasius* (female), I - *C. lancifer* (male), J - *C. lancifer* (female). Scale bars = 10 mm.

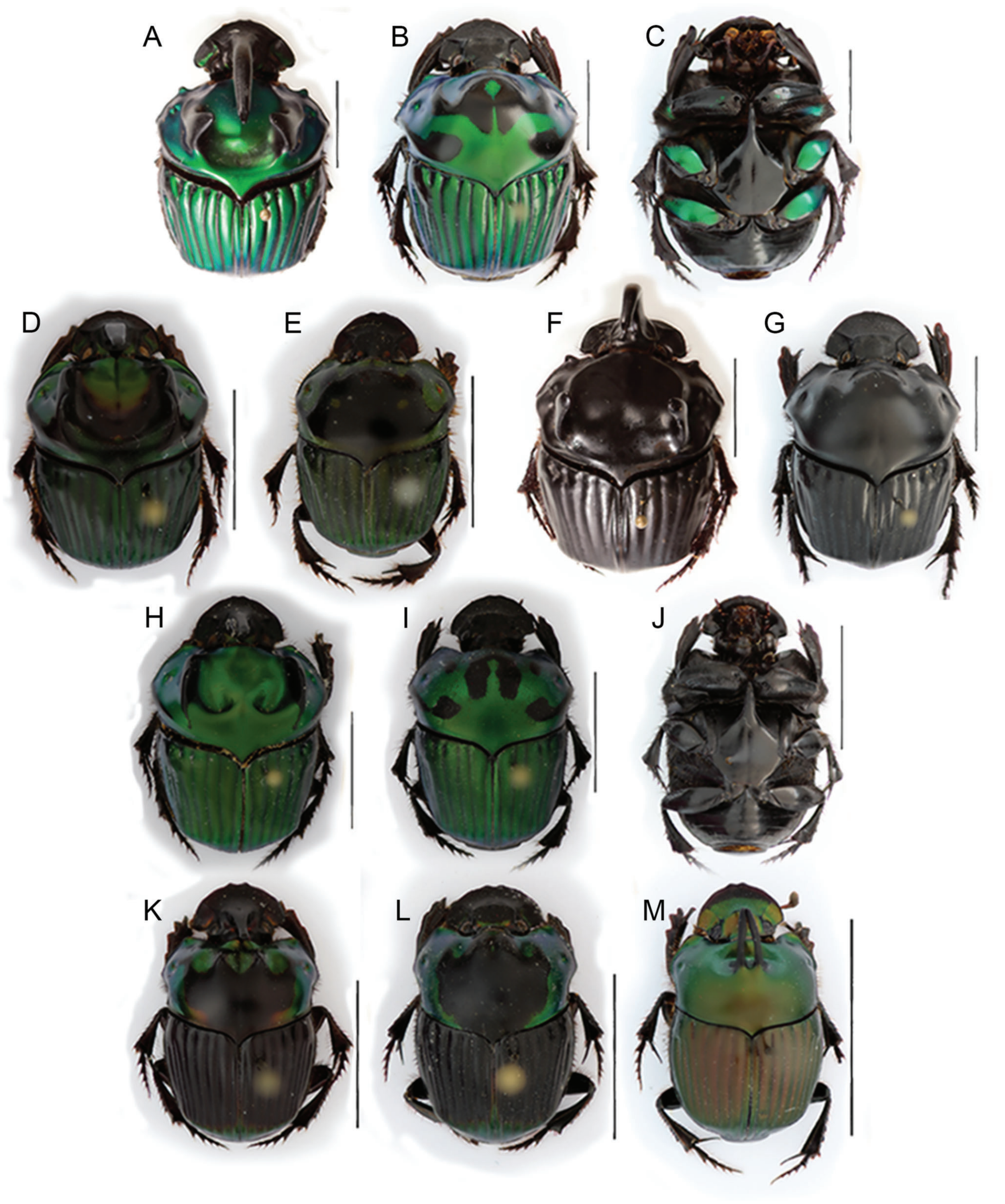

Figure 2. Species of the genus *Oxysternon* reported from or potentially occurring in Roraima: A - *O. conspicillatum conspicillatum* (male), B - *O. conspicillatum conspicillatum* (dorsal view, female), C - *O. conspicillatum conspicillatum* (ventral view, female), D - *O. durantoni* (male), E - *O. durantoni* (female), F - *O. ebeninum* (male), G - *O. ebeninum* (female), H - *O. festivum viridanum* (male), I - *O. festivum viridanum* (dorsal view, female), J - *O. festivum viridanum* (ventral view, female), K - *O. silenus chicheryi* (male), L - *O. silenus chicheryi* (female), M - *O. spiniferum spiniferum* (male). Scale bars = 10 mm.

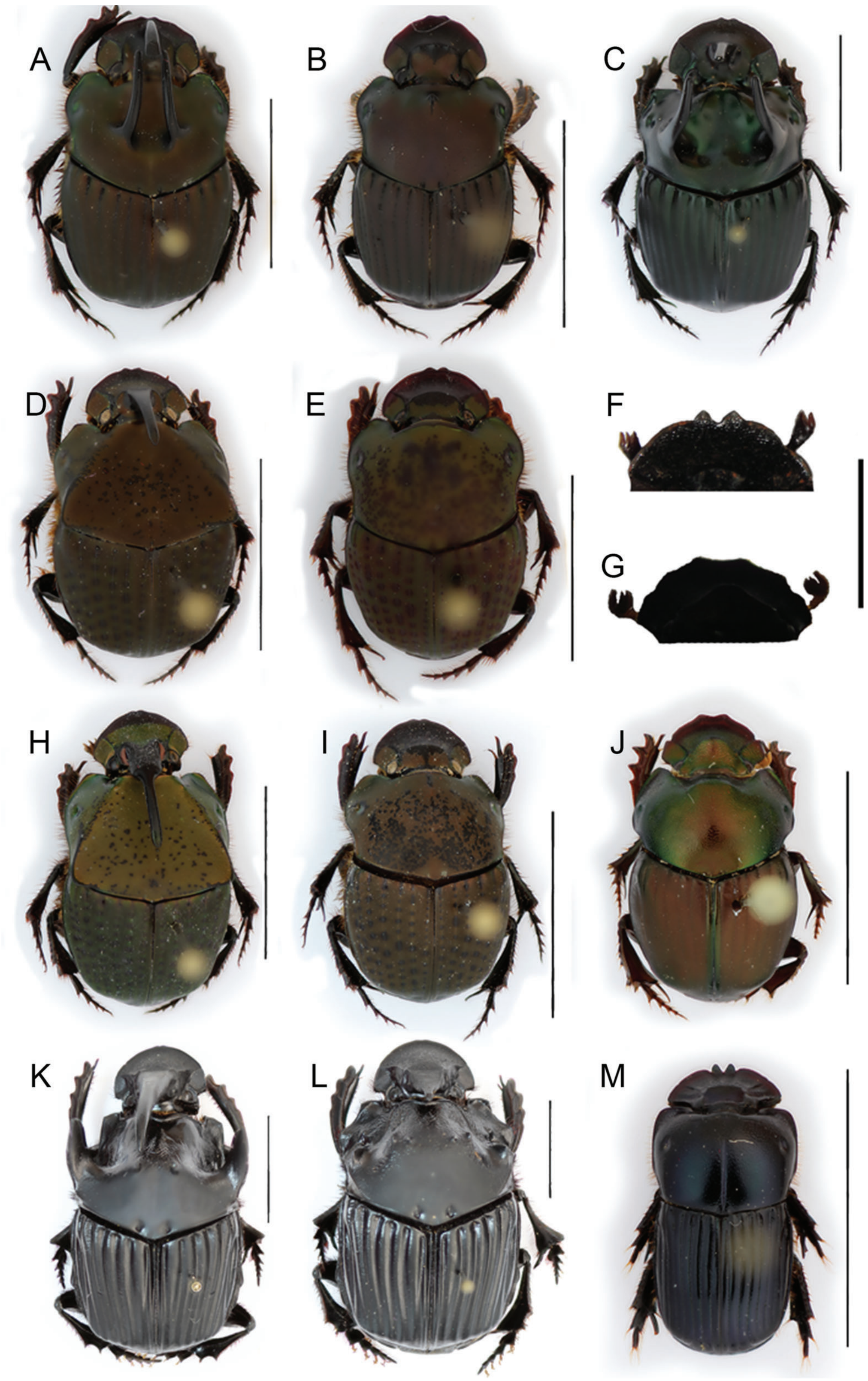

Figure 3. Species of the genera *Dendropaemon, Gromphas, Phanaeus* and *Sulcophanaeus* reported from or potentially occurring in Roraima: A - *Phanaeus bispinus* (male), B - *P. bispinus* (female), C - *P. bordoni* (male), D - *P. cambeforti* (male), E - *P. cambeforti* (female), F - anterior part of head of *Dendropaemon viridipennis*, G - anterior part of head of *Gromphas* sp., H - *Phanaeus chalcomelas* (male), I - *P. chalcomelas* (female), J - *Gromphas aeruginosa*, K - *Sulcophanaeus faunus* (male), L - *S. faunus* (female), M - *Dendropaemon* sp. Scale bars = 10 mm.

coloration, but elytra in the middle and posterior part of pronotum always black. Male cephalic horn laminate… ***Coprophanaeus (Coprophanaeus)* d'Olsoufieff, 1924** … 7

7. Anterior margin of pronotum (circumnotal ridge) interrupted behind each eye. Frontoclypeal carina of males rectangular, with two horns in extremes sides. Pronotum of males with strong bilobed projection, with an oval concavity at each side, below it; anterolateral portions strongly deep … ***Coprophanaeus (Coprophanaeus) dardanus* (MacLeay, 1819)** (Figure 1CD)

   Anterior margin of pronotum (circumnotal ridge) not interrupted behind each eye. Frontoclypeal carina of males with trituberde horn. Pronotum of males with either one or three apical tubercles in central projection, anterolateral portions not deep … 8
8. Posteromedian region of pronotum strongly punctured, especially between the fossae; pronotum of large males with three tubercles almost aligned; tubercles of females pronotum not distinct, only with a high ridge in anteromedian region. Species associated with savannah formations … ***Coprophanaeus (Coprophanaeus) gamezi* Arnaud, 2002** (Figure 1EF)

   Posteromedian region of pronotum weakly punctured, smooth between the fossae. Species associated with forest formations, sympatrical … 9
9. Pronotum of large males with central tubercle longer than lateral tubercles, triangularly expanded with an obtuse tip; in females anteromedian region of pronotum with a high transverse carina, rectangular in posterior view … ***Coprophanaeus (Coprophanaeus) abas* (MacLeay, 1819)** (Figure 1AB)

   Pronotum of large males with central tubercle not much larger than others, not triangularly expanded, small and with acute tip; in females anteromedial region with a high transverse carina, trapeziform in posterior view … ***Coprophanaeus (Coprophanaeus) jasius* (Olivier, 1789)** (Figure 1GH)
10. Specimens longer than 15 mm. Clypeus with one transversally oriented ventral carina… ***Oxysternon (Oxysternon)* Castelnau, 1840 … 11**

    Specimens up to 13 mm long. Clypeus without ventral carina … ***Oxysternon (Mioxysternon) spiniferum* Castelnau, 1840** (Figure 2M)
11. Elytra bicolored, dorsally black but with metallic posteriorad and laterad. Pronotum green with red metallic reflexes, generally with one black spot in its median region. Pronotum of males with two small tubercles … ***Oxysternon (Oxysternon) silenus chicheryi* Arnaud, 2001** (Figure 2KL)

    Elytra unicolored, entirely green (except for striae that appear black in first glance) or black. Large males usually with two large tubercles in pronotum … 12
12. Femora ventrally green. Elytra and pronotum also green, with black spots in female pronotum. Cephalic horn of males usually large and curved towards the median region of pronotum. Pronotum of males with one median depression forming two lateral carinae, and in the apex with two large tubercles curved towards the middle … ***Oxysternon (Oxysternon) conspicillatum conspicillatum* (Weber, 1801)** (Figure 2ABC)

    Middle and posterior femora ventrally black, other characters variable … 13
13. Coloration uniformly black. Cephalic horn of males curved towards the median region of pronotum. Pronotum of males flat, with two large tubercles curved towards the middle region of pronotum … ***Oxysternon (Oxysternon) ebeninum* (Nevinson, 1890)** (Figure 2FG)

    Coloration metallic, at least elytra green, other characters variable … 14
14. Size usually between 15 and 19 mm. Pronotum and elytra always distinct in color, pronotum usually red at least in anterior region (black in the middle), elytra green with dark striae. Posterior region of abdomen metallic green … ***Oxysternon (Oxysternon) durantoni* Arnaud, 1984** (Figure 2DE)

    Size usually between 18 and 25 mm. Pronotum and elytra with the same color, except for black spots in the pronotal disc of females and small males. Ventral region totally black, including the posterior region of abdomen … ***Oxysternon (Oxysternon) festivum viridanum* d'Olsoufieff, 1924** (Figure 2HIJ)
15. Disc of pronotum of males never flattened, but either convex or strongly concave, with two projections directed towards the anterior region (Figure 3A) … 16

    Disc of pronotum of males flattened, without projections (Figure 3D) … 17
16. Color dorsally brown. Pronotum of males with two median tubercles anteriorly directed. Elytra with striae strongly punctured … ***Phanaeus (Notiophanaeus) bispinus* Bates, 1868** (Figure 3AB)

    Dark coloration, with green or blue reflex. Pronotum of males with two lateral tubercles, directed medially and then anteriorly. Elytral striae with very fine punctures if any … ***Phanaeus (Notiophanaeus) bordoni* Arnaud, 1996** (Figure 3C)
17. Anteromedial angle of metasternum capped. Basal third of cephalic horn of males abruptly expanded laterally. Pronotum of males with disperse black punctures; pronotum of females with a concavity, bearing an small anterior tubercle, a bigger posterior tubercle, and at each side with one lateral tubercle … ***Phanaeus (Notiophanaeus) chalcomelas* (Perty, 1830)** (Figure 3HI)

    Anteromedial angle of metasternum smooth. Cephalic horn of males not abruptly expanded. Pronotum of males with black punctures concentrated in posteromedian region; pronotum of females lacking concavity, with three central tubercles disposed approximately in a transverse row, sometimes the central one more anterior than lateral ones … ***Phanaeus (Notiophanaeus) cambeforti* Arnaud, 1982** (Figure 3DE)

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How climate change can affect the distribution range and conservation status of an endemic bird from the highlands of eastern Brazil: the case of the Gray-backed Tachuri, *Polystictus superciliaris* (Aves, Tyrannidae)

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HOFFMANN, D., VASCONCELOS, M.F., MARTINS, R.P. **How climate change can affect the distribution range and conservation status of an endemic bird from the highlands of eastern Brazil: the case of the Gray-backed Tachuri, *Polystictus superciliaris* (Aves, Tyrannidae).** Biota Neotropica. 15(2): e20130075. http://dx.doi.org/10.1590/1676-06032015007513

Abstract: The Gray-backed Tachuri (*Polystictus superciliaris*) is a Tyrannidae restricted to eastern Brazilian highlands. Its population and range are still thought to be declining mainly due to habitat loss, caused by land use. We evaluated the impacts on its range (increase or decrease, displacement in latitude and altitude), considering possible effects caused by inappropriate land use and climatic changes. For this purpose, we modeled its current range and estimated its overlap between the predicted area and future scenarios. We also analyzed the efficiency of the Brazilian reserves to the species' protection. The range established by the Maxent model was 76.1% lower than that available in the literature and presented a decrease in the future. Range contraction for the periods under consideration ranged from 22.5% to 77.3%. The distribution center shifts to the southwest (from 102.5 km to 275.4 km) and to higher elevations (1,102 m to 1,428 m). From the predicted range, 20% are under some kind of human occupation. The Brazilian reserves partially protect the species, with only 12% of its range, from the 44.2% expected. Based on these predictions, and depending on the species' dispersal ability and adaptation, it may become vulnerable in the period of 2080. This study demonstrates that the most important areas for maintaining populations of *P. superciliaris* now and in the future are those located in the 'Iron Quadrangle', especially the Serra da Gandarela, where it was partially protected by the recently decreed Gandarela National Park. This region should receive special attention because it is strongly threatened by iron mining in areas relevant for conservation located outside this reserve.

Keywords: *Climate change, Evaluation reserve efficiency, Espinhaço range, Species distribution model.*

HOFFMANN, D., VASCONCELOS, M.F., MARTINS, R.P. **Como as mudanças climáticas podem afetar a área de distribuição e o status de conservação de uma ave endêmica das montanhas do leste do Brazil: o caso do papa-moscas-de-costas-cinzentas, *Polystictus superciliaris* (Aves, Tyrannidae).** Biota Neotropica. 15(2): e20130075. http://dx.doi.org/10.1590/1676-06032015007513

Resumo: O papa-moscas-de-costas-cinzentas (*Polystictus superciliaris*) é uma espécie de Tyrannidae endêmica dos topos de montanha do leste do Brasil. Sua população e área de distribuição estão em declínio principalmente devido à perda de habitat causada pelo uso inadequado da terra. Nós avaliamos os impactos sobre sua distribuição (aumento ou diminuição, deslocamento em latitude e altitude), considerando os possíveis efeitos causados pelo uso do solo e pelas mudanças climáticas. Para esse propósito, modelamos a distribuição atual e avaliamos a sobreposição entre a área predita e os cenários futuros. Também avaliamos a eficiência das Unidades de Conservação brasileiras para a proteção da espécie. A área de distribuição estimada por meio do programa Maxent foi 79,1% menor que a área encontrada na literatura, apresentando uma tendência a diminuição no futuro. Foi projetada uma contração de 22,5% a 77,3% da área de distribuição atual para o futuro. O centro da área de distribuição deslocou-se para o sudeste (de 102,5 a 275,4 km) e para áreas com alta elevação (1.102 m a 1.428 m). Da área projetada, 20% encontra-se sob algum tipo de ocupação humana. As Unidades de Conservação brasileiras protegem parcialmente a espécie, com somente 12% de sua distribuição quando o esperado seriam 44,2%. Baseado nas projeções e, dependendo das habilidades de dispersão e adaptação da espécie, ela pode se tornar vulnerável no período de 2080. Este estudo demonstrou que as áreas mais importantes para a manutenção de *P. superciliaris* na atualidade e em períodos futuros situam-se no Quadrilátero Ferrífero, especialmente na Serra da Gandarela, onde parte foi recentemente decretada como Parque Nacional da Gandarela. Essa região deve receber atenção especial por ser altamente ameaçada pela exploração do minério de Ferro e por áreas relevantes continuarem desprotegidas fora da abrangência do novo Parque.

Palavras-chave: *Mudanças climáticas, Avaliação da eficiência de Reservas, Cadeia do Espinhaço, Modelos de distribuição de espécies.*

Introduction

Current climatic models predict global warming during the present century (IPCC 2007b). It is likely that the ranges of many species will change drastically (IPCC 2007a). Recent studies have shown that several species are responding to these changes and this pattern tends to increase in the future (e.g. Hughes 2000, Parmesan & Yohe 2003). Thus, it is expected that these changes will also increase the threat to some species, especially those living at high latitudes and elevations (Millennium Ecosystem Assessment 2005). In this case, largest impacts of climate change are predicted to occur in the high mountain ranges, for example, in the Alps (Beniston et al. 1997, Hughes 2000, Sérgio 2003). This would occur because species living in mountains tend to be more sensitive to climatic changes and present limited ability to adjust their ranges because of the decreasing of available surface with the increasing of elevation (Thuiller et al. 2005, Rull & Vegas-Vilarrúbia 2006, Pauli et al. 2007).

In this way, it is essential to predict effects and potential management strategies for these species by developing practices aiming to measure how they can be affected by these changes (Jiguet et al. 2010). Aiming the projection of the future suitable range of several species and possible impacts of climatic change on them, several modeling algorithms have been used to define the relationship between the current range of species and the current climatic variables (Thuiller et al. 2005, Heikkinen et al. 2006, Virkkala et al. 2008).

Several authors have assessed the potential impacts of climate change on Neotropical birds (e.g. Anciães & Peterson 2006, Nunes et al. 2007, Marini et al. 2009b, a, Marini et al. 2010).Nevertheless, studies focusing birds endemic to high-altitude areas are very scarce and restricted to the Andean region (e.g. Graham et al. 2010, Şekercioglu et al. 2012).

In this respect, eastern Brazilian mountains are located between two important global and highly threatened hotspots: the Atlantic Forest and the Cerrado (Silva & Bates 2002, Mittermeier et al. 2004). These mountains are also considered important centers of diversity and endemism of plants (Giulietti et al. 1997, Safford 1999) and animals (Rodrigues 1988, Stattersfield et al. 1998, Vasconcelos 2008). One of these endemic species is the Gray-backed Tachuri (*Polystictus superciliaris*), a bird from the family Tyrannidae, which occurs from central Bahia state to northern São Paulo state (Vasconcelos et al. 2003, Vasconcelos 2008). This species lives in the 'campos rupestres' (rocky fields) and 'campos de altitude' (high altitude grasslands), between 950 m and 1,950 m (Sick 1997, Stattersfield et al. 1998, Vasconcelos et al. 2003). Gray-backed Tachuri populations are thought to be declining due to its restricted range associated to habitat loss (Stattersfield et al. 1998, Vasconcelos et al. 2003, BirdLife International 2014). Nevertheless, the species' known range presented in the basic literature and used to infer its current conservation status (see Ridgely & Tudor 2009) does not include several localities where it has recent confirmed records (Vasconcelos et al. 2003, Vasconcelos 2008), and includes many areas where conditions are not propitious to its occurrence (e.g., lowlands, forests, and degraded areas), based on our field observations. This is due to the methodology employed by those authors, which basically consists on the union of localities (points) where the species has been recorded, which creates a range. This usually includes deviations of species' ranges, because it is restricted to mountaintops, without records in adjacent lowlands. For an example in the case of the Gray-backed Tachuri, compare the figure with species' range presented by Ridgely & Tudor (2009) to figure 5 of Vasconcelos (2008).

For species with restricted ranges, including most of the mountaintops endemics, habitat loss is the main factor influencing populations decline and their vulnerabilities (Davies et al. 2009). Knowledge on the impacts of climatic changes and habitat loss on such species is essential to understand how they may persist in the future, specially in regions facing rapid socio-economic development (Pressey et al. 2007), such as Eastern Brazil. Thus, range assessment is important for endemic species, such as the the Gray-backed Tachuri, for which there is little information and, therefore, is likely to become threatened in the future. Furthermore, this approach is also important to assess its conservation status (Anderson & Martínez-Meyer 2004, Hernandez et al. 2006) and also to determine its actual level of threats and protection (Fuller et al. 2006). In this context, such procedures may contribute to the correct management and successful application of resources for conservation, which are usually scarce.

Under this perspective, we inferred the current and the future ranges with suitable conditions for the Gray-backed Tachuri, in order to assess possible impacts of climatic changes and find new areas with favorable conditions for its occurrence outside its known range, which can be used to guide the application of resources for its conservation. We also evaluated the percentage of its range that coincides with current protected areas (based on available database of reserves decreed until 2011), to determine the need of investments in its protection and to identify possible new areas for its conservation, since it is possible that the species is not fully protected by not occurring in several reserves. Thus, we expect to provide new information for the protection of the Gray-backed Tachuri and its habitat preservation, in order to prevent that this endemic bird will be among the endangered species in the near future.

Materials and Methods

1. Species occurrence locations

In order to determine the localities of occurrence for the Gray-backed Tachuri, we used records obtained by specimens deposited in museums, literature review and our own field records (see Vasconcelos 2008, Vasconcelos & Rodrigues 2010 for sources). Geographic coordinates from museum specimens were obtained from the collection sites listed in their original labels or based on Paynter Jr. & Traylor Jr. (1991) and Vanzolini (1992). All records with geographic coordinates were plotted within a grid of 30" cells (~0.833 x 0.833 km^2). Duplicate records within a single cell were removed.

2. *Environmental dataset and climatic change scenarios*

We discarded variables highly correlated and used the six remainder bioclimatic variables of temperature and precipitation for projections of current and future ranges with suitable conditions. These variables were: minimum temperature of the coldest month, maximum temperature of the warmest month, mean annual temperature, annual precipitation, precipitation of the driest month and precipitation of the wettest month. The dataset was obtained from WorldClim (Hijmans et al. 2005), based on interpolations of observed data, representative of 1950-2000. We also used three topographic variables (slope, aspect and compound topographic index), obtained from the database of the US Geological Survey's Hydro1k base 'http://eros.usgs.gov/'). Soil data was obtained from FAO (1998). Vegetation layers were not included in the models because they are not available for future scenarios. All variables used for species distribution model (current and future periods) were standardized to the resolution of 30" over into the Brazilian's political limits.

For future projections, we used the same variables for each period (2020, 2050 and 2080), by considering three General Circulation Models of gases (GCMs) (CCMA, HADCM3 and CSIRO) and two scenarios of the Special Report Emissions Scenarios (SRES) of the IPCC (2007a) (A2a e B2a), which reflect the potential impacts of different possible demographic, socio-economic and technological developments in the emission of greenhouse gases.

3. *Distribution modeling*

We used Maxent version 3.2.19 with the default setting (Phillips et al. 2006) to model current and future potential suitable ranges for the Gray-backed Tachuri. The projection of current distribution was generated using 75% of occurrence records randomly selected and evaluated with the remaining 25%. The models were evaluated using an area under the relative operating characteristic curve (AUC/ROC) (Fielding & Bell 1997). The curve considers the rate of failure in relation to the predicted fractional area. The data were divided this way five times and it was calculated the average AUC with a more robust estimate of the predictive performance. We used all available data to obtain the final distribution range projection.

For the projection of the suitable range for the Gray-backed Tachuri, in each of the three future periods, we obtained a consensus among six projections (three GCMs x two SRES scenarios), maximizing the accuracy and achieving a central trend. To transform the probabilistic ranges (present and future) in a binary map of presence/absence, we selected a threshold value that would encompass all sites (Pearson et al. 2007). Thus, we considered the possibility of 5% error in the forecast, because, occasionally, some records could represent individuals outside of its optimal niche or in transitional areas. All cells below the threshold value were set to '0' and kept the probability of occurrence of the above. The area was calculated by summing all pixels that presented the average probability of conditions higher than '0' among the six projections of presence and absence. Finally, we removed from the predicted areas the overlapping lands already converted into intensive agriculture, urban areas and water bodies, using a land cover map presented by Eva et al. (2002).

In order to analyze the responses of the Gray-backed Tachuri to the climatic changes based on its range, we evaluated the extension and central point (centroid of its range) of predicted range in future periods. The distribution range was calculated by summing all pixels above the threshold value. To assess whether there was range shift, we calculated the distance between the centers of current and future ranges.

For each period, we estimated the ratio between the size of the future and current range, as a measurement of potential impact of climatic changes. This estimate assumes that the species is able to disperse from its present range to a predicted range in the future, without any environmental or physiological impairment (hypothesis of total dispersion). We also calculated the percentage of overlap of the range of each future period in relation to the present, which assumes that the species is unable to disperse into new areas and may occupy only those areas with favorable current conditions and that are predicted in the future as climatically favorable (hypothesis of null dispersion).

To assess whether there was an altitudinal shift, we calculated the difference between the average elevation of the future range projected for each period and the current projection. In this case, the altitude was extracted from all pixels of the predicted range by overlapping a relief map from the US Geological Survey's Hydro1k base (http://eros.usgs.gov/) for subsequent calculation of its average.

4. *Reserves data set and species representation*

Data on the distribution of protected areas in Brazil were obtained from the databases available in ICMBio (http://www4.icmbio.gov.br). This database consists of about 1,000 federal, state and municipal reserves, implemented until 2006 (equivalent to reserves of category II of IUCN) (MMA 2006). We performed gap analyzes, considering the projection of the current suitable range for the Gray-backed Tachuri and projections for future periods. For each period, an analysis was performed with all reserves. The predicted suitable range was overlapped with reserves distribution and we calculated the percentage of this range found in the protected area. We followed the methods proposed by Rodrigues et al. (2004) and Catullo et al. (2008) in order to identify a representation target (Scott et al. 1993), depending on the extent of the predicted suitable range for the species. Representation is the amount of the range of a species within protected areas, a parameter commonly used in conservation plans to evaluate the need for protection. Analyses were performed considering the following representation targets: i) species with restricted range (area of potential presence less than 1,000 km^2), which should be protected in 100% of its range; ii) widespread species (area of potential presence larger than 250,000 km^2), which should be protected in 10%; and iii) species with an area of potential presence of more than 1,000 km^2 and less than 250,000 km^2, which should have a representation target obtained by interpolation between the two extremes, using a linear regression of log-transformed area of potential presence

(Rodrigues et al. 2004). A total gap occurs when a species is not represented in any reserve, a partial gap occurs when a species is represented only partially, and the species is considered covered when the representation target is fully met (Catullo et al. 2008). Representation under climate change was evaluated considering total and null capacity of dispersion (for each scenarios, present, 2020, 2050 and 2080).

Results

To model the potential distribution, we used 41 spatially independent points of occurrence of the Gray-backed Tachuri. The accuracy of the distribution model in predicting favorable conditions for the presence of the Gray-backed Tachuri was better than random. The AUC mean, based on test data generated from five models, was 0.993 (SD 0.007) and the selected cumulative threshold was 57. The omission range of the test data was 0.08 (SD 0.11) and the fractional predicted area was 0.003.

1. Current distribution

The predicted current distribution of the Gray-backed Tachuri, with favorable conditions, was 30,745 km^2 (Figure 1). This range was 76.1% lower than that presented by the literature (129,012 km^2) (Ridgely & Tudor 2009) (Figure 2a) and 90.2% lower than that used to it conservation status assessment (314,000 km^2) (BirdLife International 2014). The range with natural vegetation currently available for the species was 25,240 km^2, not considering those areas converted by intensive agriculture, urban areas and water bodies (5,505 km^2).

2. Distribution in future scenarios

The suitable range for the Gray-backed Tachuri exhibited a contraction for future periods in relation to present range with favorable conditions. Under the null hypothesis of dispersion for the 2080 period, only a fifth of the current range remains (Figures 2b-d). Considering the hypothesis of total dispersion, the decrease in the current distribution for 2080 was of 64.7% (Table 1). Under the null hypothesis of dispersion, the range decrease was of 77.3%.

The range shift in future periods showed a gradual increase until 2080. This displacement was of 275.4 km under the total dispersion hypothesis and of 250.7 km considering the null hypothesis of dispersion. In addition, we obtained an altitudinal shift average of 325.5 m and 275.1 m, considering the two hypotheses, respectively (Table 1). For all future periods, the distribution center showed a shift toward the southwest (Figures 2b-d).

3. Coverage by the National System of Conservation Units (SNUC)

The predicted area with favorable conditions for the presence of the Gray-backed Tachuri reached 27 to 42 reserves (current and future scenarios). Those reserves protect a total area that ranges from 7,248 km^2 to 9,635 km^2, depending on the specific scenario (Table 2). Nevertheless, only 49% of this area presented suitable environments for the species' occurrence (Table 2) and represented only 11.7% of the predicted current range, from an expected range of at least, 44.2% (Table 1).

Similarly, in future periods, it was observed the loss of favorable conditions for up to eight reserves, considering the null hypothesis of dispersion, and the addition of up to 17 new reserves, if we consider the hypothesis of total dispersion (Table 2). Among the reserves that had favorable current conditions (27), 19 remained, at least partially, favorable in all future scenarios. Among the 13 reserves predicted by the model that have records for the species, 12 partially remained suitable conditions for all future periods (Table 3). The majority of the reserves showed a decrease in their areas of potential occurrence for the species in relation to the current scenario. Most affected areas in future scenarios are located in the northern Minas Gerais and Bahia, as is the case of the Morro do Chapéu State Park (Bahia), Biribiri State Park and Sempre Vivas National Park (Minas Gerais), which showed extinction conditions for 2080 (Table 3).

Discussion

1. Current predicted distribution

Recents records support our projections of current suitable range for the Gray-backed Tachuri, considering that these new records made on Caparaó National Park (Costa 2011) and Serra dos Órgãos National Park (Rennó 2012) were not used in the models, and were predicted by these (Figures 2b-d, fine and isolated areas).

The predicted current suitable range for the Gray-backed Tachuri showed to be 75% lower than that presented by the literature (Ridgely & Tudor 2009) (Figure 2a). Probably the range of this species will prove to be even lower if vegetation is considered. This is because some sites where the soil is deeper and more fertile are covered by forest patches, and because deforestation is a dynamic process that can negatively affect the extent of projected occurrence for future scenarios. This difference may be related to the methods employed by these authors, which are similar to the minimum convex polygon (Odum & Kuenzler 1955), that consists in the union of all points of occurrence in a polygon, not taking into account the habitat preferences of species. Thus, many areas with unfavorable conditions may be considered favorable. Both hatched areas presented in Figure 2a can be explained because there were only two isolated sets of points at the time of delimitation of the specie's range, which suggested two disjunct populations. Nevertheless, recent surveys have shown that this species is distributed throughout the entire Espinhaço Range, from its southern portion 'Iron Quadrangle' to its northern end, known as the Chapada Diamantina, and also in the Serra da Canastra, to the west, and part of Serra da Mantiqueira and Serra do Mar Ranges, to the south (Vasconcelos et al. 2003, Vasconcelos & D'Angelo Neto 2007, Vasconcelos 2008, Vasconcelos & Rodrigues 2010). Costa et al. (2010) reported a genetic isolation between specimens of two areas that in current predicted range are isolated by physical barriers corresponding to lowland areas. In this context and based on the current predicted range we were able to identify seven possible populations may be isolated in the eastern Brazilian highlands by lowland barriers (Figure 1). Therefore, further phylogeographic studies and information on the ability of transposition of unfavorable areas by the species are necessary to assess if there is interruption of gene flow by these other possible barriers.

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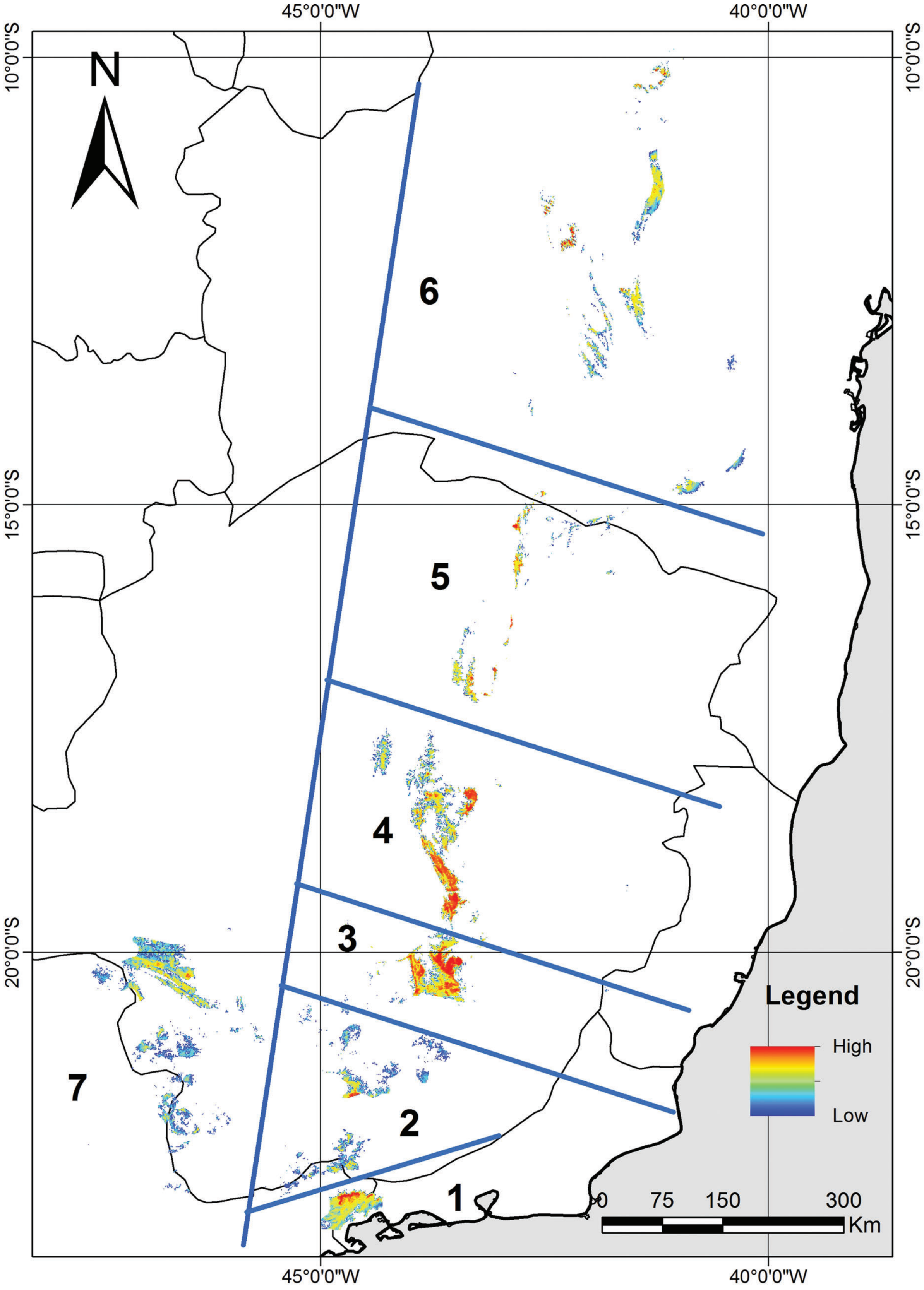

Figure 1. Current predicted distribution of the Gray-backed Tachuri (*Polystictus superciliaris*). The color scale represents the probability of favorable conditions within each pixel above the threshold of sensitivityspecificity, from lower (light blue) to highest (red). White areas are below the favorable conditions. Lines represent possible geographical natural barriers to the dispersal of the species and probably dividing isolated subpopulations (numbers).

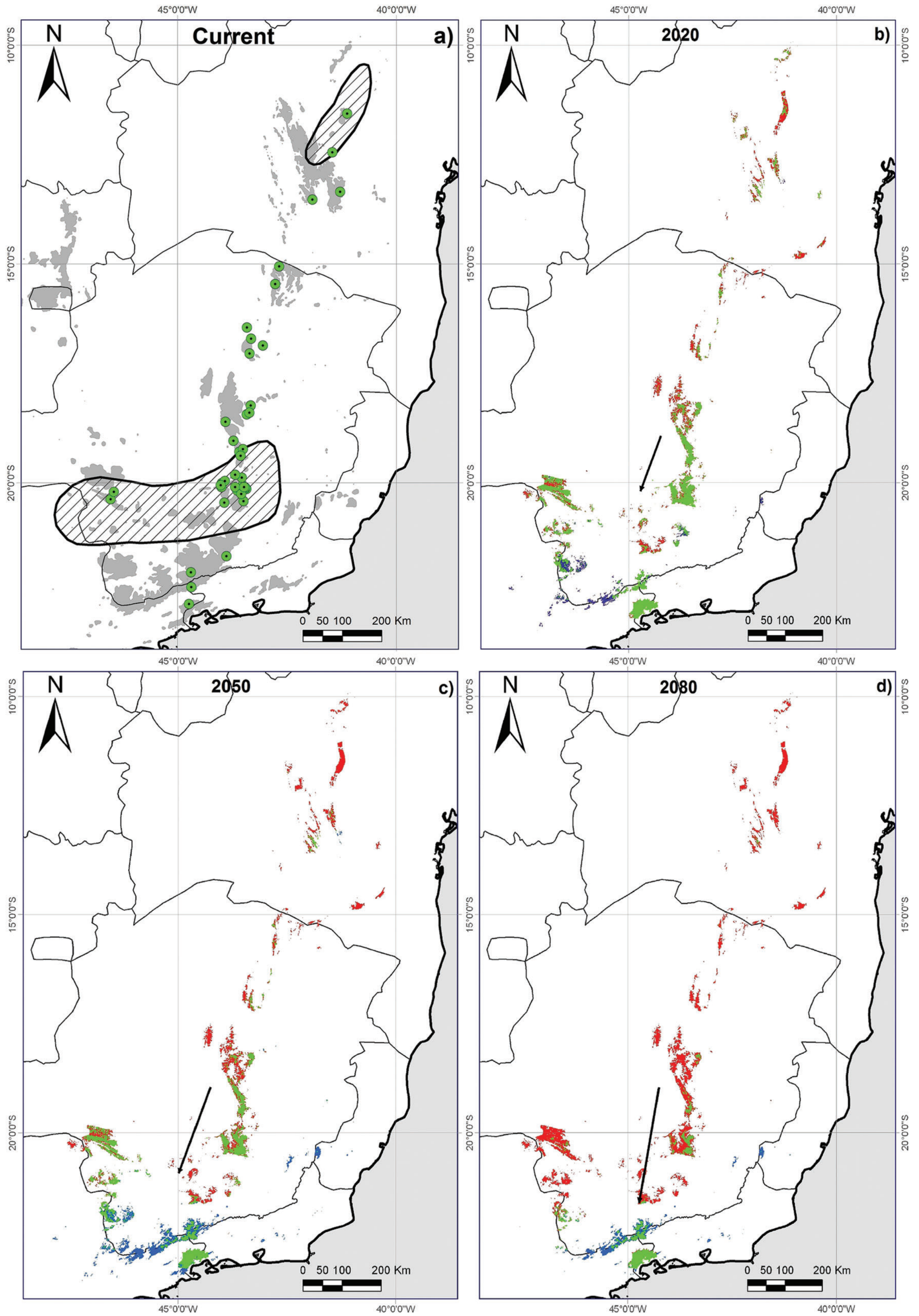

Figure 2. (a) Range of the Gray-backed Tachuri (*Polystictus superciliaris*) (shaded area) following Ridgely & Tudor (2009) and real distribution based on museum specimens, literature and fieldwork (points); altitudes above 1,000 m are represented in gray; (b-d) area with constant favorable conditions (current and future periods) for the presence of the Gray-backed Tachuri (green), potential area for future occupation/dispersal but not currently (blue), current area with the possibility of loss of favorable conditions (red) in future periods (2020, 2050 and 2080, respectively) and shift of distribution center in relation to the current distribution (black arrows).

Table 1. Estimation of the distribution of the Gray-backed Tachuri (*Polystictus superciliaris*) for current and future periods; predicted area currently impacted; expected level of effective protection in reserves; variation in size and loss of area; direction and displacement of the area centroid and altitudinal shift in future periods in relation to the present, under the assumptions of the hypothesis of total dispersion and the null hypothesis of dispersion.

	Projected range (km^2)	Used area within range (km^2)	Protected area expected (%)	Protected area in all reserves (%)	Loss of range (%)	Range shift (km)	Altitudinal shift (m)	Range shift direction
				With dispersion				
Current	30,745	5,505	44.2	11.7	*	*	*	*
2020	22,247	4,178	49.4	13.1	27.6	138	126	Southwest
2050	23,837	3,937	48.3	13.8	22.5	216	186	Southwest
2080	10,837	851	61.2	17.0	64.8	275	326	Southwest
				Without dispersion				
Current	30,745	5,505	44.2	11.7	*	*	*	*
2020	19,036	3,268	52.0	13.8	38.1	103	110	Southwest
2050	15,537	2,589	55.3	15.5	49.5	170	136	Southwest
2080	6,986	649	68.3	17.0	77.3	251	275	Southwest

Table 2. Number of reserves with high suitability for the occurrence of the Gray-backed Tachuri (*Polystictus superciliaris*) at present and in future periods, considering the variation in the extent of the area, the total area of reserves and percentage of area represented.

	Present	With dispersion			Without dispersion		
		2020	2050	2080	2020	2050	2080
Number of reserves	27	30	42	30	26	25	19
Reserves with decrease of range	0	16	16	10	16	16	10
Reserves with increase of range	0	5	7	7	5	7	7
Reserves that have lost conditions	0	1	2	8	1	2	8
Reserves added	0	4	17	11	0	0	0
Reserves in which the range remain constant	0	5	2	2	5	2	2
Reserves areas (km^2)	7,248	7,558	9,635	7,494	7,230	6,828	5,216
% of suitable areas in the reserves	49%	39%	34%	25%	26%	24%	12%
Representation in the reserves (km^2)	3,586	2,924	3,292	1,839	2,628	2,403	1,188

2. Projected distribution in future scenarios

Climatic change may be an important driver for range reduction of several species (IPCC 2007a). The conversion of natural vegetation into antropic areas is a dynamic process along time (see Silva et al. 2006), being responsible for the loss of approximately 1/5 of the current range projected. Even with the extinction of these activities, our results predicted a decrease of 38.1-77.3% of the current species range.

The center of distribution of the Gray-backed Tachuri showed a gradual latitudinal shift southwestward. It also presented an altitudinal shift. These results showed that this species responds similarly to other montane species (e.g., Bussche et al. 2008, Popy et al. 2010), which tend to occupy higher areas and/or to move to higher latitudes, with temperature increase. Parmesan & Yohe (2003) considered that each 1 km of latitudinal displacement in the range would be equivalent to the displacement of 1 m in altitude. The model of distribution of the Gray-backed Tachuri partially showed this pattern, or was close to it. The shift of the species' distribution Center toward southwest coincides with this predictable hypothesis, since displacement vectors were directed to the highland areas of Espinhaço and Mantiqueira Ranges (Figure 2b-d).

In a recent gap analysis, Marini et al. (2009a) found a larger area for the current distribution (55,000 km^2) of the Gray-backed Tachuri in comparison to that observed in the present study (30,745 km^2). Similar discrepancies can also be observed for the extent of the impacted area (13000/5505 km^2) and available range (420000/25240 km^2). This difference may be related to the fact that Marini et al. (2009a) have used a larger number of algorithms and/or due a coarser resolution (of 4.5 x 4.5 km^2), which covers more unfavorable areas that were considered in the present analysis. Despite these methodological differences, a decrease in the range of the Gray-backed Tachuri in future periods is clear in both studies, as the representation of the species range in protected areas, is lower than expected. The response of the species to future climate change will depend on the availability of shrubby environments where it feeds and nests, and from the shrubby vegetation response by climate change (Hoffmann et al. 2007, Hoffmann & Rodrigues 2011) and/or on its ability to adapt to new environmental conditions.

3. Conservation and protection by the Brazilian system of conservation units (SNUC)

Among all reserves where the Gray-backed Tachuri has been recorded (n = 14) (M.F. Vasconcelos, unpublished data), 85% (n = 12) were predicted by the model. Other 15 reserves were predicted to have favorable conditions in the present and in future periods and they present shrubby vegetation that is

Table 3. Reserves with favorable conditions predicted for the occurrence of *Polystictus superciliaris* today and in future periods.

Reserve	State[a]	Municipality	Biome[b]	Area (km^2)	Present	2020	2050	2080	1[c]	2[d]
Córrego dos Fechos Ecological Station	MG	Nova Lima	Ce/Ma	4.74	x	x	x	x	-	-
Cercadinho Ecological Station	MG	Belo Horizonte	Ce/Ma	1.94	x	x	x	-	-	x
Bananal Ecological Station	SP	Bananal	Ma	7.87	x	x	x	x	-	x
Tripuí Ecological Station	MG	OuroPreto	Ce/Ma	3.85	x	x	x	x	-	-
Serra da Piedade Natural Monument	MG	Sabará, Caeté	Ce/Ma	16.78	x	x	x	x	x	-
Biribiri State Park	MG	Diamantina	Ce	148.40	x	x	x	-	-	x
Campos do Jordão State Park	SP	Campos do Jordão	Ma	71.49	x	x	x	x	-	-
Furnas do Bom Jesus State Park	SP	Pedregulho	Ce	18.57	x	-	-	-	-	-
Pedra Azul State Park	ES	Domingos Martins	Ma	8.44	-	-	x	-	-	x
Forno Grande State Park	ES	Castelo	Ma	6.85	-	-	x	x	-	x
Desengano State Park	RJ	Campos de Goytacazes, Santa Maria Madalena, São Fidélis	Ma	187.00	-	-	x	-	-	x
Itambé State Park	MG	Santo Antônio do Itambé, Serro	Ce/Ma	55.76	x	x	x	x	x	-
Pico Marumbi State Park	PR	Morretes	Ma	21.43	-	-	x	x	-	-
TrêsPicos State Park	RJ	Cachoeiras de Macacu, Teresópolis	Ma	406.24	-	-	x	x	-	x
Grão-Mogol State Park	MG	GrãoMogol	Ca/Ce	294.97	x	x	x	-	-	x
Ibitipoca State Park	MG	Lima Duarte, Santa Rita	Ce/Ma	13.19	-	x	x	x	x	-
Itacolomi State Park	MG	Mariana e OuroPreto	Ce/Ma	65.11	x	x	x	x	x	-
Mananciais de Campos do Jordão State Park	SP	Campos do Jordão	Ma	182.60	-	x	x	x	-	-
Morro do Chapéu State Park	BA	Morro do Chapéu	Ca	401.79	x	x	-	-	x	-
Rio Pardo State Park	MG	Rio Pardo de Minas	Ca/Ce/Ma	106.70	x	x	x	-	-	-
Rio Preto State Park	MG	São Gonçalo do Rio Preto	Ce	103.97	x	x	x	x	x	-
Serra do Brigadeiro State Park	MG	Araponga, Divino, Ervália, Fervedouro	Ce/Ma	130.17	-	x	x	x	-	x
Serra do Mar - N. Cunha-Indaiá State Park	SP	Cunha	Ma	66.17	-	-	x	-	-	-
Serra do Mar - N. Picinguaba State Park	SP	Ubatuba	Ma	453.20	-	-	x	x	-	-
Serra do Mar - N. Santa Virgínia State Park	SP	Natividade da Serra, São Luís do Paraitinga, Cunha	Ma	143.88	-	-	x	-	-	-
Serra do Papagaio State Park	MG	Baependi, Aiuruoca, Itamonte	Ma	200.75	x	x	x	x	x	-
Serra do Rola Moça State Park	MG	Belo Horizonte	Ce/Ma	34.81	x	x	x	x	x	-
Serra Negra State Park	MG	Itamarandiba	Ce/Ma	119.26	-	-	x	-	-	x
Chapada Diamantina National Park	BA	Mucugê, Andaraí, Lençóis, Palmeiras, Ibicoara	Ca/Ce/Ma	1246.70	x	x	x	x	x	-
Serra da Bocaina National Park	SP-RJ	Parati, Angra dos Reis, Ubatuba	Ma	862.19	x	x	x	x	x	-
Serra da Canastra National Park	MG	São Roque de Minas, Delfinópolis	Ce/Ma	1711.05	x	x	x	x	x	-
Serra do Cipó National Park	MG	Jaboticatubas, Morro do Pilar	Ce/Ma	272.07	x	x	x	x	x	-
Serra dos Órgãos National Park	RJ	Petrópolis, Guapimirim, Magé, Teresópolis	Ma	92.01	-	-	x	x	-	x
Sempre-Vivas National Park	MG	Bocaiúva, Olhos-D'água, Diamantina, Buenópolis	Ce	1058.06	x	x	x	-	-	x
Itatiaia National Park	RJ-MG	Itatiaia, Resende, Bocaina de Minas, Itamonte	Ma	247.63	x	x	x	x	x	-

Continued on next page

Table 3. Continued.

Reserve	State[a]	Municipality	Biome[b]	Area (km^2)	Present	2020	2050	2080	1[c]	2[d]
Caparaó National Park	ES-MG	Ibitirama, Alto Caparaó	Ma	274.94	x	x	x	x	-	x
Brejo Grande Municipal Natural Park	MG	Paraisópolis	Ma	2.09	-	x	x	x	-	-
Ecológico M. Sagui da Serra Municipal Natural Park	MG	Manhumirim	Ma	3.76	-	-	x	-	-	-
Mangabeiras Municipal Natural Park	MG	Belo Horizonte	Ce/Ma	2.12	x	x	x	-	-	x
Ribeirão do Campo Municipal Natural Park	MG	Conceição do Mato Dentro	Ce/Ma	26.52	x	x	x	x	-	x
Araras Biological Reserve	RJ	Petrópolis, Miguel Pereira	Ma	18.70	-	-	x	x	-	-
Serra dos Toledos Biological Reserve	MG	Itajubá	Ma	9.38	x	x	x	x	-	-
Serra Pedra do Coração Biological Reserve	MG	Caldas	Ma	0.12	x	x	x	x	-	-

[a] Biome: Am = Amazônia, Ca = Caatinga (dry Forest), Ce = Cerrado e Ma = Atlantic Forest; [b] State: Ba = Bahia; ES = Espírito Santo; MG = Minas Gerais; PR = Paraná; RJ = Rio de Janeiro and SP = São Paulo [c] Vasconcelos, 2009; [d] Phytophisiognomies with presence of shrub and rocky outcrops.

favorable to the species (M.F. Vasconcelos, unpublished data) (Table 3). However, the species has not been recorded in these locations because of the lack of avifaunal surveys, or even because of its inability to colonize these areas through lowland barriers (Chaves et al. 2014).

Currently, the species is found in reserves with more than 1,000 km^2, such as the Serra da Canastra and the Chapada Diamantina National Parks (1,711 km^2 and 1,246 km^2, respectively), but also in small reserves, with less than 20 km^2, as in the case of Ibitipoca State Park and Serra da Piedade Natural Monument (13 km^2 and 16 km^2, respectively). However, small reserves may not have enough area to maintain viable populations of the Gray-backed Tachuri, estimated as about 200 km^2 (Hoffmann 2011). Disregarding the reserve size, the Gray-backed Tachuri appeared to be less abundant in the north of its range (M.F. Vasconcelos, unpublished data), which includes the Chapada Diamantina National Park. Thus, one of the largest reserves with predicted occurrence has a low efficiency for the species' conservation.

The representation of the Gray-backed Tachuri in reserves is only one-quarter of the expected for the present and tends to decrease gradually in future periods due to range reduction. The percentage of the predicted range represented in the reserves, for considering the species protected, increased gradually in future periods. Thus, there was a decrease of the total predicted range and, consequently, the need for increasing the species' representation for, at least, 61.2 and 68.3%, considering the hypothesis of total dispersion and the null hypothesis of dispersion, respectively (Table 1). The decrease in the species' representation indicates that the reserves that currently present suitable habitat will become inefficient and inadequate for the species' conservation under future scenarios of environmental changes.

The distribution models as those generated by Maxent, could act as important tools for understanding many aspects of current and future predicted suitable ranges for the Gray-backed Tachuri, providing important information to re-evaluate its conservation status and ideas for possible conservation plans, as well as subsidizing important questions about the species, yet to be investigated. An example would be the potential barriers that probably isolate populations, in order to demonstrate the possibility of occupation of new areas in future. Knowledge on the species' ability to cross these potential barriers would be an important indicator of the possibility of colonization of new areas in the face of possible climatic changes, considering that there are no reports on the viability of translocation and reintroduction programs for small and exclusively insectivorous tyrant-flycatchers (Tyrannidae). The region where the environmental suitability for the Gray-backed Tachuri remained constant in future periods, with a great area extension, is located in the 'Iron Quadrangle' region, Minas Gerais. This region has been strongly impacted by iron mining with more than 50 iron-ore opencast mines that totalize c. 2000 ha (DNPM - Departamento Nacional de Produção Mineral 2006, Jacobi et al. 2007), which have caused high destruction of the 'campos rupestres' vegetation.

In order to review the species' conservation status it should be considered, for the estimation of its range, restrictive characteristics of its localities of occurrence (e.g. altitudinal limit and climatic variables), and not only the delineation of an area that incorporates all records of occurrence. The range of the Gray-backed Tachuri used in the assessment of its conservation status in 2008 was 104,000 km^2 and tripled (314,000 km^2) for the revaluation in 2011, lowering the species' status from 'near-threatened' to 'least concern' (BirdLife International 2014). The present results contradict this new categorization, indicating that the conservation status of many species, mainly based on their ranges, may be influenced by factors not considered limiting of their occurrence. Thus, we consider that the species should remain as 'near-threatened' and, if the impacts of climatic changes really occur, the species should be included in the 'vulnerable' category according to the B1 criterion ($<$20,000 km^2) of IUCN (2001).

The species had a projected range on the political boundaries of five Brazilian states: São Paulo, Minas Gerais, Rio de Janeiro, Espírito Santo and Bahia. Nevertheless, it is not endangered in any regional threatened category in the first four states that present regional red lists (Bergallo et al. 2000, Biodiversitas 2007, Passamani & Mendes 2007, Bressan et al. 2009). The northern range of the species is located in Bahia, a state that does not have any red list. Furthermore, the fact that the species is not represented on a list of threatened species at a regional level should be viewed with caution, since the species was recorded in the states of Rio de Janeiro and Espírito Santo after the publication of the red lists of those states. In both states there is evidence that populations of Gray-backed Tachuri are very small and present restricted range. On the other hand, in the state of São Paulo there are historical records of the species and an absence of recent records. Thus, the extent of occurrence of the species presented in this paper is also important for the assessment and reassessment of the conservation status of the species at regional levels.

Finally, we suggest investing in research on autoecology and natural history of this and other species that are virtually unknown in the Neotropics. This information may help improve the models prediction and are essential for the conservation of the Gray-backed Tachuri and probably the entire highland biota from eastern Brazil.

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New species of *Eublaberus* Hebard, 1920, new records for the genus and description of the male of *E. variegatus* R. S. Albuquerque, 1972 (Blaberidae, Blaberinae)

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LOPES, S.M., OLIVEIRA, E.H., KHOURI, A. **New species of *Eublaberus* Hebard, 1920, new records for the genus and description of the male of *E. variegatus* R. S. Albuquerque, 1972 (Blaberidae, Blaberinae).** Biota Neotropica. 15(2): e20130051. http://dx.doi.org/10.1590/1676-06032015005113

Abstract: A new species of *Eublaberus* (*E. serranus* sp. nov), also a new record for the genus in Southern Brazil, is described based on the male genitalia. The name *Eublaberus variegata* is corrected to *Eublaberus variegatus* Rocha e Silva Albuquerque, and the male of the species is described. Illustrations of the genitalia of the two species mentioned are presented and a key to species is also given.

Keywords: *Blattaria, morphology, diversity, new taxon, taxonomy.*

LOPES, S.M., OLIVEIRA, E.H., KHOURI, A. **Espécie nova de *Eublaberus* Hebard, 1920, novo registro para o gênero e descrição do macho de *E. variegatus* R.S. Albuquerque, 1972 (Blaberidae, Blaberinae).** Biota Neotropica. 15(2): e20130051. http://dx.doi.org/10.1590/1676-06032015005113

Resumo: Uma nova espécie (*E. serranus* sp. nov.) com novo registro para o gênero no Sul do Brasil é descrita com base na genitália do macho. O nome de *Eublaberus variegata* é corrigido para *Eublaberus variegatus* Rocha e Silva Albuquerque, 1972 e, pela primeira vez, tem a descrição do macho apresentada. A ilustração das genitálias das duas espécies citadas são apresentadas, bem como uma chave para as espécies, a fim de aprimorar o seu conhecimento.

Palavras-chave: *Blattaria, morfologia, diversidade, novo táxon, taxonomia.*

Introduction

When Hebard (1920) described *Eublaberus* based on *Blaberus biolleyi* Rehn, 1906 he noted that the genus is close to *Blaberus*, differing from it by having broad interocular space; antennae distinctly tapered; pronotum with lateral margins strongly angulated at the median or mesocephalic portion, or with large mesocephalic convexity. *Eublaberus* is currently classified in the family Blaberidae, subfamily Blaberinae. Roth (1970), based on characters of the male genitalia, characterized the genus by the presence of preputial spines that occur in a single series of spines, and which can be more or less tapered and sclerotized, and by the configuration of the apex of the median sclerite, hook shaped, which is more distinctly hooked in *Eublaberus* than in most species of *Blaberus*. Owing to the hook-shaped median sclerite, Roth (op.cit.) put the group in the tribe Byrsotriini, where Rehn & Hebard, 1927, *Byrsotria* Stal, 1874 and *Hemiblabera* Saussure, 1893 are also included.

More recently, Roth (2003) and Beccaloni (2014) substantiated the classification of *Eublaberus* in the Blaberinae. Beccaloni includes eight species in the genus, all Neotropical. In Brazil, the genus has been recorded in the North, Northeast, Midwest and Southeast.

Herein we describe a new species (*E. serranus*) from the state of São Paulo (Brazil), which also represents a new state record for the genus. We also describe the male of *E. variegatus* Rocha e Silva Albuquerque, 1972 that described by Albuquerque (1972) only by female.

Materials and Methods

The plates and genital parts were observed by after dissecting the apex of the abdomen of the specimens, using traditional techniques for dissection (Lopes & Oliveira, 2000).

The terms for the genitalia and taxonomic classification were based on the terms proposed by Roth (2003). The material studied belongs to the Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ).

Results

1. *Eublaberus serranus sp.nov.*

General coloration brown (Fig.1a). Pronotum with central disk dark-brown, with two pale and symmetrical areas latero-basally. Head dark-brown, eye black; antennae dark with first 12 antenomeres shiny, remaining fuscous; ocelli, clypeus and gena yellowish, palp dark with golden tomentosity, tegmina with basal stem of veins dark-brown.

Dimensions (mm): holotype male: total length – 41.2; length of pronotum – 9.4; width of pronotum – 14.0; length of

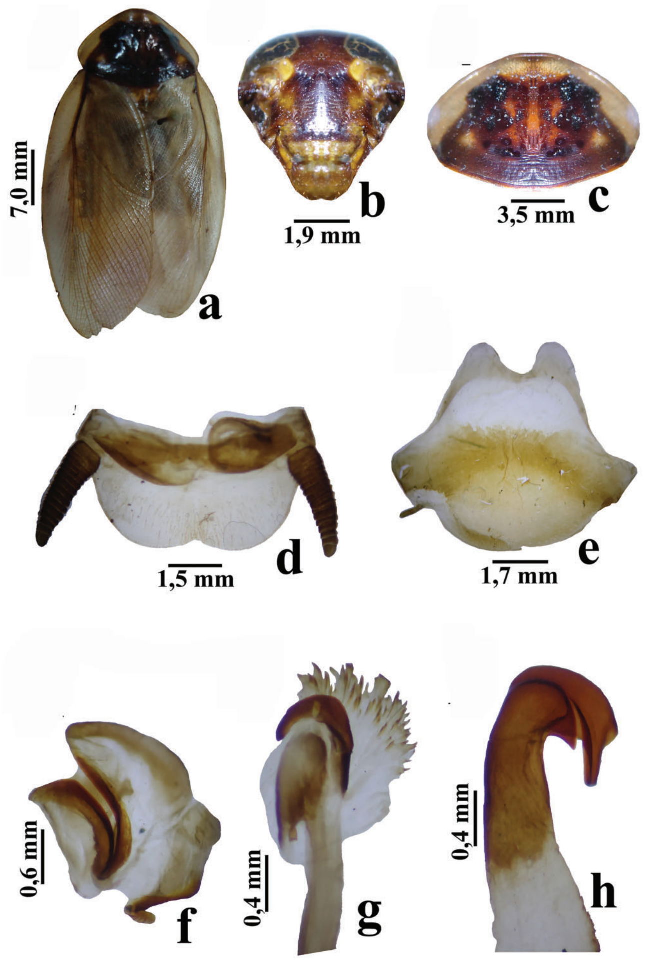

Figure 1. *Eublaberus serranus* sp. nov. (♂) a. habitus; b. head, ventral; c. pronotum, dorsal; d. supra-anal plate, dorsal; e. subgenital plate, dorsal; f. left phallomere, dorsal; g. apical median phallomere, dorsal; h. right phallomere, dorsal.

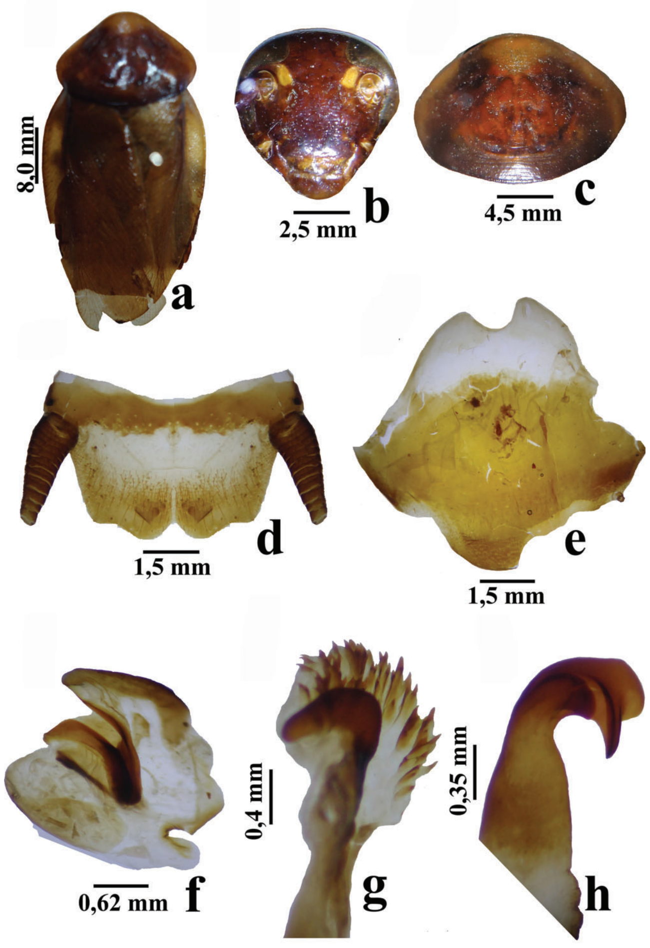

Figure 2. Rocha e Silva-Albuquerque (♂) a. habitus; b. head, ventral; c. pronotum, dorsal; d. supra-anal plate, dorsal; e. subgenital plate, dorsal; f. left phallomere, dorsal; g. apical median phallomere, dorsal; h. right phallomere, dorsal.

tegmen – 34.9 width of tegmen – 12.7; distance between antennal bases: 2.7.

Head subtriangular (Fig. 1b), antennae tomentose, average in size, not reaching middle of abdomen. Ocelli large and conspicuous; palps tomentose, 3rd and 5th articles subequal in length, the latter dilated.

Thorax with pronotum elliptical, transverse, convex (Fig. 1c), lateral flaps with round margins. Legs robust and spiny, fore femur with anteroventral surface bearing a series of small ciliform spines from base to apex, where one is robust; posteroventral surface bearing two robust spines, one on apical third and one more apical; mid femur with anteroventral surface bearing one robust apical spine; posteroventral surface bearing long cilia from base to apex, two robust, one on apical third and one apical; hind femur identical to mid femur, without robust spines posteroventral surface. Tegmen developed reaching beyond apex of cercus; anal field short and deflexed, scapular field long, with oblique venular arrangement; discoidal field ample, venular arrangement ventral tending to longitudinal, anal field ample with twenty or more axillary veins. Wings developed, costal sector with apexes of branches of radial veins not dilated; apical triangle absent and anal field folded as a fan.

Abdomen with supra-anal and subgenital plates typical of Blaberinae with supra-anal plate with little evident median reentrance; cerci enlarged. Subgenital plate asymmetric, apex rounded, small and thin styles inserted near the side of the plate ends, one of them slightly bent (Figs. 1d e 1e). Genitalia with left phallomere made up by two sclerotized plates (Fig. 1f) with apex narrow, from base to apex hook-shaped, elongate and slender, with pre-apical lateral projection round and prepuce with very small spines (Fig. 1g); right phallomere hook-shaped with apex not slender (Fig. 1h).

Material examined: Holotype male – Brazil, São Paulo, Araras, 07-XI-1984 A.G. Santos col. (MNRJ).

Eublaberus variegatus Rocha e Silva-Albuquerque, 1972

Eublaberus variegata Rocha & Silva-Albuquerque, 1972: 1-38; Beccaloni, 2014. In site

General coloration shiny brown (Fig. 2a). Pronotum with central disk uniformly dark-brown, tegmen with basal stem of veins dark, head dark-brown; eye dark-brown, ocelli yellowish; palpi brown with golden tomentosity. Legs golden tomentose; pulvilli and apex of claws dark.

Dimensions (mm): male: total length – 46.26; length of pronotum – 11.72; width of pronotum – 16.79; length of

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tegmen – 39.0; width of tegmen – 13.01; distance between antennal bases – 3.6.

Head subtriangular (Fig. 2b), apex rounded, vertex covered by the pronotum in dorsal view; eye small; interocular space ample, 80% of the area between bases of antennal sockets; palps tomentose.

Thorax with pronotum elliptical, transverse, convex, lateral flaps ample, and apex slightly protruding (Fig. 2c). Legs robust, fore femur with anteroventral surface bearing series of thin cilia from base to apex and one spine robust; posteroventral surface with sparse cilia, one robust apical, posteroventral surface with a series of cilia and two robust spines, one on apical third and one more apical; hind femur with anteroventral surface bearing sparse cilia and one apical spine; mid and hind femora with one small and robust genicular spine. Pulvilli present, arolia absent, claws symmetrical and simple. Tegmen developed, marginal field long and narrow, scapular field long, with oblique venular arrangement; anal field short and wide. Wings developed, costal sector with apex of branches of radial vein not dilated; apical triangle absent and anal field folded as a fan.

Abdomen with supra-anal plate setose, widened and salient between cerci, with slight median notch (Fig. 2d). Subgenital plates typical of Blaberinae (Fig. 2e). Genitalia with left phallomere made up by two heavily sclerotized plates (Fig. 2f); median sclerite developed with round apex; prepuce with a series of small spines (Fig. 2g); right phallomere elongate, hook-shaped with apex slender (Fig. 2h).

Material examined: 1 male – Brazil, Amazonas, Manaus; 07/VI/1941, no colector data; 1 male – Brazil, Amazonas, Reserva Duque, X/1961, Arlé col.(MNRJ).

2. *Key to the identification of males of Eublaberus Hebard, 1920*

1. Specimens shorter than 40mm long 2

1’ Specimens longer than 40mm 3

2. Pronotum with central disk homogenously dark-brown. . . . . *E. argentinus*

2’ Pronotum dark with latero-apical areas yellowish and two symmetrical, subtriangular, dark-brown marks . . . . *E. marajoara*

3. Pronotum with central disk dark-brown. Apex of median sclerite narrow from base to apex, which is long and slender . . . . *E. serranus* sp. nov.

3’ Pronotum with latero-basal, yellow, circular mark. Apex of median sclerite widened at base and narrowing apically . . . . *E. fernandoi*

3’’ Pronotum not as above. Apex of median sclerite with apex round 4

4. Pronotum with central disk with symmetrical light brown marks. Abdomen with sternites light brown with lateral dark marks . . . . *E. posticus*

4’. Pronotum with uniformly dark-brown central disk. Abdomen with uniformly dark brown sclerites . . . . . *E. variegatus*

4’’ Pronotum without dark-brown central disk. Abdomen with sternites yellowish, bearing dark lateral marks . . . . *E. distanti*

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Screening of plant growth promoting bacteria associated with barley plants (*Hordeum vulgare* L.) cultivated in South Brazil

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PONTES, A.P., SOUZA, R., GRANADA, C.E., PASSAGLIA, L.M.P. **Screening of plant growth promoting bacteria associated with barley plants (*Hordeum vulgare* L.) cultivated in South Brazil.** Biota Neotropica. 15(2): e20140105. http://dx.doi.org/10.1590/1676-06032015010514

Abstract: The occurrence of associations between bacteria and plant roots may be beneficial, neutral or detrimental. Plant growth promoting (PGP) bacteria form a heterogeneous group of beneficial microorganisms that can be found in the rhizosphere, the root surfaces or in association with host plant. The aim of this study was to isolate and characterize PGP bacteria associated to barley plants (*Hordeum vulgare* L.) aiming a future application as agricultural inoculant. One hundred and sixty bacterial strains were isolated from roots or rhizospheric soil of barley based on their growth in nitrogen-free selective media. They were evaluated for their ability to produce indolic compounds (ICs) and siderophores, and to solubilize tricalcium phosphate in *in vitro* assays. Most of them (74%) were able to synthesize ICs in the presence of the precursor L-tryptophan, while 57% of the isolates produced siderophores in Fe-limited liquid medium, and 17% were able to solubilize tricalcium phosphate. Thirty-two isolates possessing different PGP characteristics were identified by partial sequencing of their 16S rRNA gene. Strains belonging to *Cedecea* and *Microbacterium* genera promoted the growth of barley plants in insoluble phosphate conditions, indicating that these bacteria could be used as bioinoculants contributing to decrease the amount of fertilizers applied in barley crops.

Keywords: *bacterial 16S rRNA gene, inoculant, barley, phosphate solubilization.*

PONTES, A.P., SOUZA, R., GRANADA, C.E., PASSAGLIA, L.M.P. **Seleção de bactérias promotoras de crescimento vegetal associadas com plantas de cevada (*Hordeum vulgare* L.) cultivadas no Sul do Brasil.** Biota Neotropica. 15(2): e20140105. http://dx.doi.org/10.1590/1676-06032015010514

Resumo: A ocorrência de associações entre bactérias e raízes de plantas pode ser benéfica, neutra ou prejudicial. Bactérias promotoras de crescimento vegetal (BPCV) formam um grupo heterogêneo de micro-organismos benéficos que pode ser encontrado na rizosfera, superfícies de raízes ou em associação com plantas hospedeiras. O objetivo deste estudo foi isolar e caracterizar bactérias promotoras do crescimento vegetal (PCV) associadas a plantas de cevada (*Hordeum vulgare* L.), visando uma futura aplicação como inoculante agrícola. Cento e sessenta linhagens bacterianas foram isoladas a partir de raízes ou solo rizosférico de cevada com base na sua multiplicação em meios seletivos sem nitrogênio. Todos os isolados foram avaliados quanto à sua capacidade de produzir compostos indólicos (CIs), sideróforos e solubilizar fosfato tricálcio, em ensaios *in vitro*. A maioria dos isolados (74%) foi capaz de sintetizar CIs na presença do precursor L-triptofano, enquanto que 57% produziram sideróforos em meio líquido com deficiência de Fe e 17% foram capazes de solubilizar fosfato tricálcio. Trinta e dois isolados que apresentaram diferentes características PCV foram identificados pelo sequenciamento parcial do gene 16S rRNA. Linhagens pertencentes aos gêneros *Cedecea* e *Microbacterium* promoveram o crescimento de plantas de cevada em condições de fosfato insolúvel, indicando que estas bactérias podem ser utilizadas como inoculantes, contribuindo para a redução da quantidade de fertilizantes aplicados no cultivo da cevada.

Palavras-chave: *gene bacteriano 16S rRNA, inoculante, cevada, solubilização de fosfato.*

1. Introduction

The management of microbial soil-plant interactions has emerged as a power agricultural tool evidenced by an increase in crop productivity, by the reduction of production costs through the reduction of the amount of chemical fertilizers and by a better conservation of environmental resources (Shridhar 2012). One of the most promising techniques to achieve these benefits is the use of bioinoculants- also called biofertilizers, which are composed by beneficial bacteria.

The plant rhizosphere can be defined as the region of the soil where the processes mediated by microorganisms are specifically influenced by the root system (Gray & Smith 2005). Root-colonizing plant beneficial bacteria, commonly referred to as plant growth-promoting bacteria (PGPB), are rhizospheric bacteria that can enhance plant growth using a wide variety of direct and indirect mechanisms (Glick 2012). The favorable effects of PGPB inoculation on plant growth have been widely studied (Ambrosini et al. 2012; Glick 2012; Granada et al. 2013; Souza et al. 2013).

PGPBs are able to accelerate seed germination, improve seedling emergence, protect plants from disease, and promote root growth (Lugtenberg et al. 2002). PGPB can also exert biocontrol of pathogenic fungi through the production of antibiotics, competition for nutrients or by the induction of systemic resistance (Glick 2012). Moreover, such bacteria may improve the nutritional status of plants through biological nitrogen fixation (Saikia & Jain 2007), phosphate solubilization through the production of organic acids and phosphatases (Chen et al. 2006; Rodríguez et al. 2006), and siderophores production (Lemanceau et al. 2009). In addition, the hormonal effects that occurred when PGPB produce chemical compounds, such as auxins, cytokinins, and gibberellins, directly impact the plant growth by stimulating the uptake of nutrients (Vessey 2003; Jha & Saraf 2012). Thus, PGPB are able to use different pathways to promote plant growth at various stages during the plant life cycle. The manner in which each PGPB can influence plant growth differs from species to species as well as by strain (Glick et al. 1999).

Barley (*Hordeum vulgare* L.) is a fast growing annual grain crop that could be used as forage or cover crop to improve soil fertility (Ghanbari et al. 2012). Moreover, it is often grown for many purposes, including as a source of protein for animal or human consumption as well as for malting. This study was undertaken in order to: (i) isolate and identify putative PGPB associated with rhizospheric soil and roots of barley plants cropped in different areas of southern Brazil; (ii) evaluate several plant growth promotion (PGP) activities of the bacterial isolates; (iii) and test their PGP abilities to promote plant growth in a growth chamber experiment.

2. Materials and Methods

2.1. Sampling and isolation of putative plant growth promoting bacteria

Samples were collected from three different barley producing regions in the state of Rio Grande do Sul (RS), Brazil: Júlio de Castilhos (JC; 29° 13’ 37” S, 53° 40’ 54” W), São Borja (SB; 28°39’ 39” S, 56° 00’ 14” W), and Vacaria (VA; 28°30’ 43” S, 50° 56’ 02” W).

Rhizospheric and root-associated bacteria were isolated from five independent plants collected from each sampling region with adhering (rhizospheric) soil that were spaced at least 2 m away from each other. Samples were randomly taken and bulked to obtain a representative composite sample. To isolate root-associated bacteria, root samples were first sterilized by surface disinfection performed by washing the roots in running tap water, followed by a 70% ethanol wash for 1 min, a sodium hypochlorite solution (4%, v/v) wash for 2 min, and five serial rinses in sterilized distilled water. After disinfection, 10 g of roots from each sampling region was sliced with a sterile scalpel and placed into 250 ml Erlenmeyer flasks containing 90 ml of sterile saline solution (0.85% NaCl). Rhizospheric bacteria were isolated from 10 g of rhizospheric soil from each sampling region that was also placed in 250 ml Erlenmeyer flasks containing 90 ml of sterile saline solution. Both rhizospheric soil and sliced roots samples were incubated at 4°C with agitation (125 rpm) for 4-6 h.

Putative diazotrophic bacteria were isolated according to Döbereiner (1988), using the nitrogen-free semi-solid NFb, LGI, and LGI-P media, with the modifications described in Ambrosini et al. (2012) and Souza et al. (2013). After incubation, distinct colonies were randomly selected and grown in liquid LB medium (Sambrook & Russel 2001) at 28°C under agitation (200 rpm). From each sampled region, 30 colonies of root-associated bacteria and 30 colonies of rhizospheric soil bacteria (totaling approximately 60 colonies from each region) were isolated. These bacterial isolates were individually analyzed by Gram-staining and immediately stored in sterile glycerol solution (50%) at -20°C.

2.2. Evaluation of the characteristics that promote plant growth

The putative PGP capacity of the bacterial isolates was evaluated by *in vitro* tests. Bacterial suspensions (10 µl of 10^8 CFU ml^{-1}) of each isolate grown in LB medium at 28°C with agitation (125 rpm) for 48 h were used as inocula for the PGP experiments. Analysis of production of indolic compounds (ICs) and siderophores, and tricalcium phosphate solubilization activities were carried out for all bacterial isolates.

The *in vitro* ICs production assay was performed in King B medium with tryptophan (Glickmann & Dessaux 1995) by incubation the isolates at 28°C under agitation (200 rpm) for 72 h. As described in Ambrosini et al. (2012) the supernatant (500 µl) was mixed with an equal volume of Salkowski reagent ($12\ g\ l^{-1}\ FeCl_3 + 7.9\ M\ H_2SO_4$) in test tubes, and the mixture was kept in the dark for 30 min to allow for color development. The pink to red color produced after exposure to Salkowski reagent was considered to be indicative of bacterial production of ICs. The samples were measured spectrophotometrically at 550 nm using a standard curve for calibration.

Siderophores production was assayed according to Schwyn & Neilands (1987) using King B medium (Glickmann & Dessaux 1995) without tryptophan. The isolates were spot inoculated onto Chrome azurol S agar plates and incubated at 28°C for 48-72 h. Development of a yellow, orange or violet halo around the bacterial colony was considered to be positive for siderophores production.

To identify isolates able to solubilize tricalcium phosphate bacteria were grown in glucose yeast medium (GY). Two other solutions were prepared separately, one containing 5 g K_2HPO_4 in 50 ml of distilled water, and the other containing 10 g $CaCl_2$ in 100 ml of distilled water. These solutions were added to one liter of GY medium just before pouring onto Petri dishes, and together they formed an insoluble layer of calcium phosphate that made the medium opaque. The plates were inoculated with the bacterial isolates, and then incubated for seven days at 28°C. Those isolates that formed visibly clear halos around their colonies were considered to be tricalcium phosphate solubilizers.

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2.3. Extraction of bacterial DNA, PCR amplification and partial sequencing of the 16S rRNA gene

Bacterial DNA extraction was performed according to Ambrosini et al. (2012). Phenol-chloroform extraction and ethanol precipitation were performed as described by Sambrook & Russel (2001). The quality and integrity of the DNA were determined by electrophoresis in 0.8% agarose gels containing ethidium bromide and visualized under UV light. Fifty nanograms of bacterial DNA were used as a template for PCR procedures.

Partial sequences of the 16S rRNA gene (roughly 450 bp) from each isolate were amplified using the primers U968 (AACGCGAAGAACCTTAC) and L1401 (CGGTGTGTA CAAGACCC) (Felske et al. 1997), which cover the region between nucleotides 968 and 1401 of the *Escherichia coli* 16S rRNA gene, and using the conditions described in Souza et al. (2013). Thermal cycling was performed according to Garbeva et al. (2003). PCR products were analyzed by electrophoresis in 1% agarose gels containing ethidium bromide and visualized under UV light.

Sequences were trimmed to exclude low quality sequenced nucleotides. DNA sequences were compared with sequences from the EzTaxon Server version 2.1 (http://eztaxon-e.ezbiocloud.net/) and the GenBank using BLASTN software (http://blast.ncbi.nlm.nih.gov/). The nucleotide sequences of the 32 partial 16S rRNA gene segments determined in this study have been deposited in GenBank (accession numbers KM068182 to KM068213).

2.4. Growth chamber assay

Bacterial isolates demonstrating different PGP characteristics were tested in experiments with barley (*Hordeum vulgare* L.) in a growth chamber. The growth chamber experiment was conducted with a photoperiod cycle of 14 h light at 28°C and 10 h dark at 20°C. The experimental units consisted of pots (15 X 20 cm) sterilized with 0.7% sodium hypochlorite solution before seeding. Barley seeds were surface-disinfected as described by Souza et al. (2013) and were planted in sterile vermiculite, 2 cm below the surface. Three bacterial isolates (JC57, SB41, and VA7) were grown in LB medium with agitation (125 rpm) for 48 h at 28°C. Pure bacterial cultures were centrifuged and diluted to a final concentration of 10^9 CFU ml^{-1} in sterile saline solution. Seeds were inoculated with 5 ml aliquots of the cell suspensions by direct irrigation of the substrate. The treatments were as follows: seeds inoculated with JC57, SB41 or VA7 isolates and a non-inoculated control. The experiment consisted of five replicates per treatment and a completely randomized design. A 50 ml volume of Hoagland's nutrient solution (Hoagland & Snyder 1933) diluted to 25% was added to each pot every 15 days. All treatments were divided into two conditions: one received soluble phosphate (complete Hoagland's nutrient solution), while the other received insoluble phosphate (Hoagland's nutrient solution without KH_2PO_4 but supplemented with 0.2 g of rock phosphate per pot in total). The experiment was maintained for 40 days, after which plants were harvested and length data were recorded. Shoots and roots were dried at 65°C to constant weight to evaluate dry matter.

Data from the pot trials were statistically analyzed using ANOVA, and the means were compared using Tukey test ($p = 0.05\%$). Homoscedasticity was verified using Levene's test and normality by histogram analysis.

3. Results and Discussion

3.1. Isolation, screening of plant growth-promoting (PGP) traits, and identification of bacterial isolates

In this work, bacteria possessing different PGP characteristics were isolated from rhizospheric soil and roots of barley plants collected from three different barley-producing regions of the state of Rio Grande do Sul, Brazil. In total, 160 bacterial strains were selectively isolated based on their growth in three selective semi-solid nitrogen free media, NFb, LGI, and LGI-P. These selective media were used as a discriminating strategy to select putative nitrogen-fixing and plant growth-promoting rhizobacteria. After the isolation, the production of ICs and siderophores and the ability to solubilize tricalcium phosphate were analyzed for the 160 bacterial strains (Table 1).

According to Table 1, one of the most evident characteristic among the isolates was their ability to produce ICs: 118 (74%) isolates were able to synthesize ICs in the presence of the precursor L-tryptophan, which can act as a phytohormone. Of these, four bacterial isolates produced among 51-100 μg of ICs ml^{-1} after 72 h of incubation. Our results agreed with those of Ahmad et al. (2006), who also reported that ICs production was the most prevalent plant growth promoting characteristic in the majority of their isolates. High numbers of ICs-producing bacteria have also been documented by other studies (Ambrosini et al. 2012; Costa et al. 2013; Granada et al. 2013; Souza et al. 2013).

Table 1. Number of isolates, siderophores production, tricalcium phosphate solubilization, and indolic compound (ICs) production by bacterial isolates at each sampling site.

Site		**Number of isolates**	**Siderophores production**	**Phosphate solubilization**	**ICs production (μg ml^{-1})**		
					0.1-50	**51-100**	**>100**
São Borja	Root	27	20	8	19	1	1
	Soil	28	12	10	14	1	0
Vacaria	Root	26	16	0	20	2	0
	Soil	28	11	3	26	0	0
Júlio de Castilhos	Root	27	15	4	21	0	0
	Soil	24	17	3	13	0	0
Total		160	91	28	113	4	1

Table 2. Identification and PGP attributes of selected isolates.

Isolates[a]	16S rRNA gene sequence[b]	Phosphate solubilization	Siderophores production	ICs production ($\mu g\ ml^{-1}$)
SB41	*Cedecea* sp. (100%)	+	+	55
VA7	*Microbacterium* sp. (99%)	-	-	84
JC57	*Ochrobactrum* sp. (100%)	-	+	12

[a] Bacteria isolated from: SB41 (São Borja); VA7(Vacaria); JC57 (Júlio de Castilhos).
[b] Identities are based on comparison with the GenBank database using the BLASTN program.

Among the phytohormones, the auxin (indole-3-acetic acid, IAA) is widely distributed among bacteria associated with plants (Spaepen et al. 2007), and approximately 80% of bacterial isolates from the rhizosphere are capable of produce IAA (Patten & Glick 2002).

Another ability displayed by most of the isolates was siderophores production (91 out of 160; Table 1). Moreover, the barley roots sampled from São Borja locality showed the highest number of siderophores-producing strains (22%) when compared to the other regions. Many microorganisms can produce siderophores which are involved in the sequestration of iron as Fe^{3+} that displays low solubility in aerobic conditions (Masalha et al. 2000). Souza et al. (2013), for example, evaluating the diversity of cultivable siderophores-producing bacteria associate to rice (*Oryza sativa* L.) found that 84% of the 336 isolates examined produced siderophores in Fe-limited liquid medium. According to Wei Jin et al. (2010) plants submitted to iron deficiency may alter the community of associated siderophores-producing bacteria. These authors submitted plants of clover (*Trifolium pratense*) to the treatment with deficiency of iron and found a highest number of bacteria that secreted siderophores within the first 24 h of growth when compared with the iron control condition. Besides high affinity for iron, siderophores may have affinity for other metals. In a study with *Azotobacter vinelandii*, Kraepiel et al. (2009) showed that this bacterium excretes catecholate compounds previously identified as siderophores, which bind to metal cofactors of the nitrogenase (Mo, V and Fe) enzyme.

In addition to the above characteristics, 28 of 160 isolates were able to solubilize tricalcium phosphate (Table 1); the rhizospheric soil and barley roots obtained from São Borja locality showed the highest number of phosphate-solubilizing strains (65%) when compared to the other regions. The sources of phosphorus (P) in soil are available from organic phosphate compounds (Richardson & Simpson 2011) and inorganic phosphate compounds, mainly in the form of insoluble mineral complexes (Rodriguez et al. 2006). Phosphate-solubilizing bacteria are able to solubilize phosphate inorganic compounds, for example, tricalcium phosphate, by the production of organic acids (Chen et al. 2006). Similarly low numbers of phosphate-solubilizing bacteria have been documented by other studies (Beneduzi et al. 2008; Ambrosini et al. 2012; Costa et al. 2013; Granada et al. 2013; Souza et al. 2013).

Many of the 160 bacterial strains isolated in this study presented more than one PGP attribute: 70 (45%) isolates were capable to produce ICs and siderophores; 19 (12%) isolates were able to produce siderophores and solubilize tricalcium phosphate, 16 (10%) were able to produce ICs and siderophore, and 13 (8.1%) were able to produce ICs and siderophores and to solubilize tricalcium phosphate at the same time. According to Glick et al. (1999) rhizospheric bacteria are able to use different pathways to promote plant growth at various stages during the plant life cycle and the manner in which PGPB can influence plant growth differs from species to species as well as by strain.

Of those 160 bacterial strains, a total of thirty-two isolates possessing different PGP characteristics were selected and identified by PCR amplification and partial sequencing of the 16S rRNA gene. According to the partial sequences of the 16S rRNA gene, the main bacterial strains identified belonged predominantly to *Achromobacter* (8), *Burkholderia* (4), *Cedecea* (1), *Devosia* (1), *Enterobacter* (1), *Herbaspirillum* (1), *Leclercia* (2), *Pseudomonas* (1), *Microbacterium* (1), *Ochrobactrum* (1), *Rhizobium* (7), *Salmonella* (1), *Staphylococcus* (2) and *Stenotrophomonas* (1) genera. Of the identified bacteria, three strains were further selected for the growth chamber experiment. The selection was based on their PGP characteristics and their taxonomic identification (Table 2). According to Bhromsiri & Bhromsiri (2010) PGPB constitute a heterogeneous and beneficial group of microorganisms that may be found in the rhizosphere or in association with the host plant. Moreover, different strains belonging to *Burkholderia, Cedecea, Rhizobium, Enterobacter*, and *Stenotrophomonas* genera were also found in the roots and rhizospheric soil of different plants (Lim et al. 2008; Magnani et al. 2010; Santi Ferrara et al. 2011; Ambrosini et al. 2012; Farina et al. 2012; Costa et al. 2013; Granada et al. 2013; Souza et al. 2013).

3.2. Efficiency of growth promotion by bacterial inoculation of barley plants

To test the interaction between PGPB and barley, an *in vivo* experiment was conducted with three selected isolates in a growth chamber. Table 2 shows the results of the PGP activities evaluated for these isolates. The bacterial isolates used to inoculate the seeds of barley were identified as JC57 (*Ochrobactrum* sp.), SB41 (*Cedecea* sp.), and VA7 (*Microbacterium* sp.).

According to Table 3, in the treatment with soluble phosphate, the growth of plants inoculated with bacterial isolates was statistically equivalent to those of plants without inoculation regarding all parameters of plant growth analyzed.

In relation to the treatment with insoluble phosphate two selected isolates used for the inoculation of barley seeds resulted in satisfactory effects on plant growth compared with the non-inoculated plants (Table 3). Barley plants inoculated with SB41 (*Cedecea* sp.) and VA7 (*Microbacterium* sp.) isolates presented significantly higher results than the non-inoculated control plants in terms of dry shoot biomass. Moreover, plants inoculated with VA7 strain presented a significant increase in the dry root weight as well in the root length when compared with the non-inoculated plants (Table 3). Barley plants inoculated with P solubilizing bacteria showed significantly enhanced growth when fertilized with rock phosphate (insoluble phosphate) (Belimov et al. 1995). Similar results were

Table 3. The effect of the inoculation of native PGPB on the promotion of barley growth under growth chamber conditions in the presence of soluble phosphate.

Treatment[a]	**Soluble phosphate**				**Insoluble phosphate**			
	Shoot growth		**Root growth**		**Shoot growth**		**Root growth**	
	Lenght (mm)	**Dry matter (mg)**	**Lenght (mm)**	**Dry matter (mg)**	**Lenght (mm)**	**Dry matter (mg)**	**Lenght (mm)**	**Dry matter (mg)**
Non-inoculated	189.5 a	143.7 a	450.2 a	198.4 a	457.0 a	113.9 b	164.2 b	110.9 c
SB41	189.5 a	119.2 b	477.5 a	192.6 a	463.5 a	155.5 a	171.2 b	120.6 bc
VA7	198.5 a	143.4 a	459.0 a	198.9 a	456.2 a	157.6 a	212.5 a	148.6 a
JC57	185.5 a	156.4 a	460.0 a	201.1 a	478.5 a	148.3 ab	195.7 ab	139.0 ab

Data represent the means of 5 replicates of plants grown in vermiculite in a photoperiod chamber.
Values in the same column followed by the same letter did not differ significantly at $P > 0.05$ (Tukey Test).
[a]Bacteria isolated from: SB41 (São Borja); VA7(Vacaria); JC57 (Júlio de Castilhos).

showed by Granada et al. (2013) in an experiment conducted with *Lupinus albescens* plants, involving soluble and insoluble phosphate. In this work, the authors demonstrated that the inoculation of *L. albescens* with the 103R (*Ochrobactrum* sp.), 22R (*Sphingomonas* sp.), and 230S (*Burkholderia* sp.) isolates improved plant growth, with the best results obtained under the insoluble P condition. The favorable effects of PGPB inoculation on plant growth have also been extensively reported in others works (Beneduzi et al. 2008; Sasaki et al. 2010; Santi Ferrara et al. 2011; Ambrosini et al. 2012; Glick 2012; Arruda et al. 2013; Costa et al. 2013; Souza et al. 2013).

Plant growth-promoting bacteria can affect host plants directly or indirectly. The SB41 and VA7 isolates displayed different PGP attributes in our *in vitro* assays. These observations indicated that these growth promotion mechanisms could have influenced the plant development and growth. The hormone auxin is an important regulator that directly influences plant development and growth (Jaillais & Chory 2010). Several studies show that the excretion of siderophores by rhizospheric bacteria may stimulate plant growth, improving plant nutrition (Masalha et al. 2000). On other hand, phosphate solubilizing bacteria can facilitate the conversion of insoluble forms of P making it available to plants (Chen et al. 2006).

4. Conclusion

Bacterial strains associated with roots and rhizospheric soil of barley display different plant growth-promoting traits that can be used to promote plant growth. The growth chamber experiment showed that bacterial isolates from the rhizosphere of barley presented a plant growth-promoting effect in insoluble phosphate conditions. The present work clearly indicates that SB41 (*Cedecea* sp.) and VA7 (*Microbacterium* sp.) strains may be a good candidates for formulation of a bioinoculant, allowing a reduction in the use of fertilizers and reducing environmental problems.

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inventory

Small mammals (Chiroptera, Didelphimorphia, and Rodentia) from Jaíba, middle Rio São Francisco, northern Minas Gerais State, Brazil

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Abstract: We report the results of small mammals inventories conducted in the region of Jaíba, northern Minas Gerais state, southeastern Brazil, from 1990 to 1995. This region is located in the southern limit of the Caatinga biome, and harbors a unique set of natural ecosystems and extensive agricultural areas. With a total effort of 2964 trap-nights and 44 net sessions, we captured 893 small mammals from 46 species, including four marsupials, 13 rodents, and 29 bats. We report on species that are endemic to the Caatinga (*Wiedomys pyrrhorhinos* and *Xeronycteris vieirai*), and species that are new to the mammal fauna of the state of Minas Gerais (*Tonatia saurophila*, *X. vieirai*, and *Myotis lavali*). We also provide the first valid voucher-supported record of *Micronycteris sanborni* from southeastern Brazil, and extend the known range of *X. vieirai* 800 km southward. All bats highlighted here as endemic or representing new records were associated to limestone outcrops, suggesting that preservation of this kind of habitat may be particularly relevant to the conservation of these mammals.

Keywords: *Caatinga, limestone outcrop, endemic species, range extension, taxonomy.*

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Resumo: Reportamos os resultados de inventários de pequenos mamíferos conduzidos na região de Jaíba, norte de Minas Gerais, sudeste do Brasil, entre 1990 e 1995. Essa região está localizada no limite sul do bioma Caatinga, e abriga um conjunto único de ecossistemas naturais e extensas áreas cultivadas. Com um esforço total de 2964 armadilhas-noite e 44 sessões de captura com redes de neblina, nós capturamos 893 pequenos mamíferos, que permitiram a identificação de 46 espécies, incluindo quatro marsupiais, 13 roedores e 29 morcegos. Nós reportamos espécies endêmicas da Caatinga (*Wiedomys pyrrhorhinos* e *Xeronycteris vieirai*) e espécies que são novas para a fauna de mamíferos de Minas Gerais (*Tonatia saurophila*, *X. vieirai* e *Myotis lavali*). Nós também fornecemos o primeiro registro válido, com material testemunho, de *Micronycteris sanborni* para o sudeste do Brasil, e estendemos a distribuição geográfica conhecida de *X. vieirai* em 800 km na direção sul. Todos os morcegos destacados aqui como endêmicos ou representando novos registros estiveram associados a afloramentos de calcário, sugerindo que a preservação deste tipo de hábitat pode ser particularmente relevante para conservação desses mamíferos.

Palavras-chave: *Caatinga, afloramento de calcário, espécie endêmica, extensão de distribuição, taxonomia.*

Introduction

The region of Jaíba, in northern Minas Gerais state, has been classified under high levels of biological importance at both regional and national scales (Costa et al. 1998, MMA 2002). It is located in the southern limit of the Caatinga domain (Andrade-Lima 1981) and harbors a unique set of ecosystems, influenced by the proximity with the Cerrado biome and the presence of water courses, lagoons, and limestone outcrops. This region also holds one of the largest irrigation projects in South America (Projeto Jaíba) (Rodrigues 2001), which over the past decades has converted thousands of hectares of natural habitats into agricultural plots and anthropic areas.

Spix & Martius (1828) provided the earliest records on the mammals of northern Minas Gerais state in their list for the "Sertão dos Campos Gerais de São Felipe". These authors reported two marsupials and 10 rodents, in addition to several medium to large mammals, but no precise locality records were provided. Hershkovitz (1987) described this list as an "uncritical compilation", including data from a variety of sources. Empirical, voucher-supported records were obtained, therefore, only in the 1990s, but these data remained under restricted access (available only as meeting abstracts) until Oliveira et al. (2003) summarized them in a check list. This list has been very useful in the evaluation of the biological importance of Jaíba, but lacks methodological and ecological information from the original surveys, including a list of the voucher material available. Part of the material collected in Jaíba during the 1990s was listed by Tavares et al. (2010) in a check list for the state of Minas Gerais, but more detailed information, including field observations, remain available only for a few taxa (Nogueira & Pol 1998, Nogueira et al. 2003, 2008). In the most recent assessment of the bat diversity in northern Minas Gerais, Falcão et al. (2014) reported 22 species for the Mata Seca State Park, but no voucher material was prepared in this study. Herein we provide a revised list for the small mammals of Jaíba, including information on the sampling techniques, collection sites, taxonomy, and reproductive biology of selected species.

Material and Methods

1. *Sampling techniques and data analysis*

Terrestrial small mammals were captured using live traps measuring 20x20x30 cm, baited with banana, cassava, peanut butter, codfish liver oil, and bologna. Traps were set in line transects, within which they were placed 10 m apart from each other, on the ground or in the lower strata of the dossel. We gave priority to places in which known or potential roosts (burrows, hollow trees, stones, ground vegetation), or water bodies, were available. The number of traps varied from place to place, but usually a total of 100 traps was used in each field trip. The number of traps used each day in each site was multiplied by the number of sampled days to estimate the capture effort, reported as the number of traps x nights (trap-nights).

Bats were sampled mainly at ground level with mist nets opened along trails inside or at the border of forests, close to flowering trees, water bodies, and roosts. In a few instances, hand nets were also employed inside roosts. Nets were usually opened just before dusk and closed between three to five hours later. Because no consistent information on the size and number of nets was recorded for each net session, we do not refer to any sampling effort based on these variables. Instead, we generally refer to "net sessions", which in most cases was equivalent to three 15 m^2 nets opened along 4 hours. Excluding diurnal samplings at roost sites, a total of 44 net sessions were performed in Jaíba. Number of individuals captured in both mist nets and live traps were used to construct individual-based rarefaction curves (Magurran 2011). These analyses were performed in the software PAST version 2.17c (Hammer et al. 2001).

Together with captured specimens, we also considered in this inventory species represented by any sort of material evidence that could lead to an unequivocal taxonomic determination. Thus, carcasses, bone, and tegumental remains were collected and identified by comparison with specimens housed in the Mammals Collection at the Museu Nacional. Non-flying small mammals and a few bats were prepared as skin and skull, whereas most bats were prepared as fluid-preserved specimens. Voucher specimens were deposited at the Adriano Lucio Peracchi Mammal Collection, Laboratório de Mastozoologia, Instituto de Biologia, Universidade Federal Rural do Rio de Janeiro (ALP), and at the Mammals Collection at the Museu Nacional, Universidade Federal do Rio de Janeiro (MN). Select rodent species were also karyotyped following the protocol by Ford & Hamerton (1956). Available karyotype data obtained from the specimens, as well as diagnostic characters relevant for identification, were included in the species accounts as "taxonomic notes" when regarded necessary. For rodents and marsupials, we report the weight and four standard external measurements, recorded in the flesh, respectively with a spring scale and a millimetric rule following Moojen (1943). Measurements of forearm and craniodental features of bats were taken with digital calipers following the protocol described by Williams et al. (1995). In the case of *Micronycteris*, we also measured the condyloincisive length from the anteriormost point of the upper inner incisors to the posteriormost point on the occipital condyles. Reproductive data, when available, is presented. Pregnancy and lactation were detected via palpation, and embryos were measured in natural position (crown-rump length).

Nomenclature and taxonomy adopted here for bats are the same used by Nogueira et al. (2014a). For rodents and marsupials we follow, respectively, Patton et al. (2015) and Gardner (2008).

2. *Study area*

The region of Jaíba is located in northern Minas Gerais state, between the right margin of the Rio São Francisco and the left margin of the Rio Verde Grande (Figure 1). Most specimens obtained in this region came from sites located around Mocambinho, a small village situated close to the right margin of the Rio São Francisco, in the municipality of Jaíba.

The Jaíba region is situated in the southern limit of the Caatinga, close to areas of Cerrado (Figure 1) (Andrade-Lima 1981, Fernandes & Bezerra 1990, Rizzini 1997), and presents a number of distinct vegetation physiognomies, described in detail by Magalhães & Ferreira (1976). The climate is mild semi-arid, characterized by the occurrence of six dry months, from May to October (Nimer 1989). Mean annual rainfall and temperature were, respectively, 832 mm and 26.6°C (data from 1984 to 1994). For the same period, the month with the lowest mean rainfall was July (1.7 mm), whereas the highest mean rainfall was recorded in December (236.9 mm). July was also the

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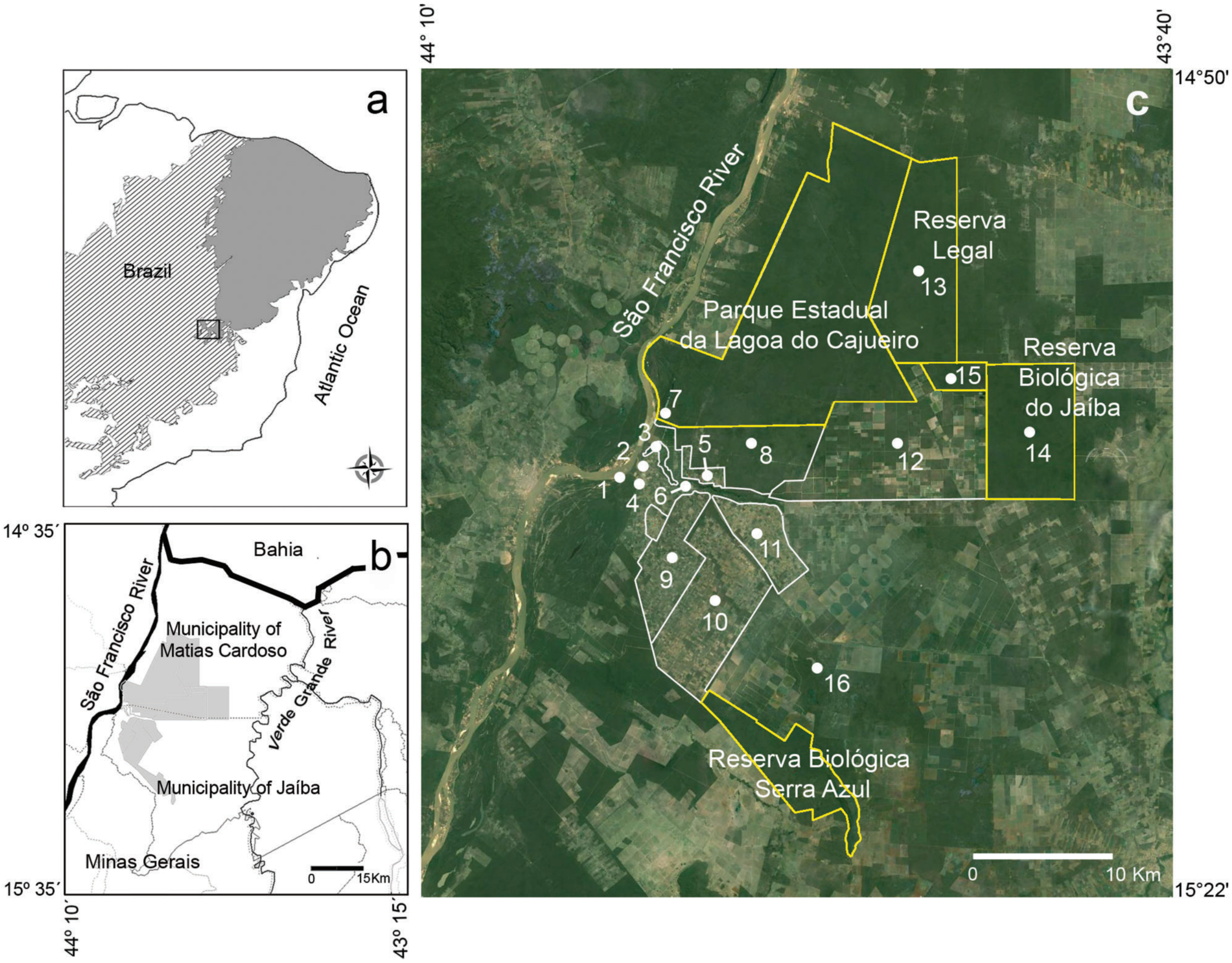

Figure 1. Maps showing the localization of the region of Jaíba at (a) the southern limit of the Caatinga biome (gray), close to areas of Cerrado (diagonal lines), and in (b) northern Minas Gerais state, southeastern Brazil (areas delimited in Figure 1c are represented in gray). Sites where small mammals were sampled at Jaíba are also shown, with delimitation of conservation units (yellow) and areas of the Jaíba Irrigation Project (white) where some of these sites are included (Rebio Serra Azul was not sampled, but site 16 represents the same habitat type: limestone outcrop) (c); see Material and methods for site names.

month with the lowest mean temperature (24.5°C), while the highest mean (28.4°C) was recorded in October. Most altitudes in the Jaíba region range from 440 to 500 m, but the highest site of the region, at Serra Azul, achieves 724 m (Panoso et al. 1976).

Small mammals were sampled in the Jaíba region from March 1990 to July 1995, as part of the faunal monitoring program held by the Companhia do Desenvolvimento dos Vales do São Francisco e do Parnaíba (CODEVASF), in areas under influence of the Projeto Jaíba. Bellow we provide a brief description of the sampling sites (vegetation data mainly based on Magalhães & Ferreira 1976) and information on the period of sampling and sampling effort. Labels used here include capital letters originally applied in the context of the Projeto Jaíba to areas that were subsequently converted into agricultural plots, and local names referring to geographical landmarks (rivers, lakes, mountains).

1. "Riacho Mocambinho" (15°05'49" S, 44°02'04" W): besides the Rio São Francisco and Rio Verde Grande, this is the only perennial water course in the region of Jaíba. Its riparian forest is recognized as an evergreen formation. Bat samples were obtained close to the confluence of the riacho Mocambinho and the Rio São Francisco. At this point, the riparian forest is reduced to a narrow stripe surrounded by *várzea* fields, an evergreen herbaceous-shrubby physiognomy, disturbed by anthropic influence. Capture effort: two net sessions (April 11 and October 24, 1994).
2. "Mocambinho" (15°05'27" S, 44°01'08" W): urban village located at the right margin of the Rio São Francisco, where roofs of residences were searched for the presence of bats. Capture effort: one net session on March 12, 1990; and two on October 6 and 21, 1994.
3. "Lagoa do Sossego" (15°04'39" S, 44°00'33" W): a marginal lagoon of the Rio São Francisco. Terrestrial small mammal capture effort: 17 trap-nights on July 10–11, 1990; and 100 trap-nights on November 5–10, 1993. Bat capture effort: one net session on August 20, 1992.
4. "Campus Avançado de Monitoramento" (CAM) (15°06'05" S, 44°01'13" W): located close to the Rio São Francisco, this site is characterized by the presence of *várzea* fields and the anthropic fields. This latter formation is composed by shrubs, grasses, and sparse trees, including

invasive and local species. We frequently observed *Hymenaea* and *Calliandra* (Leguminosae Fabaceae-Mimosoidea) at this site. Bat capture effort: seven net sessions (April 4–5, 17–18, 27, 30, 1994; and May 2, 1994).

5. "Reserva da Fazenda Yamada" ("Mata da Agroceres") (15°04'18"S, 43°59'44"W): this area is adjacent to the Dreno Jaíba and is covered by a subcaducifolious forest, with a discontinuous upper stratum of canopy reaching 19 m in height. We also noticed the presence of *Cereus jamacaru* (Cactaceae), endemic to the Caatinga, at this site. Terrestrial small mammal capture effort: 126 trap-nights on March 10–12, 1990; 147 on July 7–11, 1990; 125 on August 18–22, 1990; 150 on June 23–25, 1992; and 90 on October 22–25, 1992. Bat capture effort: two net sessions on August 19 and 25, 1992, and one on October 10, 1994, in a trail inside the forest.
6. "Dreno Jaíba" (15°05'59" S, 43°59'24" W) (Figure 2): a natural depression, also known as "Riacho Tapera", which is an extension of the "Lagoa do Sossego". Often flooded during the rainy season, as a result of the overflow of the Rio São Francisco and of the lagoon. The "Dreno Jaíba" is adjacent to the subcaducifolious forest of "Reserva da Fazenda Yamada". Terrestrial small mammals capture effort: 106 trap-nights on August 17–22, 1992. Bat capture effort: four net sessions close to the body of water (July 11, 1990; October 13 and 20, 1994; and February 21, 1995).
7. "Lagoa do Cajueiro" (15°03'16" S, 44°00'19" W): a lake complex that nowadays is part of a conservation area (Parque Estadual da Lagoa do Cajueiro). Terrestrial small mammals capture effort: 64 trap-nights set on June 24–25, 1992. Sixteen traps were set at the margin of one of the lakes, situated at Fazenda Profaz, eight at a dry forest situated between the lake and the Rio São Francisco, and eight in grasslands at the margin of this river, in the same area.
8. "Fazenda Solagro" (15°05'05" S, 43°56'31" W): at this site bats were sampled in mist nets set at the border of a cattle pond (Figure 3). This pond was available even during the dry season. Vegetation around the pond was characterized as anthropic fields. Bat capture effort: two net sessions (November 14, 1994; January 13, 1995).

9/10. "Area B" (15°10'41.72"S, 43°58'14.82" W) and "Area A" (15°8'39.25"S, 44°0'19.11"W): these sites were visited before their conversion into agricultural plots. Traps and nets were set in places dominated by homogeneous shrubby caatinga 2–3 m high. Terrestrial small mammals capture effort: 165 trap-nights on March 9–12, 1990; 256 trap-nights on July 6–11, 1990; and 60 trap-nights on November 6-9, 1993. Bat capture effort: three net sessions on January 10–12, 1995.

11. "Area F" (15°08'19"S, 43°56'10"W): at this area, the original cover of arboreal caatinga had been completely removed when traps were set. It was separated from the adjacent Area A, which was still bearing its forests at that moment, by an irrigation channel and a road. Samples were obtained in an agricultural plot mainly explored for banana plantations (*Musa*, Musaceae). A small orchard with fruiting trees, such as guavas (*Psidium guayava*,

Figure 2. Dreno Jaíba, a natural depression at the right margin of the Rio São Francisco, region of Jaíba, northern Minas Gerais state. A subcaducifolious forest bordered the Dreno at this collecting site.

Figure 3. Cattle pond at Fazenda Solagro, region of Jaíba, northern Minas Gerais state. The surrounding area is characterized as anthropic fields.

Myrtaceae) and mangos (*Mangifera indica*, Anacardiaceae), was also present at this site. Terrestrial small mammals capture effort: 53 trap-nights on August 19–22, 1990. Bat capture effort: two net sessions (June 16, 1994; October 11, 1994).

12. "Area C2" (15°04'19" S, 43°50'43" W): this site was predominantly composed by arboreal caatinga, a deciduous formation in which the highest trees achieve 15 to 30 m. Captures occurred during the clearing of the area to form agricultural plots, by sampling in recently disturbed forest edges. Terrestrial small mammals capture effort: 120 trap-nights on August 18–22, 1990; 270 trap-nights on June 19–22, 1992; 20 trap-nights on August 25–27, 1992; and 120 trap-nights between March, 30 and April, 2, 1994.
13. "Reserva Legal" (14°57'52" S, 43°50'3" W): a 20.281 ha area, originally designated to be a forest reserve, covered mainly by arboreal caatinga. Terrestrial small mammals capture effort: 50 trap-nights on September 25-28, 1990; 345 trap-nights on August 21–27, 1992, and 120 traps-nights between March 30 and April 2, 1994. Bat capture effort: two net sessions.
14. "Reserva Biológica do Jaíba" (Rebio Jaíba; 15° 04'7.25"S, 43°45'37"W): a 6,358 ha area covered mainly by arboreal caatinga (Figure 4). Trees at this formation range from 6 to 12 m in height, and the shrubby strata included several lianas, cactus (e.g. *Cereus*), and bromeliads. It includes a marked anthropic area locally known as "Lagoa Santa", a water body already in accentuated drought in August, 1992, and with recorded presence of domestic animals. Terrestrial small mammals capture effort: 100 trap-nights on September 25–28, 1990; 15 on August 21, 1992; and 129 on November 6–9, 1993. Bat capture effort: two net sessions on August 21, 1992; and two on May 3 and 5, 1994.
15. "Corredor Ecológico" (15°02'00" S, 43°48'42" W): this area connects the reserve areas "Reserva Legal" and "REBIO Jaíba", presenting the same type of vegetation (arboreal caatinga). As in the preceding site, traps were set in a trail perpendicular to the road that crosses the "Reserva Legal" and the "Corredor Ecológico". Terrestrial small mammals capture effort: 50 trap-nights between September 25–28, 1990.
16. "Fazenda Serra Azul": 18 km from the village of Mocambinho, in the road to Jaíba. The sampling area was a limestone outcrop locally known as "Morro Solto" (15°13'14" S, 43°54'06" W; ca. 510 m elevation). This *serrote* is covered by arboreal caatinga at its slopes and hyper-xerophytic at its top (Figure 5). This latter vegetation is characterized by the dominance of Cactaceae and bromeliads. Limestone cavities are abundant at Morro Solto, which is also characterized by the presence of some mesophytic plants such as *Cecropia* and *Ficus*. Terrestrial small mammals effort: 166 trap-nights on March 28–30, 1994. Traps were set in the limestone outcrop (46) and in the bordering dry forest (37). Bat effort: 11 net sessions (March 31, 1994; April 6–7, 9, 1994; June 14, 1994; August 26, 1994; October 14 and 25, 1994; February 20 and 28, 1995; and March 1, 1995) in the same habitats reported for terrestrial small mammals.

Figure 4. General view of the Reserva Biológica do Jaíba, region of Jaíba, northern Minas Gerais state, during the dry season. The typical vegetation here is the arboreal caatinga.

Results

With a total effort of 2964 trap-nights, 44 net sessions, and occasional samplings at roosts, we captured 893 small mammals, including 39 marsupials, 118 rodents, and 714 bats. A total of 403 specimens were prepared as vouchers, including 38 marsupials, 119 rodents, and 246 bats. Three additional rodents were recorded, one based on a manual capture and two based on material obtained from local hunters. The total numbers of species and genera for each of these orders are, respectively, 4/4, 13/13, and 29/23, for a total of 46 species, 40 genera, and 11 families. Species accumulation curves for both nonflying-small mammals and bats (Figures 6 and 7) show a tendency to stabilization, suggesting that most species prone to be captured by mist nets and live traps in the visited habitats were sampled.

The more common rodent species in our traps were *Thrichomys apereoides* (34% among rodents only and 25% among non-flying small mammals) and *Galea spixii* (18% and 13% for the same groups, respectively), while the more frequently captured marsupials were *Marmosops incanus* (49% among marsupials only and 13% among non-flying small mammals) and *Monodelphis domestica* (31% and 8% for the same groups, respectively). Among bats captured in mist nets (individuals captured directly from roosts excluded), *Desmodus rotundus* was the most common species (16%), which is related to our sampling at Morro Solto, where we found a large colony (ca. 150 individuals) in a cave. The second most common bat in mist nets was *Artibeus planirostris* (12%), a species found to be widespread in the region, as were three other bat species, similarly common in our sample (*Glossophaga soricina* [10%], *Phyllostomus discolor* [10%], and *Carollia perspicillata* [9%]). Together, these five species accounted for 50% of our captures in mist nets, while the other 50% was included in captures from 21 species. This abundance pattern, with few common species and a larger number of rare ones (Figure 8), was also observed in our data from live traps (Figure 9). Details of our captures at Jaíba are presented in the following account (measurements from voucher specimens in Tables 1 and 2).

Species accounts
Order Didelphimorphia
Family Didelphidae Gray, 1821
Didelphis albiventris Lund, 1840
VOUCHER MATERIAL (4): males – MN 34403, 34438, 43812; female – MN 34390.
FIELD NOTES: the white-eared opossum was recorded in distinct habitats at the region of Jaíba, including the subcaducifolious forest at the Mata da Agroceres, the shrubby caatinga at the Area B, and the arboreal caatinga at the Rebio Jaíba. Juvenile specimens were recorded in February.

Gracilinanus agilis (Burmeister, 1854)
VOUCHER MATERIAL (4): males – MN 29043, 34392, 34399; female – MN 34393.
FIELD NOTES: captured at Dreno Jaíba and at the Rebio Jaíba.

Figure 5. Limestone outcrop of Morro Solto, Fazenda Serra Azul, region of Jaíba, northern Minas Gerais state, with a view of the hyper-xerophytic caatinga (front) and the arboreal caatinga (back).

Marmosops incanus (Lund, 1841)
VOUCHER MATERIAL (22): males – MN 28875, 28876, 28888, 29006, 29063, 33839, 33841, 34391, 34395, 34396, 34397, 34401, 34402, 34428, 46598, 81179; females – MN 28887, 29024, 29431, 34398, 46600, 46601.

FIELD NOTES: individuals were captured at Areas A and B, Mata da Agroceres, Rebio Jaíba, and Reserva Legal. Young specimens were obtained in March. Specimens obtained during this study were kept in captivity and analyzed in studies of age structure and reproduction in this species by Oliveira et al. (1992) and

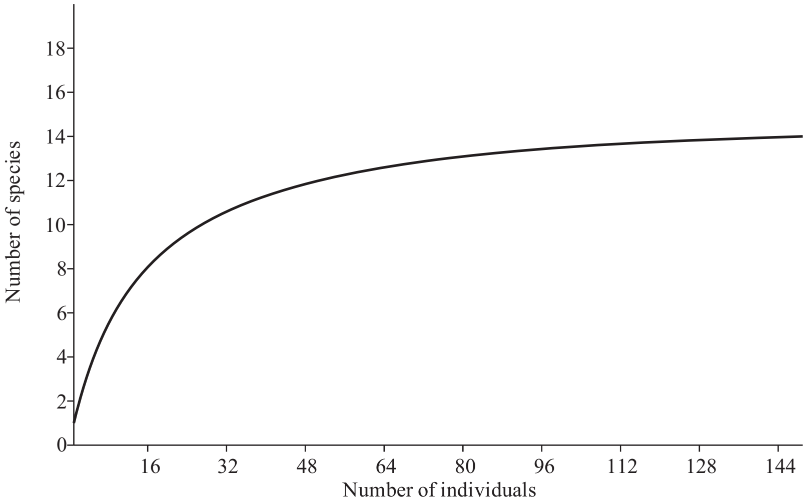

Figure 6. Rarefaction curve for non-flying small mammals (rodents and marsupials) sampled in live traps in the region of Jaíba, northern Minas Gerais state (captures inside roosts excluded).

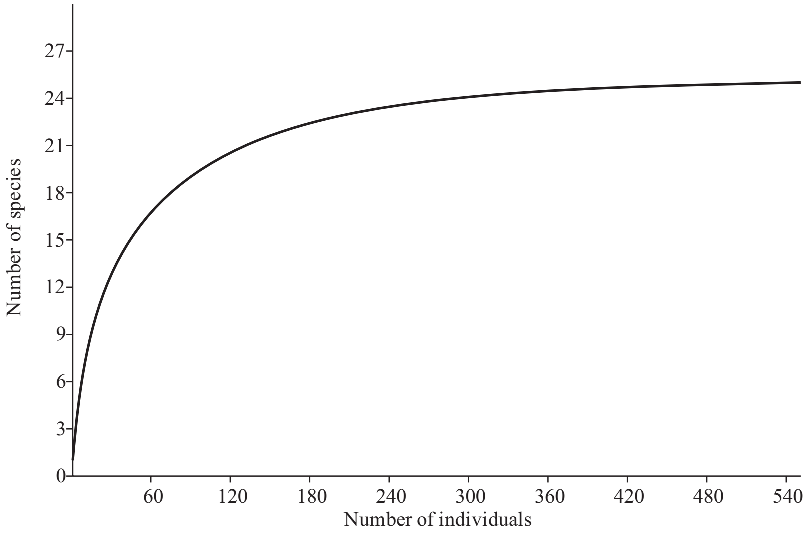

Figure 7. Rarefaction curve for bats sampled in mist nets in the region of Jaíba, northern Minas Gerais state (captures in front or inside roosts excluded).

Lorini et al. (1994), revealing an interesting pattern of semelparity previously unrecorded for the genus.

Monodelphis domestica (Wagner, 1842).
Voucher material (8): males – MN 28879, 28892, 29010, 29012, 29029, 34394, 81180; female – MN 34400.
Field notes: Captured at the Mata da Agroceres, Rebio Jaíba, and Fazenda Serra Azul.

Order Rodentia
Family Muridae
Calomys expulsus (Lund, 1841)
Voucher material (21): males – MN 29002, 29004, 29005, 29017, 29021, 29025, 29032, 29040, 29042, 29048, 34420, 81143; females – MN 29003, 29033, 29039, 29041, 29050; indet. – 43831–34.
Field notes: captured at Mata da Agroceres, Areas A, F, and C2, at Fazenda Serra Azul, and at the borders of Lagoa do

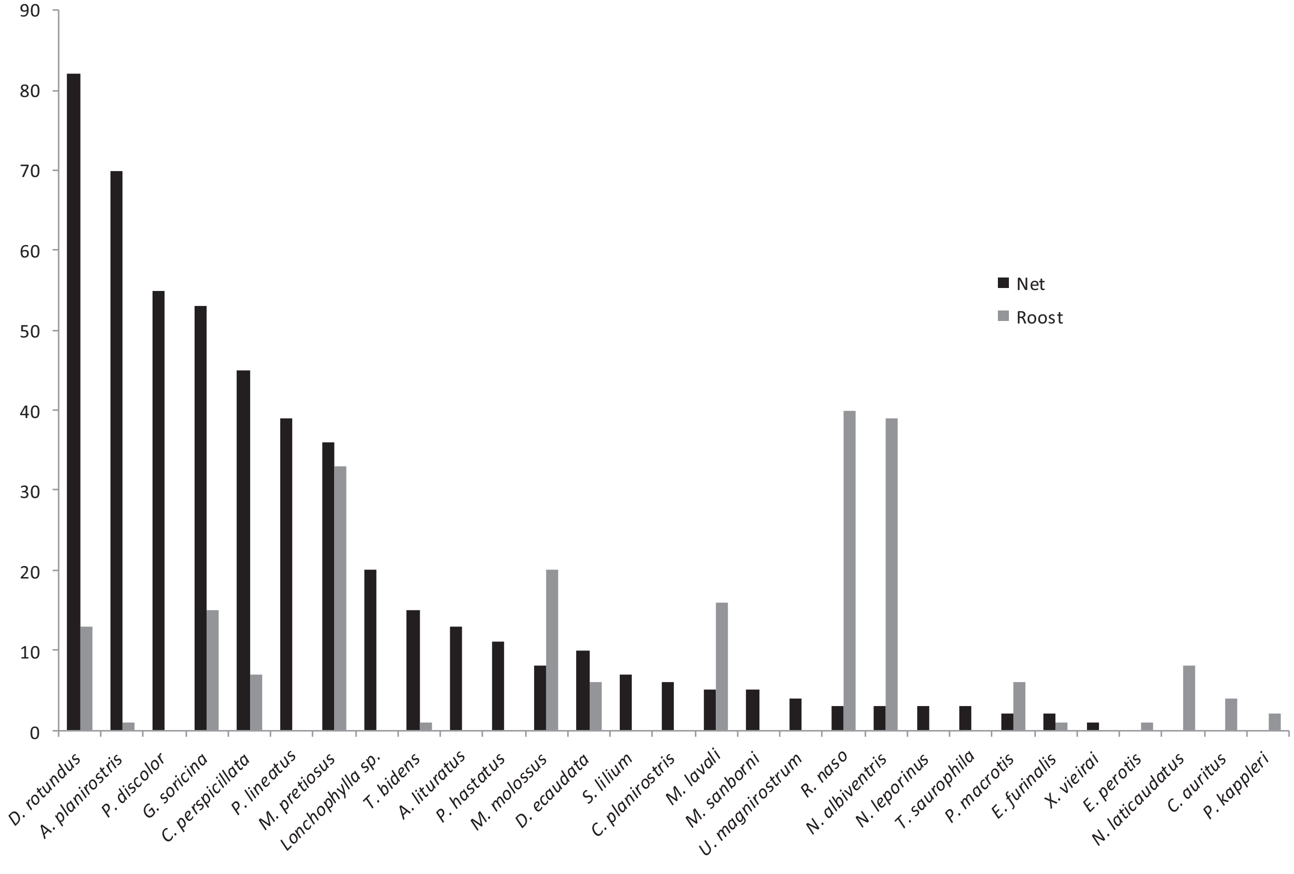

Figure 8. Capture numbers of bats sampled in mist nets in the region of Jaíba, northern Minas Gerais state (captures in front or inside roosts excluded).

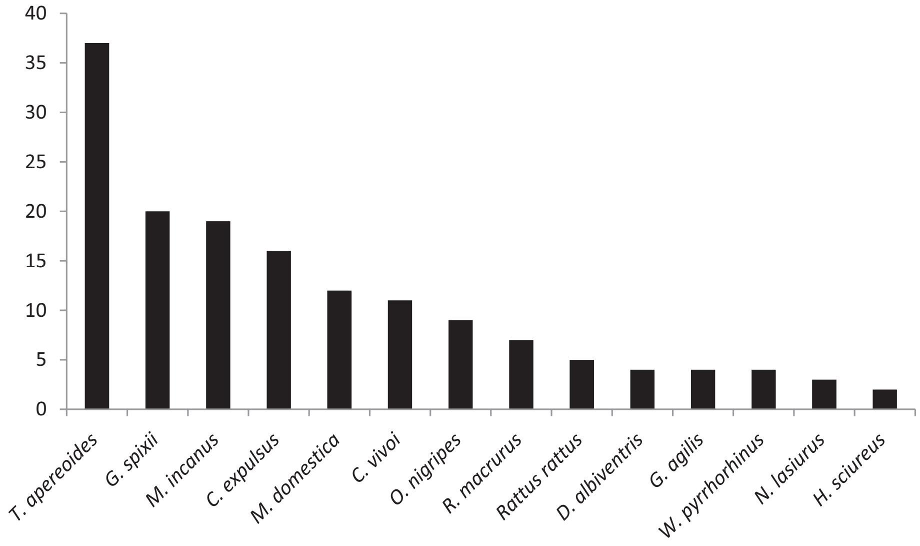

Figure 9. Capture numbers of non-flying small mammals (rodents and marsupials) sampled in live traps in the region of Jaíba, northern Minas Gerais state (captures inside roosts excluded).

Sossego, Dreno Jaíba, and Lagoa do Cajueiro during 1990. A female captured on August 21, 1990, in Area F had four embryos. Although fairly abundant during the field surveys in 1990, this species was not recorded in Jaíba between 1992–1994, suggesting that local populations may alternate periods of abundance and reduction in subsequent years. The finding of old skeletons in cisterns, in the village of Mocambinho, in February 1993, may constitute additional evidence of a previous outbreak of this species in the Jaíba region.

Necromys lasiurus (Lund, 1841)
VOUCHER MATERIAL (3): males – MN 29019, 29020, 29031.
FIELD NOTES: captured close to the Lagoa do Sossego and at Dreno Jaíba. This otherwise ubiquous and abundant rodent was recorded in the humid areas near the Rio São Francisco in lower densities than other sigmodontines of similar size recorded in the region, *Calomys expulsus* and *Oligoryzomys nigripes*.

Oligoryzomys nigripes (Olfers, 1818)
VOUCHER MATERIAL (9): males – MN 29013–14, 29026, 29051–52, 29055–56, 34018; female – MN 29038.
FIELD NOTES: captured at Mata da Agroceres, Dreno Jaíba, and Reserva Legal. Similarly to the pattern revealed for *Calomys expulsus*, most individuals were collected during July and August, 1990 in the more humid areas of Mata da Agroceres and Dreno Jaíba. The only exception was a specimen obtained in August 1992 in the Reserva Legal (Parque Florestal da Jaíba).

Cerradomys vivoi Percequillo, Hingst-Zaher & Bonvicino, 2008
VOUCHER MATERIAL (11): males – MN 29035, 34433, 34435, 34436, 43814, 43816, 46456; females – MN 29057, 34432, 34434, 43815.
FIELD NOTES: captured at Dreno Jaíba and at riacho Mocambinho, humid areas near the Rio São Francisco. Abundance pattern of this larger sigmodont was different from those of the former three species, with more than 80% of the specimens being collected in 1993.
TAXONOMY: Six specimens were karyotyped (MN 34433, 34434, 34436, 43814, 43815, and 43816), revealing a diploid number (2n) varying between 50 and 52, but with a constant fundamental number (FN) = 62. This variability is due to

Table 1. Weight (g) and body measurements (mm) of marsupials and rodents from the region of Jaíba, northern Minas Gerais state, southeastern Brazil. For each species we present mean values, range (in parentheses), and sample sizes.

Species	Weight	Head-and-Body length	Tail length	Hindfoot (with claw)	Ear from notch
Didelphis albiventris	566.3 (415.0–700.0) 4	299.5 (270.0–323.0) 4	297.5 (280.0–314.0) 4	47.8 (42.0–64.0) 4	52.7 (47.0–58.0) 4
Gracilinanus agilis	26.0 (16.0–32.0) 3	100.8 (88.0–111.0) 4	147.7 (138.0–157.0) 4	15.5 (15.0–16.0) 4	23.0 (21.0–25.0) 4
Marmosops incanus	69.9 (46.0–108.0) 10	148.1 (143.0–160.0) 10	187.7 (160.0–205.0) 9	19.6 (17.0–22.0) 10	27.8 (23.0–32.5) 10
Monodelphis domestica	49.3 (39.0–64.0) 4	123.7 (120.0–126.0) 3	86.0 (75.0–87.0) 3	20.3 (20.0–21.0) 3	18.3 (16.5–20.0) 3
Calomys expulsus	23.2 (21.0–41.0) 14	86.4 (72.0–105.0) 12	73.1 (51.0–77.0) 12	18.8 (15.0–21.5) 12	13.9 (12.0–15.8) 12
Necromys lasiurus	41.3 (27.0–50.0) 3	112.3 (91.0–107.0) 3	79.0 (71.0–85.0) 3	23.0 (21.0–24.0) 3	15.6 (15.0–16.0) 3
Oligoryzomys nigripes	38 (24.0–72.0) 7	94.7 (84.0–96.0) 6	115.1 (99.0–134.0) 7	24.2 (20.4–26.0) 6	14.7 (13.0–16.0) 7
Cerradomys vivoi	77.0 (65.0–90.0) 10	147.8 (137.0–159.0) 11	174.9 (165.0–200.0) 11	34.1 (32.5–36.0) 11	21.7 (18.0–23.0) 11
Holochilus sciureus	87.0 (75.0–100.0) 3	151.0 (144.0–158.0) 2	131.0 (123.0–139.0) 2	37.5 (37.0–38.0) 2	16.5 (16.0–17.0) 2
Rhipidomys macrurus	62.0 (70.0–102.0) 4	142.3 (132.0–152.0) 5	180–8 (166.0–216.0) 4	27.8 (26.0–29.0) 5	19.5 (17.0–23.0) 5
Wiedomys pyrrhorhinos	41.3 (28.0–51.0) 4	115.8 (108.0–122.0) 4	184.8 (160.0–197.0) 4	26.5 (26.0–27.0) 4	20.3 (19.0–22.0) 4
Rattus rattus	53.7 (37.0–94.0) 3	134.0 (116.0–152.0) 2	177.5 (148.0–207.0) 2	35 (33.0–34.0) 2	20.0 (20.0–20.0) 2
Galea spixii	321.1 (248.0–429.0) 14	247.8 (234.0–273.0) 14	-	52.5 (49.0–58.0) 12	29.2 (25.0–33.0) 14
Thrichomys apereoides	202.3 (91.0–337.0) 17	190.3 (145.0–225.0) 23	174.5 (146.0–203.0) 21	42.5 (36.0–48.0) 22	21.9 (19.0–26.0) 22

Table 2. Forearm and craniodental measurements (mm) of bats from the region of Jaíba, northern Minas Gerais state, southeastern Brazil. Data for each species (separated by sex) include mean and range values (n = sample size).

Species	*n*, sex	Forearm length	Greatest length of skull	Zygomatic breadth	Postorbital breadth	Braincase breadth	Mastoid breadth	Maxillary toothrow length	Breadth across molars	Breadth across canines
P. kappleri	1 ♀	48.7	17.0	10.1	3.3	7.4	8.5	6.7	7.4	4.4
P. macrotis	4 ♂♂	38.5 (38–39.4)	13.1 (13–13.2)	7.7 (7.5–7.9)	2.8 (2.5–3.0)	6.3 (6.1–6.6)	7.1 (6.8–7.3)	5.0 (4.9–5.1)	5.5 (5.3–5.8)	3.0 (3–3.2)
	3 ♀♀	42.0 (41.6–42.4)	14.0 (13.9–14.1)	8.2 (7.9–8.4)	2.9 (2.8–3.0)	6.3 (6.3–6.4)	7.3 (7.3–7.4)	5.3 (5.3–5.4)	6.0 (5.9–6.1)	3.5 (3.4–3.6)
R. naso	3 ♂♂	39.7 (38.0–40.8)	12.4 (12.3–12.4)	7.3 (7.3–7.4)	2.7 (2.6–2.9)	6.3 (6.1–6.4)	6.6 (6.6–6.7)	4.4 (4.4–4.5)	4.6 (4.5–4.8)	3.4 (3.3–3.5)
	9 ♀♀	41.0 (39.2–43.1)	12.2 (11.8–12.5)	7.4 (7.2–7.6)	2.6 (2.4–2.8)	6.4 (6.3–6.7)	6.7 (6.5–6.8)	4.4 (4.3–4.5)	4.6 (4.5–4.9)	3.2 (3.0–3.4)
M. sanborni	1 ♂	34.5	17.4	-	4.2	7.4	8.4	5.9	5.6	2.8
	2 ♀♀	35.0 (34.9–35.0)	17.8 (17.9–17.7)	8.1 (8.1–8.2)	4.0 (4.0–4.0)	7.4 (7.4–7.5)	8.4 (8.2–8.6)	6.0 (5.9–6.0)	5.5 (5.4–5.6)	2.8 (2.8–2.9)
D. rotundus	3 ♂♂	62.2 (61.7–63.2)	25.4 (25.2–25.8)	12.6 (12.5–12.7)	5.7 (5.6–5.8)	12.4 (12.3–12.7)	12.7 (12.6–12.9)	3.7 (3.5–3.8)	7.1 (6.75–7.5)	6.5 (6.5–6.6)
	1 ♀	66.4	25.8	12.5	5.7	12.2	12.7	3.6	6.5	6.3
D. ecaudata	4 ♂♂	53.6 (52.8–54.7)	22.8 (22.4–23.0)	12.7 (12.4–13.0)	6.6 (6.4–6.9)	11.1 (10.9–11.4)	11.8 (11.6–12.2)	3.4 (3.3–3.6)	6.0 (5.9–6.3)	5.4 (5.4–5.5)
	1 ♀	55.6	23.1	13.2	7.0	11.5	12.2	3.7	6.2	5.5
C. auritus	2 ♂♂	82.9 (82.8–83.0)	36.6 (36.5–36.7)	19.6 (19.5–19.7)	6.2 (6.17–6.2)	14.0 (14.0–14.0)	18.0 (17.9–18.1)	13.4 (13.2–13.5)	12.2 (12.0–12.3)	7.9 (7.8–8.0)
	1 ♀	84.5	37.6	20.1	6.4	14.4	17.9	13.5	12.7	8.0
P. discolor	3 ♀♀	59.4 (58.8–60.7)	29.4 (29.0–29.9)	15.3 (15.1–15.5)	6.5 (6.3–6.7)	12.3 (12.0–12.4)	14.5 (14.5–14.5)	9.2 (9.0–9.4)	9.8 (9.5–10.0)	6.7 (6.6–6.7)
P. hastatus	2 ♂♂	83.8 (83.0–84.5)	38.9 (38.5–39.3)	21.0 (20.7–20.9)	7.5 (7.4–7.6)	13.9 (13.9–13.9)	19.9 (19.8–19.9)	13.00 (12.9–13.2)	13.3 (13.2–13.4)	9.3 (9.2–9.3)
	1 ♀	81.0	37.0	20.0	7.1	14.0	18.0	12.0	13.0	8.5
T. bidens	2 ♂♂	58.3 (58.2–58.5)	28.2 (28.2–28.3)	13.3 (13.2–13.5)	6.1 (6.0–6.25)	10.8 (10.8–10.8)	12.9 (12.9–13.0)	9.8 (9.8–9.9)	8.6 (8.6–8.7)	5.9 (5.9–5.9)
	3 ♀♀	56.5 (56.2–57.2)	27.7 (27.5–27.9)	13.2 (13.1–13.4)	5.8* (5.6–6.0)	10.5 (10.4–10.6)	12.8 (12.8–12.8)	9.6 (9.5–9.8)	8.6 (8.5–8.9)	5.9 (5.7–6.0)
T. saurophila	1 ♂	56.6	27.9	-	5.5	10.0	12.9	9.7	8.7	5.6
	2 ♀♀	58.4 (56.8–60.0)	28.9 (28.9–29.0)	14.4 (14.3–14.5)	5.3 (5.3–5.4)	10.5 (10.4–10.6)	- 13.33	10.0 (9.9–10.1)	8.7 (8.5–8.9)	5.9 (5.8–6.0)
G. soricina	9 ♂♂	35.4 (33.7–36.5)	20.6 (20.0–21.2)	9.2 (8.9–9.6)	4.7 (4.5–5)	8.6 (8.35–8.75)	8.8 (8.5–9.2)	7.1 (6.8-7.4)	5.4 (5.2–5.6)	3.9 (3.7–4.2)
	7 ♀♀	35.9 (34.5–36.9)	20.9 (20.5–21.1)	9.3 (9.0–9.7)	4.7 (4.7–4.8)	8.8 (8.5–9.0)	8.9 (8.7–9.1)	7.2 (7.1–7.4)	5.4 (5.1–5.8)	4.0 (3.7–4.2)
Lonchophylla sp.	3 ♂♂	36.7 (35.2–37.6)	22.7 (22.2–22.9)	8.9 (8.8–9)	4.2 (4.2–4.3)	8.5 (8.4–8.6)	9.10 (8.9–9.3)	7.7 (7.6–7.8)	5.0 (5–5.1)	3.7 (3.7–3.7)
	1 ♀	34.1	22.7	8.9	4.3	8.6	9.1	7.7	5.2	3.6
C. perspicillata	4 ♂♂	43.7 (43.6–43.9)	23.2 (23.1–23.4)	11.7 (11.6–12.0)	5.6 (5.5–5.8)	9.8 (9.7–10.0)	11.4 (11.2–11.6)	7.8 (7.7–7.9)	8.2 (8.0–8.6)	5.4 (5.2–5.6)
	4 ♀♀	42.5 (40.6–44.0)	23.0 (22.5–23.4)	11.1 (10.8–11.3)	5.7 (5.5–5.8)	9.4 (8.9–9.8)	11.2 (10.8–11.6)	7.8 (7.7–8.0)	8.2 (7.9–8.6)	5.2 (5.0–5.4)
A. lituratus	2 ♂♂	69.8 (68.3–71.2)	31.6 (31–32.2)	19.2 (18.6–19.8)	6.6 (6.2–7.0)	13.0 (12.9–13.2)	16.8 (16.3–17.2)	11.6 (11.6–11.6)	14.2 (14.0–14.5)	9.2 (9.1–9.2)
	1 ♀	72.9	32.4	19.5	7.2	12.5	17.5	11.2	13.7	8.7
A. planirostris	9 ♂♂	60.01 (57.9–62.1)	27.6 (27.2–28.6)	17.2 (16.5–17.6)	7.1 (6.7–7.5)	12.2 (11.7–12.7)	15.1 (14.6–15.9)	10.13 (10.0–10.4)	12.4 (12.0–12.8)	8.0 (7.5–8.3)
	4 ♀♀	60.5 (60.0–61.6)	27.9 (27.6–28.2)	17.1 (16.9–17.7)	7.1 (6.9–7.3)	12.1 (12.0–12.3)	14.9 (14.4–15.6)	10.1 (10.0–10.3)	12.3 (12.0–12.7)	7.9 (7.8–8.0)
P. lineatus	8 ♂♂	46.0 (42.5–49.4)	24.7 (23.9–25.7)	14.3 (13.8–15.0)	6.1 (5.9–6.4)	10.5 (10.2–10.8)	12.2 (11.8–12.6)	8.7 (8.4–9.2)	10.1 (9.6–10.5)	6.0 (5.6–6.3)
S. lilium	4 ♂♂	42.9 (42.0–43.7)	23.0 (22.9–23.1)	14.3 (13.8–14.7)	6.0 (5.9–6.2)	10.3 (10.2–10.5)	12.6 (12.5–12.9)	6.6 (6.3– 6.9)	8.2 (8– 8.4)	6.5 (6.4–6.6)
N. albiventris	5 ♂♂	60.0 (59.0–61.1)	19.36 (19.3–19.6)	14.59 (14.2–15.1)	5.9 (5.8–6.3)	11.0 (10.8–12.5)	14.5 (13.7–15.6)	7.3 (7.2–7.4)	9.1 (9.0–9.5)	7.0 (6.6–7.3)
	5 ♀♀	58.0 (57.2–59.2)	18.7 (18.3–18.9)	13.9 (13.3–14.5)	5.7 (5.6–5.9)	11.0 (10.6–11.4)	12.4 (12.0–13.2)	7.1 (7.0–7.4)	8.9 (8.7–9.2)	6.4 (6.2–6.5)
N. leporinus	1 ♂	86.65	26.9	19.9	6.7	13.5	17.3	10.5	12.8	9.2
C. planirostris	3 ♂♂	31.9 (29.9–33.1)	16.7 (16.5–16.8)	11.0 (10.9–11.0)	4.2 (4.2–4.3)	7.9 (7.8–8.2)	10.3 (9.7–11.2)	6.2 (6.1–6.5)	7.5 (7.4–7.5)	4.7 (4.6–4.8)
	2 ♀♀	31.6 (31.5–31.8)	15.8 (15.7–16.0)	10.5 (10.5–10.6)	4.4 (4.3–4.6)	7.9 (7.8–8)	10.1 (9.9–10.3)	6.1 (5.9–6.2)	7.5 (7.4–7.5)	4.3 (4.3–4.4)
E. perotis	1 ♀	80.3	33.4	19.3	5.5	14.3	15.5	12.9	12.9	8.5
M. molossus	4 ♂♂	40.0 (38.9–41.4)	17.6 (17.4–17.8)	10.8 (10.6–10.9)	3.8 (3.6–3.9)	8.9 (8.7–9.1)	10.8 (10.4–11.8)	6.2 (6.0–6.5)	7.7 (7.4–7.8)	4.5 (4.4–4.5)
	2 ♀♀	39.4 (38.9–39.8)	16.8 (16.5–17.1)	10.5 (10.6–10.4)	3.8 (3.9–3.6)	8.6 (8.6–8.7)	10.3 (10.4–10.2)	6.0 (6.0–6.0)	7.7 (8.0–7.5)	4.4 (4.3–4.4)
M. pretiosus	4 ♀♀	45.7 (45.1–46.0)	20.1 (19.8–20.4)	12.7 (12.4–12.9)	4.1 (4.0–4.2)	10.1 (10.0–10.4)	12.4 (12.0–12.8)	7.3 (7.3–7.4)	9.1 (8.93–9.29)	5.2 (5.1–5.3)
N. laticaudatus	1 ♂	43.8	17.9	10.7	4.2	8.8	10.2	6.5	7.4	4.0
E. furinalis	1 ♀	39.0	15.9	11.1	3.9	7.2	8.4	5.9	6.6	5.0
M. lavali	2 ♂♂	34.5 (34.1–35.0)	14.2 (14.1–14.3)	-	3.4 (3.4–3.5)	6.7 (6.6–6.8)	7.2 (7.2–7.2)	5.3 (5.3–5.3)	5.5 (5.5–5.5)	3.4 (3.4–3.5)

*n = 2

robertsonian rearrangments, the 2n = 50 karyotype presenting a median metacentric pair that is absent in the 2n = 52 karyotype, which by its turn presents two pairs of small acrocentric chromosomes, individuals with 2n = 51 being heterozygote with respect to this rearrange (Pessôa et al. 1994). Specimens MN 34432 - 35436 were designated as paratypes of *Cerradomys vivoi* by Percequillo et al. (2008).

Holochilus sciureus (Wagner, 1842)
VOUCHER MATERIAL (4): males – MN 34419, 43825; females – MN 81145; 81181.
FIELD NOTES: captured at Mocambinho (1) and at Lagoa do Sossego (3). The specimen from Mocambinho was collected from the mouth of a domestic cat.
TAXONOMY: Specimen MN 43825 was karyotyped, revealing 2n = 56 and FN = 56. This karyotype, together with the short hindfeet lacking the hypothenar pad, tail shorter than head and body, and the lophs/ids compressed with strongly acute, prismatic and sharp outer margins (Gonçalves et al. 2015), conform to the diagnostic characters of *Holochilus sciureus* among other similar species of the genus.

Rhipidomys macrurus (Gervais, 1855)
VOUCHER MATERIAL (8): males – MN 28874, 34408, 34410, 46563, 81142, 81174; females – MN 34409, 34429.
FIELD NOTES: captured at Area B, Mata da Agroceres, and Rebio Jaíba. The specimen MN 34429, captured in Mata da Agroceres on June 26, 1992, gave birth to two cubs in the next day, one of which lived in captivity for 14 months.
TAXONOMY: Specimen MN 81174, a juvenile male collected in "Lagoa do Sossego" in August 11, 1993, showed 2n = 44 and FN = 48, the karyotype composed of 18 pairs of acrocentric chromosomes, varying from large to small, a pair of submetacentric chromosomes of medium size, and 2 small metacentric pairs. The X chromosome is a large submetacentric and the Y is a small acrocentric (Corrêa and Pessôa, 1996).

Wiedomys pyrrhorhinos (Wied-Neuwied, 1821)
VOUCHER MATERIAL (4): males – MN 34413, 62180, 62081; female – MN 34412.
FIELD NOTES: captured only at the Rebio Jaíba, the driest section of the Jaíba region. This species was only recorded in the 1992-1993 field surveys.
TAXONOMY: The longer molar toothrow, the broader incisive foramina, and the lack of the alisphenoid strut in the specimens from Jaíba conform to the recognized distinctive characters of *W. pyrrhorhinos* with respect to *W. cerradensis*, a species described from Jaborandi, Bahia, by Gonçalves et al. (2005).

Rattus rattus (Linnaeus, 1758)
VOUCHER MATERIAL (5): males – MN 29046, 29047, 29053, 34421; female – MN 29045.
FIELD NOTES: captured inside or near residences in Mocambinho ($n = 1$) and in the Area F ($n = 3$), but also at the Rebio Jaíba ($n = 1$), in a road crossing the biological reserve. It is interesting to note that the record from Rebio Jaíba was obtained in a region distant from any human settlement, a relatively unusual condition for *Rattus*, and may be due to its accidental transportation along the dirt road that crossed the reserve.

Family Erethizonthidae
Coendou prehensilis (Linnaeus, 1758)
VOUCHER MATERIAL (1): MN 29080.
FIELD NOTES: spines that allowed the identification of this species were obtained from a hunter from Fazenda Santa Idália, municipality of Matias Cardoso.

Family Dasyproctidae
Dasyprocta azarae Lichtenstein, 1823
VOUCHER MATERIAL (1): MN 29059.
FIELD NOTES: the skin of a specimen collected at Area A was obtained from a hunter.

Family Caviidae
Galea spixii (Wagler, 1831)
VOUCHER MATERIAL (18): males – MN 29018, 29064, 29065, 29069, 29072, 34414–15, 43811; females – MN 29068, 29070, 29071, 34414, 34416, 34417, 34437, 43813, 43817, 43818.
FIELD NOTES: captured in an area close to the Lagoa do Sossego and at the Rebio Jaíba. This species was usually spotted at night at margins of dirt roads, in groups of several individuals. Of five specimens trapped (three of them released) in November 1993, four were pregnant, with one embryo each. Nursing females had been captured in February of the same year.

Family Echimyidae
Thrichomys apereoides (Lund, 1839)
VOUCHER MATERIAL (34): males – MN 28878, 28880-82, 28885, 29022, 29034, 29067, 34404, 59444–46, 81140–141; females – MN 28872–73; 28877, 28883–84, 29007, 29009, 29015–16, 29023, 29036–37, 29044, 29066, 29067, 34405, 34407, 46599; indet. – MN 29011, 81139.
FIELD NOTES: sampled at the Mata da Agroceres, Dreno Jaíba, and Rebio Jaíba, living under dead trunks of fallen trees, and in tree holes. Six additional individuals captured in the limestone outcrops of Fazenda Serra Azul were released. Pregnant females were captured in March, July, and August 1990, and in August 1992. An individual that was already adult when trapped (MN 81141) lived additional four years in captivity.
TAXONOMY: A karyotyped specimen, a female (MN 34407) captured in Parque Florestal da Jaíba in 21/08/1992, showed 2n = 30 and NF = 54 comprising 12 pairs of metacentric, one pair of submetacentric, and one acrocentric pair. The first pair carries a large interstitial secondary constriction on the short arm (Pessôa et al. 2004). This karyotype differed from the topotypical *T. apereoides* karyotype (2n = 28, FN = 50), but we tentatively assign the Jaíba population to this species, pending a better sampling of the karyological variation in the geographic range assigned to this species.

Phyllomys blainvilii (Jourdan, 1837)
VOUCHER MATERIAL (1): MN 43810.
FIELD NOTES: A juvenile female captured by hand in the ground, crossing a dirt road, at 8:00 PM, at the region of Dreno Jaíba. This arboreal species may occasionally use the ground when moving across forest remnants. As it lacks adaptations for cursorial escape, it becomes immobile at first and attempts to escape if the predator relaxes its concentration. It is then easily captured by hand in such circumstances.

Order Chiroptera
Family Emballonuridae
Peropteryx kappleri Peters, 1867
Voucher material (1): female – ALP 6980.
Field notes: sampled only at the limestone outcrop of the Fazenda Serra Azul. Two individuals were captured at cave entrances. One of them was previously roosting with another *P. kappleri* in a small cavity formed by the roots of a *Ficus* tree, at 1.70 m from the ground.

Peropteryx macrotis (Wagner, 1843)
Voucher material (8): males – ALP 6939, 6969, 6981–83; females – ALP 6858, 6904, 6988.
Taxonomy: the small, dark-winged specimens of *Peropteryx* from Jaíba (FA < 43 mm, MTL < 5.7 mm; Table 2) were promptly differentiated from the larger *P. kappleri* (FA > 45 mm, MTL > 6.5 mm; Hood & Gardner 2008), but present measurements that could be referred to both *Peropteryx trinitatis* Miller, 1899 and *P. macrotis*, since there is overlap in the mensural characters currently used in the diagnosis of these taxa (Hood & Gardner 2008). According to Simmons & Voss (1998) and Lim et al. (2010), in addition to its larger size, *P. macrotis* presents a posterior accessory cusp in the anterior upper premolar, while in *P. trinitatis* this tooth is peg-like. Hood & Gardner (2008) also included this latter character in their key to South American *Peropteryx*, but reported that a distinct posterior accessory cuspule is not always present in *P. macrotis*. In our sample, most specimens present a posterobasal extension in the anterior upper premolar, clearly forming a cuspule in ALP 6982 and 6969. We retain here our original identification of these specimens as *P. macrotis* (Oliveira et al. 2003), but we also recognize that the limits between the small dark-winged species of *Peropteryx* have yet to be further investigated.
Field notes: 12 individuals were captured (two at roosts), all at the limestone outcrop of Fazenda Serra Azul. Single individuals and small groups (2–5 bats) were frequently observed at cave entrances. Two individuals, apart 1.5 m from each other, were found at the entrance of a cave where more than 150 *D. rotundus* were roosting.

Rhynchonycteris naso (Wied-Neuwied, 1820)
Voucher material (21): males – ALP 6844, 6918, 6931, 6933, MN 28870; females – ALP 6845, 6850, 6919, 6924, 6925, 6927, 6929, 6930, 6934–38, MN 29049, 46448, 28871.
Field notes: found under wood and concrete bridges associated to the riacho Mocambinho, lagoons, and irrigation channels. Only three, out of 44 individuals, were captured in nets away from known roosts. For details, see Nogueira & Pol (1998).

Family Phyllostomidae
Subfamily Micronycterinae
Micronycteris sanborni Simmons, 1996
Voucher material (5): male – ALP 6860; females – ALP 6822, 6823, 6833, 6859.
Taxonomy: the record of *Micronycteris minuta* for Jaíba, in the compilation of Oliveira et al. (2003), is based on the specimens reported here. They present a truly white ventral pelage coloration, not seen in any other pale-bellied *Micronycteris* (Simmons 1996), and their calcar is similar in size to their foot, which is another useful diagnostic feature of this species (Williams & Genoways 2008). We noticed, however, that the specimens from Jaíba are somewhat larger, in cranial length, than the specimens in the type series (e.g. condyloincisive length 15.7 vs. 15.16 mm; Table 2). Additionally, the diastema between the outer upper incisor and the canine, a diagnostic character of *M. sanborni*, was absent in specimen ALP 6833 and relatively small in the other specimens, when compared to the holotype (Simmons, 1996). Considering the small sample available for the description of *M. sanborni* (six specimens; Simmons [1996]), we interpret these discrepancies as representing within-species variation. This supposition is also supported by the examination of a larger series of *M. sanborni* from the state of Ceará (e.g. ALP 2958, ALP 3639–40; M.R. Nogueira, unpublished data), in which the same diastema proved to be subject to some variation (the same for the second diastema, between the first and second upper premolars). This series is particularly interesting for the understanding of character variation in *M. sanborni* because all specimens were obtained from a single colony, in a crevice located in the wall of a sugar cane mill.
Field notes: six individuals were captured, all at the limestone outcrop of the Fazenda Serra Azul. Three katydids (Orthoptera) measuring about 7 mm each and two moths (Lepidoptera) with about 10 mm were offered to and promptly accepted by a single *M. sanborni* briefly kept captive.

Subfamily Desmodontinae
Desmodus rotundus (É. Geoffroy, 1810)
Voucher material (6): males – ALP 6872, 6941, 6970, MN 42740; females – ALP 6973, MN 42741.
Field notes: 100 individuals were captured, all at the Fazenda Serra Azul. A colony estimated in 150 individuals was found in a cave, the entrance of which was used as roost by *P. macrotis*. Nine *D. rotundus* were captured in a net set at the entrance of another cave, where we also sampled *C. auritus*, *T. bidens*, *C. perspicillata*, *G. soricina*, *D. ecaudata*, and *M. lavali*. We found pregnant females in April (2) and May (1), and lactating females in February (1) and April (1).

Diphylla ecaudata Spix, 1823
Voucher material (6): males – ALP 6867, 6977, 6978, 6992; females – ALP 6836, MN 42742.
Field notes: from the 14 individuals of *D. ecaudata* sampled, 13 were obtained at the Fazenda Serra Azul and one at Area F. In this latter site, individuals were captured in a net set close to a tree used as perch by helmeted guinea fowls (*Numida meleagris*) that had been attacked in the previous nights. At Serra Azul, five individuals were captured at the entrance of a cave in the same net we captured *C. auritus*, *T. bidens*, *C. perspicillata*, *G. soricina*, *D. rotundus*, and *M. lavali*.

Subfamily Phyllostominae
Chrotopterus auritus (Peters, 1856)
Voucher material (4): males – ALP 6818, 6819, 6820; female – ALP 6821.
Field notes: sampled only at the limestone outcrop of the Fazenda Serra Azul. A male was captured in a mist net set at the entrance of a cave, where we also captured *T. bidens*, *C. perspicillata*, *G. soricina*, *D. rotundus, D. ecaudata*, and *M. lavali*. The three additional individuals were obtained in a diurnal sampling inside another cave.

Phyllostomus discolor (Wagner, 1843)
Voucher material (13): males – ALP 6827, MN 42731, 42733, 42735, 42737; females – ALP 6852-53, 6965, MN 42732, 42734, 42736, 42738, 46446.
Field notes: two individuals captured in mist nets set adjacent to a cattle pond at Fazenda Solagro, one at the Reserva

Biológica do Jaíba, and 52 close to the Rio São Francisco, either at CAM, in nets set close to flowering shrubs of *Calliandra* sp. (Leguminosae, Mimosoideae), or in the Mata da Agroceres, near the village of Mocambinho. While feeding at the flowers of *Calliandra* sp., *P. discolor* landed over them. Abundant pollen was found over the head of most bats and at the ventral surface of their patagium. Lactating females were captured in March (1), April (15), and May (2). A pregnant female was found in May.

Phyllostomus hastatus (Pallas, 1767)
Voucher material (4): males – ALP 6866, 6869; females – ALP 6900, MN 42739.
Field notes: 11 individuals were captured, three at Area F, close to banana plantations, six at CAM, one at Dreno Jaíba, in the border of the forest, and one in Mocambinho. A lactating female was sampled in October.

Tonatia bidens (Spix, 1823)
Voucher material (6): males – ALP 6832, 6843; females – ALP 6837, 6838, 6839, 6842.
Field notes: all 16 individuals obtained were captured at Fazenda Serra Azul. One individual was obtained at the entrance of a cave where we also captured *C. auritus*, *C. perspicillata*, *G. soricina*, *D. rotundus*, *D. ecaudata*, and *M. lavali*. Some insects were offered to individuals briefly kept captive. Katydids (Orthoptera) ranging from 1 to 5 cm and beetles (Coleoptera) from 0.5 to 2 cm were promptly accepted. A lactating female was captured in March.

Tonatia saurophila Koopman & Williams, 1951
Voucher material (3): male – ALP 6817; females – ALP 6854, 6855.
Taxonomy: listed as *Tonatia* sp. in the compilation of Oliveira et al. (2003) for Jaíba. These specimens present the diagnostic characters described by Williams et al. (1995), including a relatively large gap between the internal basis of the lower canines (when compared to *T. bidens*), a secondary process in the mastoid, which partially covers the auditory bullae, and a well-developed (also in comparison to *T. bidens*) second lower premolar, only slightly obscured by the cingulum of the adjacent premolar. These specimens also present a white stripe on the top of the head, between ears, although in one specimen this stripe was almost indistinct. Measurements are also generally within the variation described by Williams et al. (1995) for *Tonatia s. maresi*, the geographical distribution of which extends into the Caatinga biome.
Field notes: one specimen was obtained at the Fazenda Serra Azul and two at Rebio Jaíba. At this latter site, one specimen was captured in a trail inside the forest and the other over a relatively large puddle (ca. 5 m across) formed by rainwater and located at the road that borders the reserve. Other species captured at the same puddle were *E. furinalis*, *C. planirostris*, *M. pretiosus*, and *M. molossus*.

Subfamily Glossophaginae

Glossophaga soricina (Pallas, 1766)
Voucher material (25): males – ALP 6870, 6881, 6886, 6888, 6890, 6902, 6905, 6984, MN 42752, 42759, 43248; females – ALP 6891, 6895, 6940, 6968, 6985-87, MN 42753, 42755–58, 46447.
Field notes: one of the most common bat species in the region. A total of 68 individuals were obtained at the following sites: Fazenda Serra Azul (46), CAM (8), Area F (5), Rebio Jaíba (3), Area B (1), Area C2 (1), Fazenda Yamada (1), Dreno Jaíba (1), Lagoa do Sossego (1), and Mata da Agroceres (1). Two colonies of *G. soricina*, each with five individuals, were found in small cavities at Fazenda Serra Azul. In another cave, a single individual was found in cohabitation with three *P. lineatus*. Eight individuals were captured at the entrance of a cave in the same net we captured *C. auritus*, *T. bidens*, *C. perspicillata*, *D. rotundus*, *D. ecaudata*, and *M. lavali*. We also recorded a roosting group of eight *G. soricina* (three of which were captured) in the attic of the Rebio Jaíba headquarter. All individuals captured at CAM were obtained close to flowering shrubs of *Calliandra* sp., and two of them presented abundant pollen spread over the ventral surface of their wing membrane. A pregnant female was found in April and a lactating in March. This latter individual was carrying a newborn when captured in a mist net at Fazenda Serra Azul.

Subfamily Lonchophyllinae

Lonchophylla sp.
Voucher material (5): males – ALP 6841, 6908, 6909, MN 42754; females – ALP 6840.
Taxonomy: individuals of *Lonchophylla* sp. from Jaíba present a pale yellowish-brown ventral pelage that clearly distinguished them from syntopic *G. soricina* and *X. vieirai* in the field. We initially identified these specimens as *L. mordax*, but ongoing taxonomic research on this group revealed that they might belong to a distinct new species (R. Moratelli, pers. comm.).
Field notes: one individual captured at CAM and 18 at the limestone outcrop of the Fazenda Serra Azul. Lactating females were obtained in April (6) and May (1), and a pregnant female was found in April.

Xeronycteris vieirai Gregorin & Ditchfield, 2005
Voucher material (1): female – ALP 6824.
Taxonomy: a detailed account on the morphology of this specimen and a revised diagnosis for the genus were presented elsewhere (Nogueira et al. 2014b).
Field notes: a single individual captured at the limestone outcrop of the Fazenda Serra Azul. When this individual was captured, unidentified pollen was found covering its head, confirming the nectar-feeding habits expected for this species based on its craniodental morphology and phylogenetic affinities.

Subfamily Carolliinae

Carollia perspicillata (Linnaeus, 1758)
Voucher material (21): males – ALP 6865, 6880, 6882, 6889, 6972, 6994, MN 42730, 42750; females – ALP 6828, 6883, 6884, 6907, 6950, 6951, 6989, 6991, 6993, 6995, MN 42728, 42729, 42748.
Field notes: a widely distributed species in the Jaíba region. Samples were obtained at the Fazenda Serra Azul (43), Fazenda Yamada (4), CAM (2), Fazenda Solagro (2), Area F (2), Gleba C2 (1), and Rebio Jaíba (1), where it was captured at the margins of a swamp area called “Lagoa Santa”. It was also found roosting inside an abandoned cistern, close to the headquarters of the reserve. Three specimens were found in a cluster at this roost. At the Fazenda Serra Azul, two individuals were obtained at the entrance of a cave where we also captured *C. auritus*, *T. bidens*, *G. soricina*, *D. ecaudata*, and *M. lavali*. Lactating females were found in March (1), April (1), and October(1).

Subfamily Stenodermatinae

Artibeus lituratus (Olfers, 1818)

Voucher material (3): males – ALP 6862, 6868; female – ALP 6864.

Field notes: one individual captured at Fazenda Solagro, two at the Fazenda Serra Azul, and 10 at Area F.

Artibeus planirostris (Spix, 1823)

Voucher material (16): males – ALP 6879, 6892, 6893, 6906, 6957, 6958, 6976, 6979, 6990, MN 43250; females – ALP 6861, 6863, 6887, 6956, MN 42743–44.

Taxonomy: the record of *Artibeus* sp. for Jaíba, in the compilation of Oliveira et al. (2003), is based on this material. All 13 specimens from which the skulls were removed were found to present a third small upper molar. These specimens were also referable to *A. planirostris* on the basis of their pale brown ventral pelage, inconspicuous facial stripes, horseshoe of the noseleaf centrally free from the upper lip, and nearly naked dorsal surface of the uropatagium. In *Artibeus obscurus*, which is similar in size to *A. planirostris*, the fur is blackish and the third small upper molar is absent in populations from eastern Brazil (Taddei et al. 1998).

Field notes: a frequent species at Jaíba, with captures at the Fazenda Serra Azul (58), Area F (7), Fazenda Solagro (4), Fazenda Yamada (1), and CAM (1). Lactating females were captured in April (2), October (1), and November (1).

Platyrrhinus lineatus (É. Geoffroy, 1810)

Voucher material (10 males): ALP 6829, 6830, 6871, 6894, 6903, 6954, 6955, 6971, MN 42745-6.

Taxonomy: the smallest specimen in our sample (ALP 6971) presents the forearm out of the range described for *P. lineatus*, conforming better to data available for *Platyrrhinus recifinus* (Thomas, 1901). Based on the morphology of its first lower premolar, pattern of dorsal pelage coloration, and presence of interramal vibrissae, however, we identify it as *P. lineatus* (Velazco 2005, Velazco et al. 2010). Although smaller, this specimen is similar in external morphology and skull shape to other *P. lineatus* in our sample from Jaíba.

Field notes: among the 39 individuals captured, 34 were obtained at Fazenda Serra Azul, where three individuals were found roosting in a small cave. Additional individuals were obtained at the Fazenda Solagro and at the lote agrícola. A single *G. soricina* was found in the same cave *P. lineatus* was using as roost at the Fazenda Serra Azul. One lactating female was captured in March and another in April.

Sturnira lilium (É. Geoffroy, 1810)

Voucher material (7): males – ALP 6885, 6910, 6952, 6953, 6975, MN 42727; female – ALP 6899.

Field notes: among the seven individuals obtained, three were captured at the Dreno Jaíba, two at the Fazenda Solagro, one in a trail at the Fazenda Yamada, and one at Gleba C2, 30 km distant from Mocambinho. A lactating female was obtained in October.

Uroderma magnirostrum Davis, 1968

Voucher material (3): males – ALP 6831, 6834; female – ALP 6835.

Taxonomy: data from these specimens were presented elsewhere (Nogueira et al. 2003).

Field notes: four individuals were captured, all at the limestone outcrop of the Fazenda Serra Azul. For details, see Nogueira et al. (2003).

Family Noctilionidae

Noctilio albiventris Desmarest, 1818

Voucher material (14): males – ALP 6846, 6847, 6848, 6923, 6932, 6997; females – ALP 6920, 6921, 6922, 6926, 6928, 6962, 6967, 6996.

Field notes: sampled mainly at the riacho Mocambinho (39 individuals), where a wooden bridge was used as secondary (nocturnal) roost. The same bridge was used as roost by *R. naso* (Nogueira & Pol 1998). Three other specimens were captured in mist nets set over the cattle pond at Fazenda Solagro. Reproductive data as well as more detailed sampling information can be found elsewhere (Nogueira & Pol 1998).

Noctilio leporinus (Linnaeus, 1758)

Voucher material (1): male – ALP 6849.

Field notes: two specimens were collected in a net set over the riacho Mocambinho and one over the cattle pond at Fazenda Solagro. This species was frequently observed foraging over the water at the Rio São Francisco, irrigation channels, and cattle ponds (Fazenda Solagro). A group estimated in 50 individuals was found roosting under a concrete bridge that crosses one of the irrigation channels. This roost, however, was used only during the night, when three specimens of *R. naso* could also be found, separated about 5 m from the clusters of *N. leporinus*.

Family Molossidae

Subfamily Molossinae

Cynomops planirostris (Peters, 1866)

Voucher material (5): males – ALP 6856, 6948, 6949; females ALP 6897, 6947.

Field notes: six individuals were captured, all in nets set over or adjacent to water bodies. Four specimens were obtained at the cattle pond in Fazenda Solagro, one over a puddle in the road adjacent to the Rebio Jaíba, and one at the Dreno Jaíba. A pregnant female with an embryo measuring 16.55 mm was captured in November.

Eumops perotis (Schinz, 1821)

Voucher material (1): MN 46478.

Measurements: FL, 80.25; GLS, 33.38; CBL, –; ZB, 19.28; PB, 5.48; BB, 14.26; MB, 15.51; MTL, 12.91; BAM, 12.86; BAC, 8.47.

Field notes: a female was collected by hand, in the early morning, when it was roosting on the wall of a building at the margin of an irrigation channel at Frente 3 (15°07'36" S, 44°00'43" W), a small village.

Molossus molossus (Pallas, 1766)

Voucher material (8): males – ALP 6876, 6916, MN 47079–81; females – ALP 6873, MN 47082, 47090.

Taxonomy: some small *Molossus* from Jaíba (MN 47079–47082, MN 47090) have been reported in the literature as *Molossus currentium* Thomas, 1901 (Tavares et al. 2010). However, these specimens, as well as others we have collected in the same region, present relatively long (ca. 5 mm) and bicolored dorsal fur (in *M. currentium* it is short and with no bands; Gregorin et al. 2011b), relatively narrow braincase (males with 8.71–9.14 mm vs. 9.3–10.6 mm in *M. currentium*; Gregorin et al. 2011b), and short skull (males with 17.39–17.79

mm vs. 19.2–20.3 mm in *M. currentium*; Gregorin et al. 2011b) and forearm (males with 38.87–41.4 mm vs. 41.0–44.0 mm in *M. currentium*; Gregorin et al. 2011b). As in the case of *M. pretiosus* (see below), we found variation in the shape of the upper inner incisors. In some specimens (e.g. ALP 6851 and MN 47080) these teeth are pincer-like, as described for *M. molossus*, while in others they are spatulate, as seen in *M. currentium* (Gregorin et al. 2011b). This latter condition, however, seems to be the result of a wear of these teeth.

Molossus aztecus Saussure, 1860 was recently reported for Brazil based on specimens from Minas Gerais, but in this species the braincase is wider than in *M. molossus* (like in *M. currentium*) and the basal band of the dorsal fur is shorter than in this latter species (1/3 to 1/4 vs. 1/2) (Gregorin et al. 2011b). In our specimens, the basal white band comprises 1/2 of the length of the hairs. We, therefore, recognize the small *Molossus* from Jaíba as *M. molossus*. It is noteworthy, however, that these specimens are consistently paler than specimens from moister areas we have examined.

FIELD NOTES: among the 28 sampled individuals, three were obtained in a net set crossing a relatively large puddle (ca. 5 m across) in the road that borders the Rebio Jaíba, four were captured around residences at the CAM area, one in a net set over the riacho Mocambinho, and 20 in roofs of residences at Mocambinho. At the Rebio Jaíba, in the same net we sampled *M. molossus* we also captured *T. saurophila*, *E. furinalis*, *M. pretiosus*, and *C. planirostris*. At Mocambinho, we found *M. molossus* sharing four roofs with *M. pretiosus*, and in one of them *N. laticaudatus* was also present. Pregnant females with one embryo each were recorded in October 1992 (2) and October 1994 (1), the last one measuring 16.8 mm.

Molossus pretiosus Miller, 1902

VOUCHER MATERIAL (42): males – ALP 6826, 6875, 6896, 6898, 6913, 6942, 6943, MN 22862, 47084; females – ALP 6874, 6877, 6878, 6911, 6912, 6914, 6915, 6917, 6944, 6945, 6946, 6963, 6964, 6966, MN 28863–69, 29028, 47074–47078, 47083, 47085–47089.

TAXONOMY: all large specimens of *Molossus* from Jaíba are here recognized as *M. pretiosus*. Measurements obtained for the four females from Museu Nacional cited as *Molossus rufus* É. Geoffroy, 1805 by Tavares et al. (2010) (MN 47074–77; Table 2) follow the same pattern described by Nogueira et al. (2008) for other *M. pretiosus* from Jaíba.

FIELD NOTES: widespread at the Jaíba region. All specimens not previously cited by Nogueira *et al*. (2008) were captured in roofs at Mocambinho.

Nyctinomops laticaudatus (É. Geoffroy, 1805)

VOUCHER MATERIAL (1): male – ALP 6825.

FIELD NOTES: a single specimen was captured in a mist net set close to the entrance of a roost in the roof of a residence at the CAM. Seven additional individuals were captured by hand inside another roost in the roof of a residence at Mocambinho. The number of individuals estimated to be present at this roost was 40. Other species occupying this same roost were *M. molossus* and *M. pretiosus*. A lactating female was found in May.

Family Vespertilionidae

Subfamily Vespertilioninae

Eptesicus furinalis (d'Orbigny & Gervais, 1847)

VOUCHER MATERIAL (3): males – MN 29027, ALP 6824 (only skull available); female – ALP 6857.

FIELD NOTES: two specimens were obtained at Dreno Jaíba and one at Rebio Jaíba. In this latter site, the bat was captured in a net set over a puddle in the road adjacent to the Reserve. In the same net we captured *E. furinalis* at Rebio Jaíba, we also captured *T. saurophila*, *C. planirostris*, *M. pretiosus*, and *M. molossus*. The female captured in October was lactating.

Subfamily Myotinae

Myotis lavali Moratelli, Peracchi, Dias & Oliveira, 2011

VOUCHER MATERIAL (3): males – ALP 6901, 6974; female – MN 42747.

TAXONOMY: cited as *Myotis* sp. in the compilation of Oliveira et al. (2003) for Jaíba. The strongly bicolored dorsal fur (medium-brown bases and light-brown tips) and upwardly oriented anterior rostrum found in our specimens are typical of *M. lavali* (Moratelli & Wilson 2013).

FIELD NOTES: among the 21 individuals sampled, 17 were captured in the limestone outcrop of the Fazenda Serra Azul; 16 in a net set close to the entrance of a cave, where we also captured *C. auritus*, *T. bidens*, *G. soricina*, *C. perspicillata, D. rotundus*, and *D. ecaudata*. From the four additional individuals, two were captured in nets set over a cattle pond at the Fazenda Solagro and two at Dreno Jaíba.

Discussion

Currently, 122 small mammals are assigned to the Caatinga biome, including seven didelphimorph marsupials, 35 rodents, and 80 bats (Paglia et al. 2012, Sá-Neto & Marinho-Filho 2013). The region of Jaíba, with the 46 species reported here, harbors at least 40% of this fauna. If we consider the whole mammalian fauna of Jaíba, and add to our list the 13 medium to large species recorded by Oliveira et al. (2003), this region can be recognized as harboring 38% of the mammalian fauna in the Caatinga (156 species; Paglia et al. 2012, Sá-Neto & Marinho-Filho 2013). With at least 59 species, the mammalian fauna of Jaíba can be recognized as one of the richest in the Caatinga, a conclusion anticipated by Oliveira et al. (2003) and confirmed here with the addition of some new records.

Among the 10 endemic mammalian species currently recognized for the Caatinga (Paglia et al. 2012), at least two (*Wiedomys pyrrhorhinos* and *Xeronycteris vieirai*) are found in Jaíba, and three species that are endemic to the diagonal of dry open formations that crosses South America are also represented in this region (*Rhipidomys macrurus, Thrichomys apereoides*, and *Micronycteris sanborni*). Although *Micronycteris sanborni* has been also reported to occur in the Brazilian Amazon (López-Baucells et al. 2013), this record has been disregarded due to the lack of an associated voucher (Nogueira et al. 2014a). Jaíba also remain as the single region in the Caatinga where *Molossus pretiosus* has been recorded (Nogueira et al. 2008), and its terrestrial mammal fauna includes interesting additional components, such as the didelphid *Marmosops incanus* and the echimyid *Phyllomys blainvilii*. The former is best known from coastal Atlantic forest localities ranging from Bahia to São Paulo, with a few inland samples in Caatingas of Bahia and Minas Gerais (Mustrangi & Patton 1997), and the latter is also known in the Caatinga from scattered localities in isolated areas of semideciduous forest islands (Leite 2003). Some bat species previously reported for Jaiba, however, had their records revised. Specimens supporting the occurrence of *Lonchophylla mordax* and *Micronycteris minuta*

(Oliveira et al. 2003) were assigned here as *Lonchophylla* sp. and *M. sanborni*, respectively, and those reported as *Molossus currentium* and *Molossus rufus* by Tavares et al. (2010) were identified, respectively, as *M. molossus* and *M. pretiosus*.

A total of 84 bat species are currently reported for the state of Minas Gerais (Nogueira et al. 2008, Tavares et al. 2010, Gregorin & Loureiro 2011, Gregorin et al. 2011b, Carvalho et al. 2013, Falcão et al. 2014, Velazco et al. 2014, Gregorin et al. 2015), but only 19 are assigned to caatinga regions (Nogueira et al. 2008, Tavares et al. 2010, Falcão et al. 2014). The present results increase to 34 the number of bat species recorded for the caatinga of Minas Gerais, including *T. saurophila, X. vieirai*, and *M. lavali*, new records also for the state of Minas Gerais. We also provide the first voucher-supported record of *M. sanborni* for Minas Gerais (Falcão et al. [2014] did not collect specimens in their sampling) and significantly extend the known range of *X. vieirai*. This latter species had its previous southernmost locality in the municipality of Cocorobó, state of Bahia (ca. 800 km from Jaíba), and *M. sanborni* is already known from Pantanal (Santos et al. 2010), but in eastern Brazil its previous southernmost voucher-supported record comes from Estação Ecológica Serra Geral do Tocantins, state of Tocantins (ca. 600 km from Jaíba) (Gregorin et al. 2011a). The bat fauna of Minas Gerais can now be recognized as including 86 species. This total does not include *M. currentium*, whose occurrence in Minas Gerais was relaying on specimens here assigned as *M. molossus*. Because the occurrence of *M. currentium* in Brazil was also based on the record of Tavares et al. (2010) (see Nogueira et al. 2014a), the number of Brazilian bats species can be updated to 177.

The presence of endemic taxa at the limestone outcrop of Fazenda Serra Azul confirms the importance of karstic areas to the bat fauna (Trajano 1995, Tavares et al. 2010). *Micronycteris sanborni* and *X. vieirai* were exclusively sampled at this site, as were other more widespread species, like *P. macrotis*, *P. kappleri*, *C. auritus*, and *Uroderma magnirostrum*. Additionaly, almost 50% of the bat species reported here was found at this site, where abundant roosts and core plants in the diet of stenodermatines (e.g. *Ficus* and *Cecropia*) are available (Nogueira et al. 2003). Since we conducted our last field activities in Jaíba, in 1995, extensive changes have been promoted in the landscape of this region, largely due to the continuity of the conversion of forests into agricultural plots. Of major importance to bat conservation, however, was the creation of conservation units in karstic areas. The Fazenda Serra Azul is now part of the buffer zone of the Reserva Biológica Serra Azul (3,840 ha), integrating a new system of conservation units (Sistema de Áreas Protegidas do Jaíba). Our finding of an exotic species (*Rattus rattus*) at the Reserva Biológica de Jaíba is also relevant from a conservation point of view. Although only a single specimen was recorded, and its occurrence may be merely incidental, this rodent has been widely cited as a threat to natural environments (Pimentel et al. 2000, Caut et al. 2008), justifying attention in further studies in the area.

Although rarefaction curves presented here for captures in live traps and mist nets suggest that most small mammals sampled by these methods were already recorded, additional surveys are still required, particularly in conservation areas. Our list of bats from families other than Phyllostomidae, for example, is clearly incomplete (e.g. only two vespertilionids included), and additional sampling effort through active roost search and acoustic monitoring may help to fill this gap. The advantages of these complementary sampling techniques have been well demonstrated in bat surveys (e.g. Simmons & Voss 1998, Jung & Kalko 2011). Implementation of ecological studies on endemic/data deficient species, like *X. vieirai*, is another prominent measure that may help in future conservation plans for this important region of the Caatinga biome.

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inventory

Bats of a varzea forest in the estuary of the Amazon River, state of Amapá, Northern Brazil

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CASTRO, I.J., MICHALSKI, F. **Bats of a varzea forest in the estuary of the Amazon River, state of Amapá, Northern Brazil.** Biota Neotropica. 15(2): e20140168. http://dx.doi.org/10.1590/1676-06032015016814

Abstract: The varzea forests of the estuary of the Amazon River cover 25,000 km^2 within the states of Pará and Amapá. The mammals of those forests, especially bats, are still poorly known. Hence, the present study aimed at inventorying the bat species from three localities of a varzea forest in the estuary of the Amazon River. Between November and December 2013, we selected 18 sampling sites in the mouths of three tributaries of the Amazon River: the rivers Ajuruxí, Maracá, and Mazagão. We set up ten mist nets (12 x 3 m) along a 150-m linear transect in each sampling site, in a total sampling effort of 38,888 m^2.h. We captured 403 individual bats of 40 species and five families. We recorded the families: Phyllostomidae (n = 31 species), Emballonuridae (n = 6 species), Moormopidae (n = 1 species), Vespertilionidae (n = 1 species), and Thyropteridae (n = 1 species). *Carollia perspicillata*, *Artibeus planirostris*, and *Carollia brevicauda* comprised 45% of the records. We also made the first record of *Glyphonycteris daviesi* for Amapá state, and captured rare species, such as *Dicludurus albus* and *Macrophyllum macrophylum.* Our results show that the varzea forest of the estuary of the Amazon River harbors high bat diversity, and, hence, conservation policies should be considered for the region. Those policies should encourage the responsible management of *açaí* palm (*Euterpe oleracea*) and timber. They should also fight illegal timber exploitation that threatens the fauna and flora of those biodiverse forests.

Keywords: *Chiroptera, conservation, biodiversity, floodable forest.*

CASTRO, I.J., MICHALSKI, F. **Morcegos de floresta de várzea no estuário do Rio Amazonas, estado do Amapá, Norte do Brasil.** Biota Neotropica. 15(2): e20140168. http://dx.doi.org/10.1590/1676-06032015016814

Resumo: As florestas de várzea do estuário do Rio Amazonas ocupam uma extensão 25. 000 km^2, abrangendo os estados do Pará e Amapá. Os mamíferos destas florestas, especificamente morcegos ainda são pouco conhecidos. Este estudo visa apresentar uma lista de espécies de morcegos de três localidades em floresta de várzea no estuário do Rio Amazonas, contribuindo assim com o conhecimento da quiropterofauna desta fitofisionomia. Entre Novembro e Dezembro de 2013 foram selecionados 18 sítios de coletas na foz de três rios tributários do Rio Amazonas: Rio Ajuruxí, Rio Maracá e Rio Mazagão. Com o uso de dez redes de neblina (12 x 3 m) armadas ao longo de um transecto linear de 150 metros em cada sitio de coleta e totalizando um esforço amostral de 38,888 m^2. h capturamos 403 indivíduos distribuídos em 40 espécies e cinco famílias. As famílias registradas foram Phyllostomidae (n = 31 espécies), Emballonuridae (n = 6 espécies), Moormopidae (n = 1 espécie), Vespertilionidae (n = 1 espécie) e Thyropteridae (n = 1 espécie). *Carollia perspic*illata, *Artibeus planirostris* e *Carollia brevicauda* compreenderam 45 % dos registros. Nós documentamos o primeiro registro de *Glyphonycteris daviesi* para o estado do Amapá. Registramos também espécies raras como *Dicludurus albus* e *Macrophyllum macrophylum.* Os dados obtidos neste estudo revelam que as florestas de várzea do estuário do Rio Amazonas abrigam uma alta riqueza e diversidade de morcegos e que politicas de conservação devem ser consideradas para a manutenção desta diversidade. Tais politicas devem ser focadas no incentivo para o manejo responsável do cultivo do açaizeiro (*Euterpe oleracea*) e da exploração da madeira, além da redução da exploração madeireira ilegal que causa prejuízos a fauna e flora dessas florestas ricas em biodiversidade.

Palavras-chave: *Chiroptera, conservação, biodiversidade, floresta inundável.*

Introduction

Varzea forests are subjected to the seasonal flood of white-waters rivers with neutral pH, which carry high load of sediments and nutrients, such as the rivers Amazon, Purus, and Juruá (Prance 1979, Sioli 1984). They cover an area of 200,000 km^2 in the Amazon River Basin (Junk 1984, Wittmann et al. 2010). In the estuary of the Amazon River, varzea forests cover an area of approximately 25,000 km^2, within the states of Pará and Amapá, Eastern Amazon (Lima et al. 2001). In this region of the Amazon, large areas have been altered due to the large demand for timber and cultivation of *açaí* palm (*Euterpe oleracea* Mart.,1824), which are among the products of highest economical importance in the varzea of the Amazon estuary (Muñiz-Miret et al. 1996, Queiroz & Mochiutti 2001, Brondízio et al. 2002, Weinstein & Moegenburg 2004, Homma 2012). Therefore, biodiversity maintenance in varzea forests depends mainly on the knowledge and conservation of the species that inhabit them.

Bats are a diverse and abundant group of mammals, which, depending on the region, can represent 60% of the local fauna (Simmons & Voss 1998). Bats play several roles in the regulation of tropical ecosystems: they are responsible for the seed dispersal of over 500 plant species, for the pollination of angiosperms, and for the control of insect population, which includes agricultural pests and disease vectors (Medellín et al. 2000, Jones et al. 2009, Kunz et al. 2011). The bat fauna of Brazil is very expressive: out of 701 mammal species currently known in the country (Paglia et al. 2012), at least 178 are bats (Nogueira et al. 2014). In the Brazilian Amazon, 147 bat species of nine families are recorded (Bernard et al. 2011, Castro et al. 2012). In Amapá, 86 bat species of eight families are recorded (Martins et al. 2006, Martins et al. 2011, Silva et al. 2013), but most inventories were concentrated in non-flooded plateau forests (locally known as *terra firme* forests).

In the past ten years, the number of bat studies in floodable forests of the Brazilian Amazon increased considerably, in particular studies on bat ecology, but they were concentrated in Central Amazon, in the state of Amazonas (Ramos Pereira et al. 2009, Ramos Pereira et al. 2010a, Ramos Pereira et al. 2010b, Marques et al. 2012, Bobrowiec et al. 2014). However, the varzea forests in the estuary of the Amazon River, Eastern Amazon, are still poorly known for bats. Only two studies were carried out in this part of the Amazon: one in the Marajó Region, in Anajás (Marques-Aguiar et al. 2002), and the other in the surroundings of Belém (Kalko & Handley Jr. 2001), both in the state of Pará. Taking into account the need for studies on the bat fauna in varzea forests, a bat inventory would be an important tool for decision-making in the management of those environments (Silveira et al. 2010). Hence, the present study aimed at inventorying the bat species from three localities of a varzea forest in the estuary of the Amazon River.

Material and Methods

The study area is located in the municipality of Mazagão, southeastern Amapá State, northern Brazil. This region is located within the estuary of the Amazon River. The vegetation is classified as alluvial dense rainforest (IBGE 2004), which is popularly known as varzea forest (Figure 1). The forests of the estuary of the Amazon River have a peculiarity: due to the closeness to the Atlantic Ocean, water level peaks are regulated by the tides, and the forests are flooded twice a day. The climate of the region is equatorial humid and the average temperature is 26 °C, with annual rainfall around 2,000 mm (SUDAM 1984).

We selected 18 sampling sites (Figure 1, Table1) in the mouth of three tributaries of the Amazon River: Ajuruxí, Maracá, and Mazagão. In each tributary, we selected six sampling sites, with a minimum distance of 1 km among them. In the study area, the economical activities are centered in plant extractivism, mainly of the *açaí* palm (*Euterpe oleracea*), with managed areas varying from 1 to 20 ha per family. There is also timber exploitation; timber processing is carried out in local family sawmills that supply local communities and the municipalities of Macapá and Santana, state of Amapá.

Bats were captured with mist nets set up along a 150-m linear transect in each sampling site between November and December 2013. In each sampling night, we set up 10 nets (12 x 3 m), which were opened at sunset, checked at intervals of 20-30 min, and closed after six hours of exposure. Species identification was made using an identification key for bats of the subregion of the Guiana (Lim & Engstrom 2001) and identification keys for the bats of South America (Gardner 2008). For identification, we took biometrical measurements, such as weight (with a spring scale) and forearm length (with a digital caliper). We also recorded sex, age, and reproductive status. Nomenclature followed Nogueira et al. (2014) except for recognizing *Pteronotus rubiginosus* rather than *Pteronotus parnellii* for French Guiana and Amapá State in Brazil (Thoisy et al. 2014). Bats were classified into broad foraging guilds based on published feeding habits, following Gardner (1977) for Phyllostomidae and Willig (1986) for all other families. A maximum of six vouchers of each species were collected, with a permit from SISBIO (40774-1). The vouchers were fixed in formalin at 10%, preserved in alcohol 70%, and deposited in the Animal Collection of Amapá, at the Institute of Scientific and Technological Research of Amapá (IEPA), Macapá, under the numbers IEPA 3926 and IEPA 3953-4013.

The total sampling effort of 38,888 m^2.h was calculated by multiplying the area of each net by the exposure time, number of nights, and number of nets (following Straube & Bianconi 2002). Rarefaction curves were built based on the number of individuals and species to test for the sufficiency of the sampling effort (Gotelli & Colwell 2001). To estimate bat richness we used the non-parametrical estimator Jackknife I (Magurran 2004). We estimated species diversity with Shannon index (H'). This index is considered mainly a measurement of dominance, as it gives higher weight to common species (Magurran 2004). Rarefaction curves and the calculation of Jackknife I and Shannon index (H') were made in R 3.0.1 (R Development Core Team 2013).

Results

We captured 403 individual bats of 40 species and five families, considering the whole study area. The families recorded were: Phyllostomidae (n = 31 species), Emballonuridae (n = 6 species), Moormopidae (n = 1 species), Vespertilionidae (n = 1 species), and Thyropteridae (n = 1 species) (Table 2). Nine species were captured exclusively in the mouth of the Ajuruxi River, six in the mouth of the Maracá River, and only three species were exclusive to the mouth of the Mazagão River (Table 2). All species are classified as Least Concern by IUCN (2014), except *Platyrrhinus fusciventris* and *P. incarum* which have not yet been evaluated.

The family Phyllostomidae was largely dominant, with 76.92 % of the species and 95% of the individual bats collected. *Carollia perspicillata* (96 individuals), *Artibeus planirostris* (47 individuals), and *Carollia brevicauda* (39 individuals) comprised 45 % of the records. Emballonuridae was the second family in number of species (15%) and individuals (3.5%), and included rare species, such as *Peropteryx leucoptera*, collected

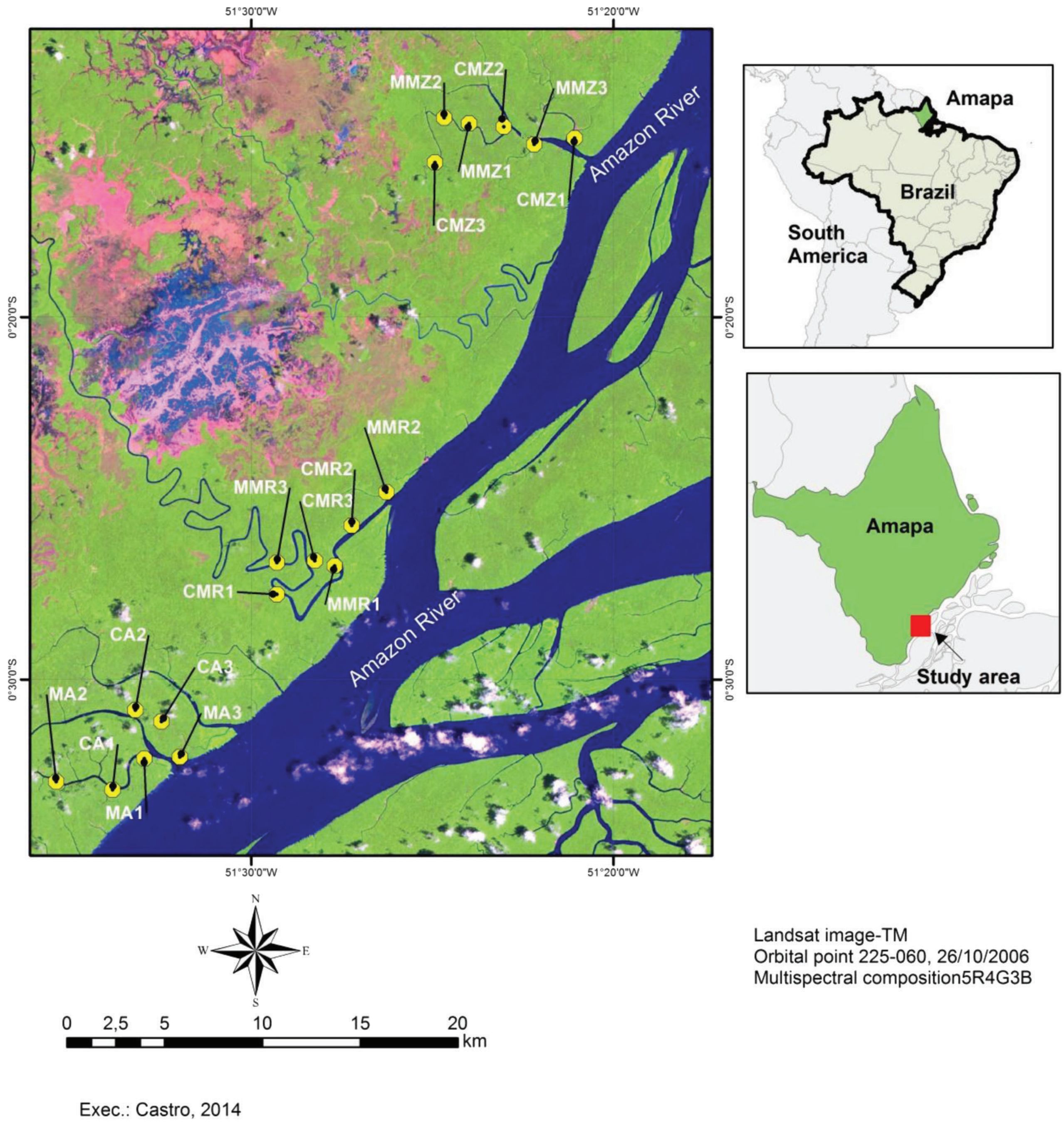

Figure 1. Location of the study area. Yellow points are the sampling sites at the mouths of the rivers Ajuruxi (MA1, MA2, MA3, CA1, CA2, CA3), Maracá (MMR1, MMR2, MMR3, CRM1, CRM2, CRM3), and Mazagão (MMZ1, MMZ2, MMZ3, CMZ1, CMZ2, CMZ3).
Figura 1. Localização da área de estudo. Pontos em amarelo são os sítios de coleta, sendo Foz do Rio Ajuruxi (MA1, MA2, MA3, CA1, CA2, CA3), Foz do Rio Maracá (MMR1, MMR2, MMR3, CRM1, CRM2, CRM3) e Foz do Rio Mazagão (MMZ1, MMZ2, MMZ3, CMZ1, CMZ2, CMZ3).

in the mouth of the Mazagão River, and *Diclidurus albus* and *Cormura brevirostris* collected in the mouth of the Maracá River (Table 2).

Based on the 40 species sampled, the Jacknife 1 estimator points that approximately 53 bat species occur in the study area. Hence, we recorded 75% of the expected local bat species. Rarefaction curves did not show signs of stabilization, which indicates that more species should be added to the list of the studied varzea forests (Figure 2).

In the present study, we made the first record of *Glyphonycteris daviesi* (collection accession number IEPA 3962) for the state of Amapá. The record was made at 19:00 on November 27, 2013, at the mouth of the Ajuruxi River, Cajari Reserve, locality of Vila Maranata. The environment where *G. daviesi* was collected is a managed *açaí* palm forest (*Euterpe oleracea*), with an unobstructed understory and large hollow trees, with the predominance of Pracuúba (*Mora paraensis*), which may provide roosts for *G. daviesi*.

The trophic structure of the bat assemblage of the three localities studied in the estuary of the Amazon River was composed of frugivores, aerial insectivores, gleaning animalivores, and sanguivores. Frugivorous bats were more abundant

Table 1. Sampling sites, geographical coordinates, number of bats species and individuals sampled in a varzea forest in the estuary of the Amazonas River. In each site were used 10 mist nets with a sampling effort of 2160 m^2.h per site.

Tabela 1. Sítios de coleta, coordenadas geográficas, número espécies de morcegos e de indivíduos amostrados em floresta de várzea no estuário do Rio Amazonas. Em cada sítio foram usadas 10 redes de neblina com um esforço amostral de 2160 m^2.h por sítio.

Site	River	Latitude	Longitude	Species	# ind.
CA1	Ajuruxi	– 0.550726	– 51.563764	5	5
CA2	Ajuruxi	– 0.514091	– 51.553349	15	44
CA3	Ajuruxi	– 0.519318	– 51.541283	11	18
MA1	Ajuruxi	– 0.536379	– 51.54919	16	38
MA2	Ajuruxi	– 0.546935	– 51.589648	8	13
MA3	Ajuruxi	– 0.535683	– 51.532811	8	15
MMR1	Maracá	– 0.447744	– 51.461611	15	34
MMR2	Maracá	– 0.413852	– 51.437795	12	28
MMR3	Maracá	– 0.446273	– 51.488222	11	32
CMR1	Maracá	– 0.460856	– 51.488209	10	20
CMR2	Maracá	– 0.429111	– 51.453823	5	9
CMR3	Maracá	– 0.445328	– 51.470813	7	10
CMZ1	Mazagão	– 0.25096	– 51.351336	11	31
CMZ2	Mazagão	– 0.245761	– 51.383893	8	20
CMZ3	Mazagão	– 0.2622	– 51.415517	12	18
MMZ1	Mazagão	– 0.244296	– 51.399837	10	27
MMZ2	Mazagão	– 0.241649	– 51.411261	12	18
MMZ3	Mazagão	– 0.253874	– 51.369926	11	23

than the others, varying from 61% to 69% of the captures (Table 2). Gleaning animalivores were the second most frequent foraging guild in the mouths of the rivers Maracá (26%) and Ajuruxi (17%), probably due to higher availability of habitats and food and better habitat conservation (Table 2). The sanguivore bat *Desmodus rotundus* was captured in all three rivers, but had a higher percentage of capture in the mouth of the Mazagão River. Aerial nectarivorous and insectivorous bats were also more abundant in the mouth of the Mazagão River (Table 2).

The Shannon index (H') calculated for the region of the estuary of the Amazon River was H' = 2.91. The region of the mouth of the Maracá River showed the highest diversity (H' = 2.75), followed by the mouth of the Ajuruxi River (H' = 2.73), and of the mouth of the Mazagão River (H' = 2.66).

Discussion

The bat species richness and the number of individuals captured in the varzea forests of the estuary of the Amazon River in Amapá (40 species and 403 individuals), was similar to that found in other studies carried out in the Brazilian Amazon (e.g. Martins et al. 2006, 39 species and 470 captures in the Montanhas do Tumucumaque National Park; Ramos Pereira et al. 2009, 43 species and 520 captures in the Amanã Sustainable Development Reserve, considering only records from várzea forest; Bobrowiec et al. 2014, 41 species and 1069 individual captured at lake Uauaçú in the lower Purus River region considering records from varzea and *terra firme* forests). The bat species recorded in the present study represent approximately 46% of the species currently known for Amapá (Silva et al. 2013), 27% of the species known for the Brazilian Amazon (Bernard et al. 2011, Castro et al. 2012) and 22.5% of the species known for Brazil (Nogueira et al. 2014). Hence, this physiognomy of forest is very important for the maintenance of bat diversity in the Amazon, and, therefore, the economical activity prioritized in this region should be low-impact extractivism.

The high diversity of the bat fauna in the varzea forests was evident from the rarefaction curves, which did not reach an asymptote. This suggests that the sampling effort of 38,888 m^2.h should be increased to obtain a more complete inventory of the varzea forest species in the Amazon estuary. The sampling effort used in our study was moderate compared with other studies conducted in the Amazon that used greater efforts (e.g. Ramos Pereira et al. 2009 used a sampling effort of 54,648 m^2.h in varzea forest in the Amanã Sustainable Development Reserve, and Bobrowiec et al. 2014 used a total of 72,000 m^2.h in varzea and *terra firme* forests in Uauacú lake in the lower Purus River region). The estimate made with Jacknife I (53 species) suggests that we recorded 75% of the bat species of the study area. The missing species probably belong to the families Molossidae and Vespertilionidae, which are more difficult to capture, because they forage at high altitudes (Voss & Emmons 1996, Bernard & Fenton 2003), frequently higher than ground-level mist nets. Species of those families are more frequently captured when mist nets are set in the canopy, when colonies are discovered in households or tree hollows, or when the bats come down to drink water from rivers, lakes, or water holes on the forest edge (Voss & Emmons 1996).

We also highlight the new record of *Glyphonycteris daviesi* for the state of Amapá, which was captured in a managed *açaí* palm forest (*Euterpe oleracea*) in the mouth of the Ajuruxi River, Cajari Reserve. Hence, the number of bat species known for Amapá raises from 86 to 87 (Martins et al. 2006, Martins & Bernard 2008, Silva et al. 2013). *G. daviesi* is a rare species, with few individuals deposited in museums (Gregorin & Rossi 2005). In Brazil it was known only for the states of Pará, Amazonas, Rondônia, and Bahia (Williams & Genoways 2008). Although this species is classified as "least concern" in the red list of IUCN 2014, in neighbor countries, such as Bolivia, it is classified as vulnerable, mainly due to threats to the montane

Table 2. Species list, number of captures and trophic guild of the bat species captured in three localities of a varzea forest in the estuary of the Amazon River. Trophic guild categories: AI = aerial insectivore, FR = frugivore, GA = gleaning animalivore, NE = nectarivore, and SAN = sanguivore.

Tabela 2. Lista de espécies, número de capturas e guilda trófica de morcegos das espécies de morcegos capturadas em três localidades de floresta de várzea no estuário do Rio Amazonas. Para guilda trófica (AI = aerial insectivore, FR = frugivore, GA = gleaning animalivore, NE = nectarivore, SAN = Sanguivore).

	Ajuruxi	**Maracá**	**Mazagão**	**Total**	**Trophic guild**
Families/Species					
Emballonuridae					
Cormura brevirostris (J. A. Wagner, 1843)	0	1	0	1	AI
Diclidurus albus (wied-Neuwied, 1820)	0	1	0	1	AI
Saccopteryx bilineata (Temminck, 1838)	3	0	4	7	AI
Saccopteryx leptura (Schreber, 1774)	0	1	2	3	AI
Peropteryx leucoptera W. Peters, 1967	0	0	1	1	AI
Peropteryx macrotis (J. A. Wagner, 1843)	1	0	0	1	AI
Momoopidae					
Pteronotus rubiginosus (Wagner, 1843)	0	0	1	1	AI
Phyllostomidae					
Artibeus lituratus (Olfers, 1818)	2	0	0	2	FR
Artibeus obscurus (Schinz, 1821)	8	4	5	17	FR
Artibeus planirostris (Leach, 1821)	11	20	16	47	FR
Carollia brevicauda (Schinz, 1821)	14	11	14	39	FR
Carollia perspicillata (Linnaeus, 1758)	35	29	32	96	FR
Chrotopterus auritus (W. Peters, 1856)	2	0	0	2	GA
Choeroniscus minor (W. Peters, 1868)	2	2	8	12	NE
Dermanura cinerea Gervais, 1856	5	3	2	10	FR
Dermanura gnoma (Handley, 1987)	1	0	0	1	FR
Desmodus rotundus (É. Geoffroy St.-Hilaire, 1810)	3	6	10	19	SAN
Glyphonycteris daviesi (Hill, 1965)	2	0	0	2	GA
Glossophaga soricina (Pallas, 1766)	4	3	4	11	NE
Lampronycteris brachyotis (Dobson, 1879)	1	0	0	1	GA
Lonchophylla thomasi J. A. Allen, 1904	6	3	2	11	NE
Lophostoma silvicolum d'Orbigny, 1836	4	6	3	13	GA
Macrophyllum macrophyllum (Schinz, 1821)	0	1	0	1	GA
Micronycteris hirsuta Peters, 1869	5	0	0	5	GA
Micronycteris megalotis (Gray, 1842)	0	3	1	4	GA
Micronycteris minuta (P. Gervais, 1856)	0	3	0	3	GA
Micronycteris schmidtorum (Sanborn, 1935)	1	0	0	1	GA
Phyllostomus elongatus (É. Geoffroy St.-Hilaire, 1810)	4	4	3	11	GA
Platyrrhinus brachycephalus (Rouk and Carter, 1972)	0	2	3	5	FR
Plathyrrhinus fusciventris Velazco, Gardner & Patterson 2010	0	3	4	7	FR
Plathyrrhinus incarum (Thomas, 1912)	0	2	0	2	FR
Rhynophilla pumilio (Peters, 1865)	7	0	1	8	FR
Tonatia saurophila (Koopman and Williams, 1951	4	1	2	7	GA
Trachops cirrhosus (Spix, 1823)	1	9	1	11	GA
Trinycteris nicefori Sanborn, 1949	0	8	1	9	GA
Uroderma bilobatum Peters, 1866	4	4	13	21	FR
Vampyriscus bidens (Dobson, 1878)	2	0	3	5	FR
Vampyrodes caraccioli (Thomas, 1889)	0	2	0	2	FR
Thyropteridae					
Thyroptera tricolor Spix, 1823	0	1	1	2	AI
Vespertilionidae					
Myotis nigricans (Schinz, 1821)	1	0	0	1	AI
Number of individuals	133	133	137	403	
Number of species	26	26	25	40	
Shannon Index (H')	2.73	2.75	2.66	2.91	

forests and lowland floodable areas where *G. daviesi* occurs (Ochoa & Velazco 2008). Hence, in Amapá *G. daviesi* deserves attention in future revisions of endangered species lists, as it was recorded only in varzea forests so far, even after a high sampling effort made in the state (Martins et al. 2006, Martins & Bernard 2008, Martins et al. 2011, Silva et al. 2013).

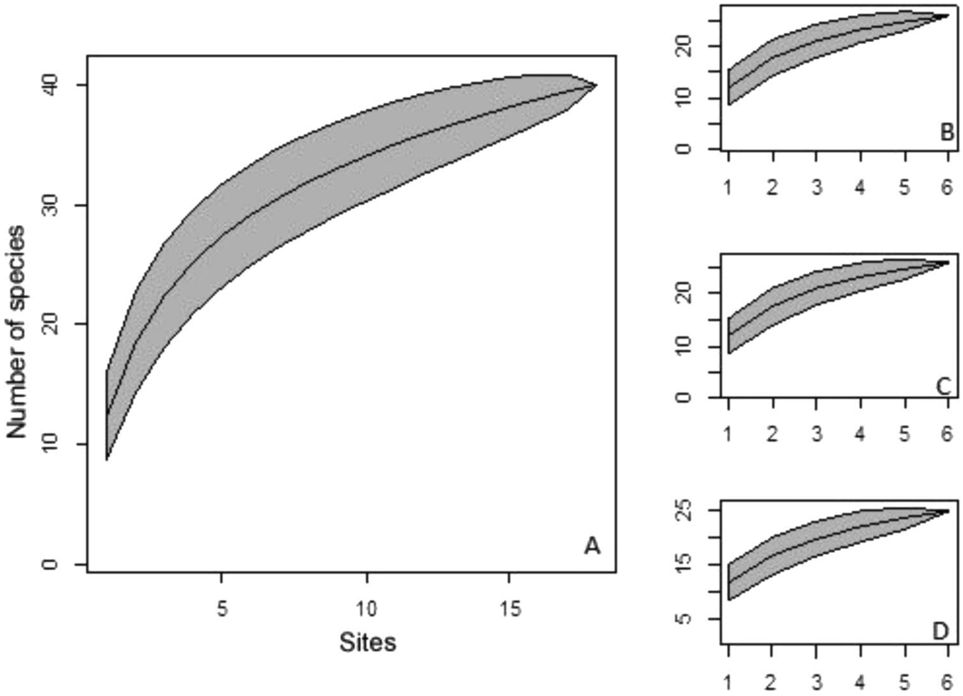

Figure 2. Rarefaction curves for the study area. A: curve for the entire inventory; B = Ajuruxi River, C = Maracá River, D = Mazagão River.
Figura 2. Curvas de rarefação para a região de estudo. A: curva para todo o inventário; B = Rio Ajuruxi, C = Rio Maracá, D = Foz do Rio Mazagão.

We found a high abundance of phyllostomid bats, as expected, in particular frugivorous species, such as *Artibeus planirostris*, which have higher biomass in the varzea forest (*várzea*) than in *terra firme* and *igapó* forests (Ramos Pereira et al. 2010a, Marques et al. 2012). Factors, such as high soil fertility in the varzea forest, allow a larger number of trees to bear fruits throughout the year (Ayres 2006, Haugaasen & Peres 2006). This could explain the high abundance and biomass of frugivorous bats in this kind of forest.

Gleaning animalivores showed high richness and abundance in the mouth of the rivers Maracá and Ajuruxi. There is a consensus in the literature that these species are sensitive to environmental changes and may be used as bioindicators (Medellín et al. 2000, Soriano & Ochoa 2001, Presley et al. 2008). Gleaning animalivores feed on arthropods and small vertebrates on the vegetation. In some cases these bats depend on specific roosts, such as termite nests (Kalko et al. 1999, Soriano & Ochoa 2001, Presley et al. 2008), and any human impact can decrease roost availability. Hence, based on the bat fauna, it is possible to infer that the mouths of the rivers Maracá and Ajuruxi are areas with good environmental integrity.

The sanguivore bat *D. rotundus* was recorded in all three river mouths, but at higher abundance at the Mazagão River. Some authors state that this species is associated with large rivers, which supposedly have higher roost abundance (Lord 1988, Taddei et al. 1991). However, other authors state that the occurrence of *D. rotundus* is more closely linked to food availability, such as farms that raise cattle, horses, and pigs (Wilkinson 1985, Aguiar 2007). The mouth of the Mazagão River meets both requirements: it is close to large rivers, such as the Amazon, and to pig farming areas held by riverine populations. It is common to listen from residents that poultry and pig farming in the region are limited due to attacks by vampire bats (Castro, I. J., *pers. comm.*). However, this problem can be solved with the adoption of simple measures, such as the use of shelters with protective screens and control of *Desmodus* populations by health agencies.

Most insectivorous bats found in the present study belong to the family Emballonuridae and were frequent in all three river mouths. These bats prefer illuminated roosts, such as tree trunks close to water bodies (Kunz & Lumsdem 2003), which are common in varzea forests and favor the occurrence of bats of this family. Two specimens of insectivorous bats (*Thyroptera tricolor*) of the family Thyropteridae were captured: one at the mouth of the Mazagão River (site MMZ2) and the other at the mouth of the Maracá River (site MMR3), where there is a large amount of plants of the genus *Heliconia*. Bats of the family Thyropteridae have adhesive disks on their feet and thumbs, which help them attach themselves to leaves of *Musa* (banana) and *Heliconia*, which they prefer (Kunz & Lumsdem 2003).

The data obtained in the present study revealed that the varzea forests of the estuary of the Amazon River harbor high richness and diversity of bats. Therefore, conservation policies should be implemented in the region. Such policies should focus on sustainable management of the *açaí* palm (*Euterpe oleracea*) and timber exploitation. Illegal timber exploitation, which can threaten the fauna and flora of those biodiversity-rich forests, should also be repressed.

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Bycatch fauna of seabob shrimp trawl fisheries from Santa Catarina State, southern Brazil

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Abstract: Marine communities in tropical regions contain a great diversity of species that play key roles in ecological processes. The observed bycatch fauna in artisanal fishing for the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) in the southwest Atlantic exceeds the quantity of commercial shrimp captured. This bycatch has not been previously inventoried extensively in Brazil, particularly in the State of Santa Catarina, where small-scale shrimp fisheries is a traditional activity and dominates the local fishing economy. Six municipalities were sampled three times a month, from 1996 to 2011, yielding 216 species belonging to the bycatch (7 cnidarians, 22 mollusks, 42 crustaceans, 11 echinoderms, and 134 fishes). Bycatch management is a pressing aspect of shrimp fisheries. By inventorying the accidental bycatch, we provide a preliminary step towards defining intervention measures to reduce or make better use of this bycatch in seabob artisanal fisheries. Conservation of marine biodiversity is still inadequate in Brazil. We have attempted to identify additional threats to vulnerable and endangered species resulting from shrimp trawling.

Keywords: *bycatch fauna, marine diversity, southwest Atlantic, threatened species, Xiphopenaeus kroyeri.*

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Resumo: Comunidades marinhas em regiões tropicais contêm uma grande diversidade de espécies que desempenham papéis-chave em processos ecológicos. A fauna acompanhante em pescas artesanais do camarão sete-barbas *Xiphopenaeus kroyeri* (Heller, 1862) no Atlântico Sudoeste excede a quantidade de camarões comerciais desta espécie capturados. Esta fauna acompanhante não foi catalogada de forma detalhada no Brasil, particularmente no Estado de Santa Catarina, onde a pescaria em pequena escala é uma atividade tradicional que domina a economia pesqueira local. Seis municípios foram amostrados três vezes por mês, de 1996 a 2011, capturando 216 espécies pertencentes à fauna acompanhante (7 cnidários, 22 moluscos, 42 crustáceos, 11 equinodermos e 134 peixes). O manejo da fauna acompanhante constitui um aspecto urgente nas pescarias de camarões. Ao listar a fauna acompanhante acidental, uma etapa preliminar é executada para a definição de medidas de intervenção, fazendo melhor uso desta fauna acompanhante na pesca artesanal de camarões. A conservação da biodiversidade marinha ainda é inadequada no Brasil. Apresentamos uma tentativa de identificar ameaças adicionais às espécies vulneráveis e em risco de extinção como resultado das pescas de arrastro.

Palavras-chave: *fauna acompanhante, diversidade marinha, Atlântico Sudoeste, espécies ameaçadas, Xiphopenaeus kroyeri.*

Introduction

Biodiversity refers to the variety of life forms that result from the process of organic evolution, at all levels of organization. It may include intra and interspecific genetic variations or the diversity of ecosystems and the physical conditions under which they are found (Wilson 1992, Gray 1997, Alho 2008).

The importance of biodiversity for human life is presently being much discussed, either as a direct provider of natural products or as an indirect maintainer of ecological processes (Alho 2008, Tundisi & Matsumura-Tundisi 2008). One activity that benefits directly from biodiversity inventories is fisheries. Fishing stands out among the four largest producers of animal protein for human consumption in Brazil. According to data from FAO, the national production in shrimp fisheries occupied the 14th place in the world from 2000 to 2005 (Gillett 2008), while in 2006 Brazil became one of the six largest nations in terms of volume of shrimp fishery (Gillett 2008).

The small-scale fisheries of the seabob shrimp *Xiphopenaeus kroyeri* (Heller, 1862) exert a relevant role in the socioeconomic and cultural context along the coast of the State of Santa Catarina, Brazil. This activity represents a legacy of our Azorean culture, which contributed markedly to the development of the artisanal and industrial fisheries in the State (Branco 2005, Branco & Verani 2006). On the other hand, due to the closing of net meshes during trawling, and thus to low selectivity of the fishing gear, a diversity of other organisms is captured incidentally. These organisms, the catch of individuals by fishing gear which is targeting another species (Keunecke et al. 2007), are known as the bycatch (Slavin 1983, Alverson et al. 1994).

This bycatch generally is quite diversified, consisting of fish, crustaceans, mollusks, among other groups. The bycatch is always considerably more abundant than the quantity of the commercial target shrimp (Coelho et al. 1986, Branco 2005). Unfortunately, shrimp trawling is undoubtedly the most damaging fishery activity in terms of biomass bycatch, and excessive bycatch discards certainly occur in Brazilian fisheries (Viana & Almeida 2005). Part of this capture, represented by specimens of economic importance and sufficient commercial size is landed, while another part, frequently the largest fraction, composed of individuals with no commercial value or by commercial specimens of small size, is returned non-living to the sea (Graça-Lopes et al. 2002, Branco 2005). This fact, allied with overfishing and the pollution of oceans, is being pinpointed as one of the main threats to the biodiversity of the marine environment (Amaral & Jablonski 2005). As an aggravating factor, tropical shrimp fishery has been found to generate the highest proportion of discard in relation to other fishery activities (Alverson et al.1994). In Brazil, studies on the biology of discarded species are deficient and scarce (Vianna et al. 2000). Such studies increase in importance when many fishery resources show signs of depletion (Vianna & Verani 2002). Vianna & D' Incao (2006) demonstrated that the use of a simple bycatch reduction device grid will greatly reduce the negative impact of this bycatch waste. Other papers (Vianna 2001, Vianna et al. 2004, Vianna & Almeida 2005, Keunecke et al. 2007) further study the impact of shrimp fisheries on the bycatch fauna.

Notwithstanding these threats, little is known about marine biodiversity (Hendrickx et al. 2002, Amaral & Jablonski 2005, Severino-Rodrigues et al. 2007, Perez 2009), especially regarding shrimp fisheries (Graça-Lopes et al. 2002, Pinheiro & Martins 2009). Bycatch is considered in Vianna (2001), Vianna et al. (2004), Keunecke et al. (2007) and Vianna & Almeida (2009). Yet most papers in our country deal only with a few individual groups, such as the ichthyofauna of Pernambuco and Alagoas (Santos et al. 2008, Santos 2000, Tischer & Santos 2001), São Paulo (Graça Lopes et al. 2002, Coelho et al. 1986, Paiva-Filho & Schmiegelow 1986), Paraná (Gomes & Chaves 2006, Schwarz Jr et al. 2007), Santa Catarina (Branco & Verani 2006, Bernardes Jr et al. 2011; Freitas et al. 2011), or the carcinofauna inventoried by Severino-Rodrigues et al. (2002), Robert et al. (2007) and Branco & Fracasso (2004), respectively, in São Paulo, Paraná and Santa Catarina.

In Santa Catarina, the analysis of the rejected bycatch is still deficient. This paper thus aims to characterize for the first time the species composition associated with the seabob shrimp fisheries, in six municipalities of the State, as a subsidy for evaluating the impact of this fishing gear in the coastal environment.

Material and methods

The present study was conducted along the coast of the State of Santa Catarina, southern Brazil, in the main fishing areas of the seabob shrimp, between the coordinates of 26°24' – 27°53' S and 48°33' – 48°38' W, covering the municipalities of Barra do Sul, Penha, Itajaí, Porto Belo, Tijucas, and Palhoça (Fig. 1, Table 1).

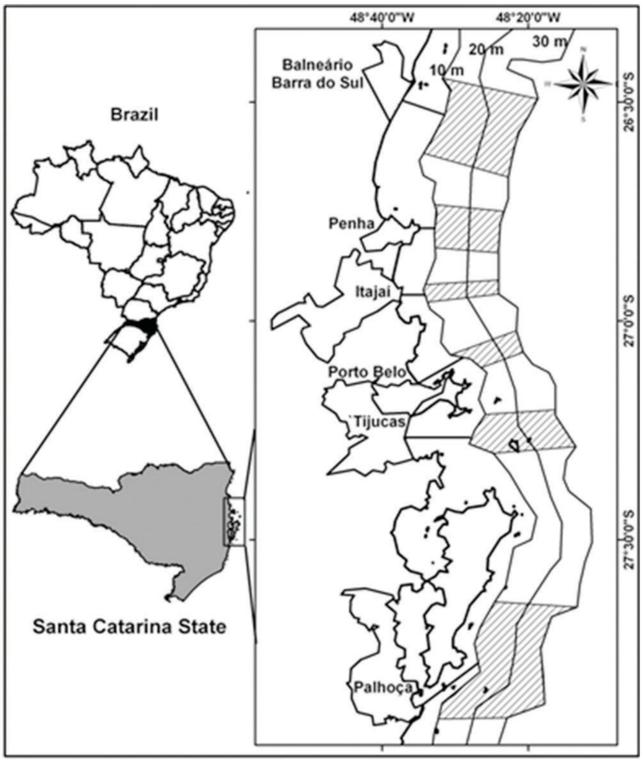

Figure 1. On the left the insertion of the State of Catarina in southern Brazil is indicated. On the right the entire coastline of the State informs the names of the coastal municipalities from north to south and shows the shallow coastal area down to 30 meters depth, the longitudinal lines indicating the isobaths of 10 and 20 m. The hatched areas represent the sampled fishing areas.

In each locality three trawls per month were made, in traditional fishing sites, with a mean duration of one hour, in depths varying from 5 to 30 m, from 1996 to 2011. For the capture of specimens, a vessel was equipped with two double-rigged trawl nets, with net meshes of 3.0 cm at net entrance and 2.0 cm in the collecting sac, and trawled at a mean speed of two knots (Branco 2005). The contents of each trawling were conditioned, tagged and maintained in isoprene boxes with ice.

In the lab, identification of the components of the fauna was made with specialized references for each group. Families were listed in conventional taxonomical order, species in alphabetical order. Species were grouped as very frequent (VF), when occurring in more than 70% of the samples; frequent (F), when abundance is from 40% to 69,9% of the samples; little frequent (LF), when abundance is between 20% and 39,9%; and occasional (O), when occurring in less than 19,9% of the samples (Severino-Rodrigues et al. 2002).

Results

During the study period a total of 216 species were identified in the artisanal fisheries for the seabob shrimp along the coast of the State of Santa Catarina, belonging to 105 families, among cnidarians, mollusks, crustaceans, echinoderms and fishes (Tables 2 to 6).

Table 1. Number of tows and depths ranges at each collecting site.

Municipality	Years	Number of tows	Depth range (m)
Barra do Sul	2007–2010	144	10 – 20 – 30
Penha	1996–2011	540	10 – 20 – 30
Itajaí	2001–2002	72	05 – 10 – 20
Porto Belo	2009–2010	72	10 – 20 – 30
Tijucas	2004–2005, 2008	108	08 – 15 – 20
Palhoça	2003–2004	72	10 – 20 – 30

Table 2. List of cnidarian species, with respective frequencies of occurrence by collecting site, during the period between years 1996 and 2010. VF: very frequent; F: frequent; LF: little frequent; O: occasional.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Cnidaria/ Anthozoa						
Actiniidae						
Bunodosoma caissarum Corrêa, 1964	VF	VF	F	F	VF	F
Renillidae						
Renilla muelleri Kölliker, 1872	O	O			O	O
Cnidaria/ Hydrozoa						
Olindiidae						
Olindias sambaquiensis Müller, 1861	O	O	O	O	O	O
Aequoridae						
Rhacostoma atlantica Agassiz, 1850	F	F	F	F	F	F
Cnidaria/ Cubozoa						
Chirodropidae						
Chiropsalmus quadrumanus (Müller , 1859)	VF	VF	VF	VF	VF	VF
Cnidaria/ Scyphozoa						
Pelagiidae						
Chrysaora lactea Eschscholtz, 1829	O	O	O	O	O	O
Lychnorhizidae						
Lychnorhiza lucerna Haeckel, 1880	F	F	F	LF	F	F

Cnidarians were represented by seven species, in seven genera and families, belonging to the classes Anthozoa, Hydrozoa, Cubozoa, and Scyphozoa. The anemone *Bunodosoma caissarum* and the medusa *Chiropsalmus quadrumanus* were considered very frequent or frequent in all sampled areas, while the penatulacean *Renilla muelleri* and the medusae *Chrysaora lactea* and *Olindias sambaquiensis* occurred occasionally (Table 2). *Rhacostoma atlanticum* and *Lychnorhiza lucerna* were frequent in the six regions, except in Tijucas, where *L. lucerna* was recorded with low frequency (Table 2).

Mollusks participated with 22 species, 21 genera and 19 families, distributed among Gastropoda, Bivalva and Cephalopoda (Table 3). Gastropods contributed with the largest number of families and species, of which 11 species occurred occasionally, while *Buccinanops gradatum* was very frequent in most sampled regions (10 were recorded in Table 3), followed by *Olivancillaria urceus*. The only captured polyplacophoran, *Chaetopleura angulata,* appeared occasionally (Table 3).

Six species of Bivalvia were recorded only in the region of Penha, occurring occasionally in samples (Table 3). Of the four Cephalopoda, the squid *Lolliguncula brevis* was very frequent (except in Itajaí), *Loligo plei* and *Loligo sanpaulensis* were frequent in Tijucas and Porto Belo, very frequent in Palhoça and occasional/little frequent in the remaining areas. *Octopus vulgaris* appeared occasionally in most areas, except in Itajaí and Tijucas (Table 3).

Among crustaceans, 42 species were identified (including the seabob shrimp), distributed into 33 genera and 17 families. Stomatopoda were represented by one family (Squillidae) and species (*Squilla empusa*), occurring little frequently or occasionally in trawls (Table 4). Decapoda contributed with a larger number of species. Portunidae with 9 species, *Callinectes danae* and *C. ornatus* being the most frequent, followed by Xanthidae and Penaeidae, both with six species (Table 4).

Hepatus pudibundus was the most frequent crab in captures, while Leucosiidae, Majidae and Parthenopidae oscillated between little frequent and occasional in the fishing areas (Table 4).

Among the Xanthidae, all species were occasional, while Penaeidae, represented by the marine shrimps of commercial value, had only the seabob shrimp (*Xiphopenaeus kroyeri*) as very frequent, followed by *Artemesia longinaris,* frequent in all localities (Table 4). The pink-shrimp (*Farfantepenaeus brasiliensis and F. paulensis*) and the white shrimp (*Litopenaeus schmitti*) alternated between little frequent and occasional in most sampled localities, except in Itajaí, where *L. schmitti* was frequent and in Palhoça, where *F. brasiliensis* was frequent (Table 4).

Table 3. List of mollusk species, with respective frequencies of occurrence by collecting site, during the period between years 1996 and 2010. VF: very frequent; F: frequent; LF: little frequent; O: occasional.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Mollusca/ Gastropoda						
Trochidae						
Tegula viridula (Gmelin, 1791)		O				LF
Turbinidae						
Astraea latispina (Philippi, 1844)		O				
Tonnidae						
Tonna galea brasiliana (Mörch, 1877)		O				
Ranellidae						
Cymatium parthenopeum (von Salis, 1793)	O	O	O	O	O	O
Muricidae						
Siratus senegalensis (Gmelin, 1790)	O	O	O	O	O	
Thaididae						
Thais haemastoma (Linnaeus, 1767)		O				O
Nassariidae						
Buccinanops gradatum (Deshayes, 1844)	VF	VF	F	VF	VF	F
Strombidae						
Strombus pugilis (Linnaeus, 1758)		O				
Olividae						
Olivancillaria urceus (Röding, 1798)	VF	VF	F	F	F	F
Volutidae						
Zidona dufresnei (Donovan, 1823)	O	O			O	
Aplysiidae						
Aplysia brasiliana Rang, 1828	O	O				
Mollusca/ Polyplacophora						
Ischnochitonidae						
Chaetopleura angulata (Spengler, 1797)	O	O			O	O
Mollusca/ Bivalvia						
Arcidae						
Anadara brasiliana (Lamarck, 1819)		O		O		
Mytilidae						
Modiolus carvalhoi Klappenbach, 1966		O				
Cardiidae						
Trachycardium muricatum (Linnaeus, 1758)		O				
Veneridae						
Chione cancellata (Linnaeus, 1767)		O				
Pitar arestus (Dall and Simpson, 1901)		O				
Tellinidae						
Temnoconcha brasiliana Dall, 1921		O				
Mollusca/ Cephalopoda						
Loliginidae						
Loligo plei Blainville, 1823	LF	LF	O	F	F	VF
Loligo sanpaulensis Brakoniecki, 1984	O	LF	LF	F	F	VF
Lolliguncula brevis (Blainville, 1823)	VF	VF	F	VF	VF	VF
Otopodidae						
Otopus vulgaris Cuvier, 1797	O	O			O	O

The solenocerid *Pleoticus muelleri,* has commercial importance in Santa Catarina, being frequent from Barra do Sul to Tijucas and very frequent in Porto Belo and Palhoça (Table 4). In the latter location, this species, together with *Artemesia longinaris*, contributed with the largest abundances, superseding the target species of shrimp. The shrimp *Acetes americanus* (Sergestidae) also had high frequency in captures, alternating between frequent and very frequent (Table 4).

Among hermit crabs (here represented by families Diogenidae and Paguridae), only *Dardanus insignis* had a high frequency of occurrence, being very frequent in Barra do Sul - Penha and frequent in the remaining localities. The remaining species have occasional or little frequent occurrences (Table 4). The crab-like *Porcellana sayana* was the most frequent anomuran in captures (Table 4).

The echinoderms were represented by 11 species, distributed in nine genera and families, among Asteroidea, Echinoidea and Ophiuroidea, where the first contributed with the largest number of families and species, with special mention of the sea-star *Astropecten marginatus.* Although this latter

Table 4. List of crustacean species, with respective frequencies of occurrence by collecting site, during the period between years 1996 and 2010. VF: very frequent; F: frequent; LF: little frequent; O: occasional.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Squillidae						
Squilla empusa Say, 1818	LF	LF		O	LF	LF
Crustacea/ Decapoda						
Penaeidae						
Artemesia longinaris Bate, 1888	F	F	F	F	F	F
Farfantepenaeus brasiliensis (Latreille, 1817)	LF	O	LF	O	LF	F
Farfantepenaeus paulensis (Pérez Farfante, 1967)	O	O	LF	O	O	LF
Litopenaeus schmitti (Burkenroad, 1936)	LF	LF	F	LF	LF	LF
Rimapenaeus constrictus (Stimpson, 1871)	O	O	O	O	LF	O
Xiphopenaeus kroyeri (C. Heller, 1862)	VF	VF	VF	VF	VF	LF
Solenoceridae						
Pleoticus muelleri (Bate, 1888)	F	F	F	F	VF	VF
Sicyoniidae						
Sicyonia dorsalis Kingsley, 1878	F	F	LF	F	VF	LF
Alpheidae						
Alpheus bouvieri A. Milne-Edwards, 1878		LF	O		O	O
Lysmatidae						
Exhippolysmata oplophoroides (Holthuis, 1948)	O	LF	O	LF	LF	O
Sergestidae						
Acetes americanus Ortmann, 1893	VF	VF	VF	F	F	F
Palaemonidae						
Nematopalaemon schmitti (Holthuis,1950)		O	O			
Diogenidae						
Dardanus insignis (de Saussure, 1858)	VF	VF	F	F	F	F
Dardanus venosus (H. Milne Edwards, 1848)		O			O	
Petrochirus diogenes (Linnaeus, 1758)	O	O	O	O	O	O
Loxopagurus loxochelis (Moreira, 1901)	LF	LF	LF	LF	LF	O
Paguridae						
Pagurus exilis (Benedict, 1892)		O			O	
Porcellanidae						
Porcellana sayana (Leach, 1820)	VF	VF	F	F	F	LF
Aethridae						
Hepatus pudibundus (Herbst, 1785)	VF	VF	VF	F	VF	VF
Leucosiidae						
Persephona lichtensteinii Leach, 1817	O	LF	LF	O	F	LF
Persephona mediterranea (Herbst, 1794)	F	LF	O	O	F	LF
Persephona punctata (Linnaeus, 1758)	LF	LF	LF	O	LF	LF
Epialtidae						
Libinia ferreirae Brito Capello, 1871	O				O	
Libinia spinosa (H. Milne Edwards, 1834)	O	LF	LF	O	F	LF
Pelia rotunda A. Milne-Edwards, 1875		O				
Majidae						
Microphrys bicornutus (Latreille, 1825)		O				
Parthenopidae						
Heterocrypta lapidea Rathbun, 190		O				
Polybiidae						
Ovalipes trimaculatus (De Haan 1833)						LF
Portunidae						
Arenaeus cribrarius (Lamarck, 1818)	LF	LF	LF		F	O
Callinectes danae Smith, 1869	VF	VF	VF	VF	VF	F
Callinectes bocourti A Milne Edwards, 1879			O			
Callinectes ornatus Ordway, 1863	VF	VF	VF	VF	VF	VF
Callinectes sapidus Rathbun, 1896		O	O	O		
Cronius ruber (Lamarck, 1818)		O			O	O
Portunus spinicarpus (Stimpson, 1871)	O	O			LF	LF
Achelous spinimanus (Latreille, 1819)	LF	O	O		F	LF

Continued on next page

Table 4. Continued.

Family/Species	**Barra do Sul**	**Penha**	**Itajaí**	**Tijucas**	**Porto Belo**	**Palhoça**
Panopeidae						
Acantholobulus schmitti (Rathbun, 1930)		O				
Eurypanopeus abbreviatus (Stimpson, 1860)		O				
Menippidae						
Menippe nodifrons Stimpson, 1859	O	O			O	O
Pilumnidae						
Pilumnus dasypodus Kingsley, 1879	O	O	O	O	O	O
Xanthidae						
Speocarcinus carolinensis Stimpson, 1859		O			O	
Speocarcinus meloi D'incao and Gomes da Silva, 1992					O	

Table 5. List of echinoderm species, with respective frequencies of occurrence by collecting site, during the period between years 1996 and 2010. VF: very frequent; F: frequent; LF: little frequent; O: occasional.

Family/Species	**Barra do Sul**	**Penha**	**Itajaí**	**Tijucas**	**Porto Belo**	**Palhoça**
Echinodermata/ Asteroidea						
Astropectinidae						
Astropecten brasiliensis Müller and Troschel, 1842	O	O	O		LF	LF
Astropecten marginatus (Gray, 1840)	F	VF	VF	F	VF	VF
Luidiidae						
Luidia clathrata (Say, 1825)		O	O			
Luidia senegalensis (Lamarck, 1816)	LF	LF	LF	O	LF	LF
Asterinidae						
Asterina stellifera (Möbius, 1859)		O			O	
Echinasteridae						
Echinaster brasiliensis (Müller and Troschel, 1842)		O			O	O
Echinodermata/ Echinoidea						
Arbaciidae						
Arbacia lixula (Linnaeus, 1758)		O				
Mellitidae						
Mellita quinquiesperforata (Leske, 1778)					O	F
Toxopneustidae						
Lytechinus variegatus (Lamarck, 1816)		O			O	LF
Echinodermata/Ophiuroidea						
Amphiuridae						
Micropholis atra (Stimpson, 1854)		O				O
Ophiactidae						
Hemipholis elongata (Say, 1825)	O	O				O

species is considered threatened, it was found very frequently in most sampled localities (Table 5). The remaining species of Asteroidea occurred occasionally or with little frequency, such as *Luidia senegalensis* (Table 5).

Among the Echinoidea, *Arbacia lixula*, *Lytechinus variegatus* and *Mellita quinquiesperforata* were registered occasionally in Penha and Porto Belo, and frequently (*M. quinquiesperforata*), or little frequently (*L. variegatus*) in Palhoça (Table 5). Ophiuroidea, with *Micropholis atra* and *Hemipholis elongata,* were of occasional occurrences in Penha, Barra do Sul and Palhoça (Table 5).

Of all the faunistic groups captured with the seabob shrimp, the ichthyofauna presented the largest number of families and species, being represented by 134 species, distributed in 53 families. Ten were elasmobranchs and 124 were bony fishes (Table 6). Elasmobranchs had a small presence in the trawls, occurring occasionally in samples, with the exception of the rays *Zapteryx brevirostris* and *Atlantoroja cyclophora*, frequent in the fisheries at Porto Belo (Table 6).

The 124 species of bony fish are distributed into 92 genera and 48 families, the occasional and little frequent species dominating the captures (Table 6). Sciaenidae contributed with most species, with high frequencies of occurrence, mainly *Paralonchurus brasiliensis*, *Stellifer brasiliensis* and *S. rastrifer*, which were very frequent in all sampled areas. They were followed by *Isopisthus parvipinnis*, *Menticirrhus americanus*, *Stellifer stellifer* and *Larimus breviceps*, which oscillated from frequent to very frequent (except for Tijucas and Palhoça) (Table 6). *Micropogonias furnieri* presented high frequency in Itajaí and Porto Belo, *Cynoscion jamaicensis* and *Cynoscion guatacupa* in Porto Belo and Palhoça, respectively, and *Ctenosciaena gracilicirrhus* in Penha.

The Sciaenidae presented the highest specific diversity, 16 species recorded, followed by 12 species of Carangidae and

Table 6. List of fish species, with respective frequencies of occurrence by collecting site, during the period between years 1996 and 2010. VF: very frequent; F: frequent; LF: little frequent; O: occasional; *, threatened species.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Chondrichthyes						
Squatinidae						
Squatina guggenheim Marini, 1936*		O				
Narcinidae						
Narcine brasiliensis (Olfers, 1831)*	O	O	O	O		O
Rhinobatidae						
Rhinobatos horkelii Müller and Henle, 1841	O	O				
Rhinobatos percellens (Walbaum, 1792)		O				O
Zapteryx brevirostris (Müller and Henle, 1841)	LF	O	O		F	O
Rajidae						
Atlantoraja cyclophora (Regan, 1903)	O	O	O		F	O
Rioraja agassizi (Müller and Henle, 1841)	O	O	O		LF	O
Sympterygia acuta Garman, 1877						O
Sympterygia bonapartei Muller and Henle, 1841						O
Rhinopteridae						
Rhinoptera bonasus (Mitchill, 1815)					O	
Actinopterigii						
Elopidae						
Elops saurus Linnaeus, 1776		O	O	O		
Muraenidae						
Gymnothorax ocellatus (Agassiz, 1831)	O	LF			F	LF
Ophichthidae						
Ophichthus gomesii (Castelnau, 1855)	O	LF	O	LF	O	O
Muraenesidae						
Cynoponticus savanna (Bancroft, 1831)						O
Congridae						
Conger orbignianus Valenciennes, 1837	O	O		O	LF	O
Pristigasteridae						
Chirocentrodon bleekerianus (Poey, 1867)	VF	F	O	O	LF	O
Pellona harroweri (Fowler, 1917)	VF	F	F	VF	VF	LF
Engraulidae						
Anchoa spinifer (Valenciennes, 1848)	O	O	O			O
Anchoviella lepidentostole (Fowler, 1911)	O	LF	O	O	O	
Cetengraulis edentulus (Cuvier,1829)		O	LF	O		
Lycengraulis grossidens Agassiz, 1829	O	LF	LF	O	O	O
Clupeidae						
Harengula clupeola (Cuvier, 1829)	O	LF	LF	O	O	O
Opisthonema oglinum (Lesuer, 1818)	O	O	O	O	O	O
Sardinella brasiliensis (Steindachner, 1879)	O	O	O	O	O	O
Ariidae						
Cathorops spixii (Agassiz, 1829)		O		VF		
Genidens genidens (Valenciennes, 1839)	O	LF	F	F	LF	O
Genidens barbus (Lacépedède, 1803)	O	LF	LF	F	F	LF
Synodontidae						
Synodus foetens (Linnaeus, 1766)	LF					LF
Synodus intermedius (Spix and Agassiz, 1829)	O					O
TrachinOephalus myops (Forster, 1801)	F					
Phycidae						
Urophycis brasiliensis (Kaup, 1858)	O	O	LF		F	LF
Ophidiidae						
Ophidion holbrookii Putnam, 1874	O	O	O			O
Raneya brasiliensis (Kaup,1856)					O	
Batrachoididae						
Porichthys porosissimus (Cuvier 1829)	LF	LF	LF	LF	F	F
Ogcocephalidae						
Ogcocephalus vespertilio (Linnaeus,1758)		O				O

Continued on next page

Table 6. Continued.

Family/Species	**Barra do Sul**	**Penha**	**Itajaí**	**Tijucas**	**Porto Belo**	**Palhoça**
Belonidae						
Strongylura timucu (Walbaum, 1792)		O	O			
Syngnathidae						
Hippocampus erectus Perry, 1810		O				
Hippocampus reidi Ginsburg, 1933		O				
Microphis lineatus (Kaup, 1856)		O	O			
Bryx dunckeri (Metzelaar, 1919)				O		
Fistularidae						
Fistularia tabacaria Linnaeus, 1758		O	O	O		
Dactylopteridae						
Dactylopterus volitans (Linneus, 1758)	O	O		O	O	O
Scorpaenidae						
Scorpaena brasiliensis Cuvier, 1829						O
Scorpaena isthmensis (Meeke and Hildebrand, 1928)					LF	
Scorpaena plumieri Bloch, 1789		O				
Triglidae						
Prionotus punctatus (Bloch, 1793)	LF	LF		O	F	F
Centropomidae						
Centropomus parallelus Poey, 1860		O	O			O
Centropomus undecimalis (Bloch, 1792)	O		O			
Serranidae						
Diplectrum formosum (Linnaeus, 1766)	O	O	O			O
Diplectrum radiale (Quoy and Gaimard, 1824)	O	O	O	O	O	LF
Dules auriga Cuvier, 1829		O	O		LF	LF
Epinephelus niveatus (Valenciennes, 1828)		O				
Mycteroperca acutirostris (Valenciennes, 1828)		O	O			
Rypticus randalli Courtenay, 1967	O					O
Priacanthidae						
Priacanthus arenatus Cuvier, 1829		O				O
Carangidae						
Caranx latus Agassiz 1831		O	O			O
Caranx crysos (Mitchill, 1815)	O	O	O			
Chloroscombrus chrysurus (Linnaeus, 1766)	LF	F	F	LF	LF	O
Decapterus macarellus (Cuvier, 1833)						O
Oligoplites saliens (Bloch, 1793)		O	O			
Oligoplites saurus (Bloch and Schneider, 1801)	O	O	O	O	O	O
Selar crumenophthalmus (Bloch, 1793)						LF
Selene setapinnis (Mitchill, 1815)	VF	LF	LF	VF	F	F
Selene vomer (Linnaeus, 1758)	F	O	O	LF	LF	O
Trachinotus carolinus (Linneaus, 1766)		O	O			
Trachinotus falcatus (Linnaeus, 1758)	O	LF	O	O		O
Trachurus lathami Nichols, 1920		O				O
Lutjanidae						
Lutjanus cyanopterus (Cuvier, 1828)			O			
Gerreidae						
Diapterus rhombeus (Cuvier, 1829)	LF	O	O	O	F	O
Eucinostomus argenteus Baird and Girard, 1855	LF	O	O			O
Eucinostomus gula (Quoy and Gaimard, 1824)	O	O	O		LF	O
Eucinostomus melanopterus (Bleeker, 1863)		O	O		O	O
Haemulidae						
Boridia grossidens Cuvier 1830		O				
Conodon nobilis (Linnaeus, 1758)	LF	O	LF			O
Genyatremus luteus (Bloch, 1790)		O				
Orthopristis ruber (Cuvier, 1830)	O	O	O	O	O	O
Pomadasys corvinaeformis (Steindachner, 1868)	F	LF	LF	O	VF	F
Sparidae						
Diplodus argenteus (Valenciennes, 1830)						O

Continued on next page

Table 6. Continued.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Polynemidae						
Polydactylus virginicus (Linnaeus, 1758)	LF			O	F	
Sciaenidae						
Bairdiella ronchus (Curvier, 1830)		O	LF			O
Ctenosciaena gracilicirrhus (Metzelaar, 1919)	VF	F		LF	F	LF
Cynoscion jamaicensis (Vaillant and Bocourt, 1883)	F	LF	O	O	VF	O
Cynoscion leiarchus (Cuvier, 1830)	O	O	O			
Cynoscion striatus (Cuvier, 1829)	LF	LF		O		VF
Isopisthus parvipinnis (Cuvier, 1830)	VF	VF	VF	VF	VF	LF
Larimus breviceps Cuvier, 1830	VF	F	F	LF	VF	LF
Macrodon atricauda (Günther, 1880)	F	F			F	O
Menticirrhus americanus (Linnaeus, 1758)	F	F	F	LF	VF	VF
Menticirrhus littoralis (Holbrook, 1847)	O	LF	LF	O	F	F
Micropogonias furnieri (Desmarest, 1823)	O	F	VF	LF	VF	LF
Paralonchurus brasiliensis (Steindachner, 1875)	VF	VF	VF	VF	VF	VF
Stellifer brasiliensis (Schultz, 1945)	VF	VF	VF	VF	VF	VF
Stellifer rastrifer (Jordan, 1889)	VF	VF	VF	VF	VF	VF
Stellifer spp.	F	F	LF	LF	VF	LF
Stellifer stellifer (Bloch, 1790)	F	F	F	F	F	F
Mullidae						
Mullus argentinae Hubbs and Marini, 1933	O	O			O	LF
Upeneus parvus Poey, 1852						O
Pomacanthidae						
Pomacanthus paru (Bloch, 1787)	O	O		O	O	O
Labridae						
Xyrichtys novacula (Linnaeus, 1758)	O	O				
Uranoscopidae						
Astroscopus sexspinosus (Steindachner, 1876)		O				
Blenniidae						
Hypleurophilus fissicornis (Quoy and Gaimard, 1824)			O			
Gobiidae						
Bathygobius soporator (Valenciennes, 1837)			O			
Ephippidae						
Chaetodipterus faber (Broussonet, 1782)	O	O	O		LF	O
Trichiuridae						
Trichiurus lepturus Linnaeus, 1758	F	LF	F	F	VF	LF
Scombridae						
Scomberomorus brasiliensis Collette, Russo and Zavala-Camin,1978		O	O			
Stromateidae						
Peprilus paru (Linnaeus, 1758)	LF	LF	LF	LF	LF	F
Paralichthyidae						
Citharichthys arenaceus Evermann and Marsh, 1900			O			O
Citharichthys macrops Dresel, 1885	LF					
Citharichthys spilopterus Günther, 1862	LF	O	F	F	F	O
Cyclopsetta chittendeni Bean, 1895					O	
Cyclopsetta decussata Gunter, 1946	O				O	
Etropus crossotus (Jordan and Gilbert, 1881)	LF	LF	F	O	VF	O
Etropus longimanus Norman, 1933	O	O			O	LF
Paralichthys brasiliensis (Ranzani, 1842)		O				O
Paralichthys orbignyanus (Valenciennes, 1842)					O	O
Paralichthys patagonicus Jordan, 1889		O				LF
Syacium micrurum Ranzani, 1842	F					
Syacium papillosum (Linnaeus, 1758)	F	O			O	
Pleuronectidae						
Oncopterus darwinii Steindachner, 1874		O				O
Achiridae						
Achirus declivis Chabanaud, 1940	LF	F	LF	O	F	

Continued on next page

Table 6. Continued.

Family/Species	Barra do Sul	Penha	Itajaí	Tijucas	Porto Belo	Palhoça
Achirus lineatus (Linnaeus, 1758)	LF	F	LF	LF	VF	O
Catathyridium garmani (Jordan, 1889)	O	O				O
Gymnachirus nudus Kaup, 1858		O				LF
Cynoglossidae						
Symphurus plagusia (Bloch and Schneider, 1801)	LF	F				
Symphurus tesselatus (Linnaeus, 1766)	F	VF		F	VF	F
Balistidae						
Balistes capriscus Gmelin, 1789	O					O
Balistes vetula Linnaeus,1758		O				O
Monocanthidae						
Stephanolepis hispidus (Linnaeus, 1766)	F	O	LF	LF	F	VF
Tetraodontidae						
Lagocephalus laevigatus (Linnaeus, 1766)	F	F	F	F	F	F
Sphoeroides greeleyi Gilbert, 1900	LF	LF	O	LF	LF	LF
Sphoeroides spengleri (Bloch, 1785)	LF	LF	O	O		O
Sphoeroides testudineus (Linnaeus, 1758)	O	LF	O	O	LF	O
Diodontidae						
Chilomycterus spinosus (Linnaeus, 1758)	LF	LF	LF	O	O	O

of Paralichthyidae (Table 6). In Carangidae, the Atlantic bumper *Chloroscombrus chrysurus* and the Atlantic moonfish *Selene setapinis* were the most frequent in trawls. In Paralichthyidae, the flatfish *Citharichthys spilopterus* and *Etropus crossotus*, as well as *Syacium micrurrum* and *Syacium papillosum,* predominated, the latter being frequent only in the region of Barra do Sul (Table 6).

Nineteen other species of fishes along the areas of artisanal fisheries of Santa Catarina present high frequencies (Table 6).

Discussion

A sustainable use of marine resources cannot be properly established without a proper dimensioning of the marine biodiversity. Knowledge and monitoring of biodiversity of an ecosystem permit not only predictions of natural effects, but also of human influences that may affect the equilibrium and distribution of species (Hendrickx et al. 2002, Lanari & Coutinho Jr 2010).

In the present study, the richness of the seabob fishing area is represented by 216 species. Of these, only 31 (four cnidarians, three mollusks, nine crustaceans, one echinoderm and 14 fish) occurred frequently throughout captures, and may be characterized as typical of the bycatch and sharing the same environment used by the seabob shrimp.

Bycatch studies of the seabob shrimp artisanal fisheries in São Paulo (Graça-Lopes et al. 2002) and of two fishing areas in Espírito Santo (Pinheiro & Martins 2009), identified 83 and 77 species, respectively, a smaller number than that obtained for the littoral zone of Santa Catarina. Environmental heterogeneity and differences in sampling efforts and methods, including the long temporal span in the present study, may have contributed to the larger number of species obtained herein.

Macromedusae are organisms of great ecological, medical and economic importance (Morandini et al. 2005), having a relevant role in marine food chains, when competing for food or predating eggs and larvae of commercial species (Purcell & Arai 2001). Furthermore, they may interfere negatively in fishing activities (Nagata et al. 2009), and may cause serious accidents to swimmers and divers (Haddad Jr et al. 2002). The species *Rhacostoma atlantica* and *Lychnorhiza lucerna* were frequent in our samples. The latter species has often been associated with losses in trawling activities (Nagata et al. 2009). It is considered to load nets, making them heavier, inducing higher fuel consumption, and obliging fishermen to utilize other regions, as well as reducing the time of trawling and the capture of shrimp. Although very frequent in trawls, *Chiropsalmus quadrumanus* contributed with a small number of specimens, but has been associated with several accidents with fisherman, producing cases of highly painful burning (Haddad Jr et al. 2002, Nagata et al. 2009).

The region of Armação do Itapocoroy (Penha) presented the largest richness of molluscs, represented mainly by living gastropods and bivalves, which were common in samples of 1996 and 1997, when trawlings were frequently conducted over bottoms covered with shells and biodetritus. Generally, the gastropods *Buccinanops gradatum* and *Olivancillaria urceus* contributed with the largest observed abundances in trawls, similarly to that recorded for the coast of São Paulo (Graça-Lopes et al. 2002). The shells of *B. gradatum* and *O. urceus* are frequently occupied by the hermit crab *Loxopagurus loxochelis* along the coast of Brazil and Argentina (Biagi et al. 2006), as well as by epibiontic organisms such as anthozoans and bryozoans (Ayres-Peres & Mantelatto 2010), having an important role in the ecology of benthic communities. In the sampled areas along Santa Catarina, the hermit crabs *Dardanus insignis* and *Loxopagurus loxochelis* commonly occupied the shells of these two gastropods, which were also associated with the epibiont anemone *Bunodosoma caissarum*.

The squids *Lolliguncula brevis, Loligo sanpaulensis* and *L. plei* was also observed to have high frequencies of occurrence, particularly *Lolliguncula brevis,* a small, euryhaline coastal species, which is abundant in bays and estuaries (Coelho et al. 2010), although with small numerical representation in the fisheries of the seabob shrimp.

The presence of decapod crustaceans in the composition of the associate fauna is high, largely superseding the observed biomass of shrimp in conditions of being commercialized

(Coelho et al. 1986). Decapods are one of the main groups identified in the bycatch of the seabob shrimp, being only superseded by fish (Graça-Lopes et al. 2002, Branco & Verani 2006, Gomes & Chaves 2006, Bernardes Jr et al. 2011, Freitas et al. 2011). In the region of Santa Catarina, families Penaeidae and Portunidae contributed with the highest observed abundances, biomasses and frequencies in the bycatch of the seabob shrimp, which has also been observed along the Brazilian littoral zone (Sampaio & Fausto-Filho 1984, Branco & Lunardon-Branco 1993, Mantelatto & Fransozo 2000, Severino-Rodrigues et al. 2002, Branco & Fracasso 2004). Among the shrimps of commercial importance, the Argentine stiletto shrimp *Artemesia longinaris* and the Argentine red shrimp *Pleoticus muelleri,* occur frequently or very frequently in samples, sharing the same environment as the seabob shrimp, as also found by Severino-Rodrigues et al. (2002) along the coast of São Paulo. However, according to Fransozo et al. (2004) and Costa et al. (2004), these two species occurred in higher abundances in deeper and more saline regions than those inhabited by the seabob shrimp. In interviews with artisanal fishermen from Itajaí (non-published data), we verified that along the year the seabob fishery vessels progress to deeper waters between 20–25 m in the months from September to November. They pursued the Argentine red shrimp, when the profitability of *X. kroyeri* became unsatisfactory, due to low abundances of this resource (Branco 2005). *Acetes americanus* and *Sicyonia dorsalis* were the most frequent shrimp species without commercial value, as also observed by Severino-Rodrigues et al. (2002).

For Brachyura, the blue-crabs *Callinectes ornatus* and *C. danae* are well represented in the economy and feeding of the riverside populations of Santa Catarina (Branco & Masunari 2000). The fishery of swimming crabs represents one of the oldest activities along the Brazilian littoral zone, presently supporting several communities that live from their commercialization (Barreto et al. 2006).

The Echinodermata are important in benthic communities, occupying diverse ecological niches. Nineteen species belonging to the classes Asteroidea, Echinoidea and Holothuroidea have been included in a list of threatened species along the Brazilian coast (MMA 2014, Amaral & Jablonski 2005, Barros Lima & Fernandes 2009). Six of these species, *Astropecten marginatus*, *Astropecten brasiliensis, Luidia clathrata*, *Luidia senegalensis*, *Asterina stellifera*, and *Echinaster brasiliensis* were collected in the present study. Only *A. marginatus* was captured very frequently in trawls, indicating that artisanal fishing may be exerting pressure on the population of this species, contributing to its present extinction status.

As in other fishing regions in the Atlantic, fishes represented the main component of the bycatch of the seabob shrimp fisheries (Pinheiro & Martins 2009, Paiva-Filho & Schmiegelow 1986, Graça-Lopes et al. 2002, Gomes & Chaves 2006, Schwarz Jr et al. 2007, Branco & Verani 2006, Freitas et al. 2011). Of the fish species captured along the coast of Santa Catarina, elasmobranchs contribute a small percentage of individuals, most being occasional in samples. Young elasmobranchs captured by artisanal fishing are infrequent in our sampling. This may be due to the fact that most species evade the nets due to the low power of many fishing vessels in the area. Notwithstanding, even occasional trappings may significantly affect the recruitment capacity of species (Costa & Chaves 2006). Considering the sharing of fishing areas by artisanal communities, and the performance of the industrial fleet, the presence of young individuals of *Rhinobatos horkelii* and Squatina guggenheim, threatened with extinction (MMA 2014), remains a worrying aspect for the conservation of the populations belonging to these species. The application of regulating acts becomes urgent for the management of the fishing activities considered herein.

Among bony fish, the Sciaenidae were most representative in number, biomass, frequency of occurrence and diversity of species, a fact observed also in other localities of the Atlantic Ocean, both in the south (Branco 2005, Branco & Verani 2006, Giannini & Paiva-Filho 1990), and in North America and the Gulf of Mexico (Pellegrin Jr 1983). According to Souza et al. (2008), it is possible that the Sciaenidae seek the same depths and areas with muddy or sandy sediments as the seabob shrimp. It may also be possible that this co-occurrence is a feeding requirement, considering the several species of shrimp found in their stomachs. The predation of shrimps by the Sciaenidae, particularly of their larval stages, may attain intensities up to three times the depletion rate exerted by the fishing fleet (Dall et al. 1990). The dominance of sciaenid species represents a key character, determining the structure of the local ichthyofaunal community. Their absence would result in a substantially different fish fauna (Freitas et al. 2011).

The occurrence of the flatfish *Cyclopsetta chittendeni* in the present study suggests an extension of its distributional range, which was previously known only to reach Guarujá, State of São Paulo, southeastern Brazil. The capture of three specimens of *Cyclopsetta decussata* represents the first record of the species for the Brazilian coast, a single specimen having been found previously only in the Gulf of Mexico (Gunter 1946). These two new occurrences reinforce the importance of continuing faunistic inventories for the knowledge and conservation of the biodiversity of the Brazilian coast. The king weakfish *Macrodon ancylodon* was revised by Carvalho-Filho et al. (2010). *Macrodon atricauda* remains valid for specimens captured in the southeast-south regions.

Thirty-one species sharing the same habitat as the seabob shrimp in Santa Catarina are mostly discarded by the artisanal fishing communities. This represents both an environmental loss, because they represent key species in the community structure, and an economic loss, because some species have potential commercial value, but are not exploited due to their small size, making their conservation on board and their future processing impractical.

Bycatch is one of the most pressing and controversial aspects of shrimp fishing. Much of the management attention associated with shrimp fisheries is focused on reducing it. Bycatch management is defined as intervention to reduce or make better use of bycatch, in order to reduce waste and threats to vulnerable and endangered species (Gillett 2008).

Alternatives for the problem of the accidental capture of the bycatch have been largely discussed worldwide, with positive results obtained from the development of Bycatch Reduction Devices – BRDs (Hannah & Jones 2000, Broadhurst 2000, Pascoe & Revill 2004, Eayrs 2007). Techniques to reduce bycatch levels include: 1) traditional net selectivity; 2) fishing gear development; 3) trying to take advantage of differential species behavior; and 4) time/area restrictions. Emerging ideas include:1) effort reduction; 2) incentive programs; and 3) moving the responsibility for bycatch reduction to the individual vessel level (Alverson et al. 1994). Complementary strategies are the creation of exclusive fishing zones, in which actions aim to ensure minimum pools of species that may recolonize adjacent areas to those subject to fishing activities. In this way, more successful conservation of species is attempted. Despite existing enforced law and several protected areas in Brazil, conservation of marine biodiversity is still broadly inadequate (Amaral & Jablonsky 2005). Protection areas are still insufficient considering the large extent of the Brazilian coastal zone.

Bycatch is one of the most pressing and controversial aspects of shrimp fishing. Much of the management attention associated with shrimp fisheries is focused on reducing it. Conservation actions aim to ensure minimum pools of species that may recolonize areas adjacent to those subject to fishing activities. In this way, more successful conservation of species is attempted. Despite existing enforced law and several protected areas in Brazil, conservation of marine biodiversity is still broadly inadequate in our country.

In the State of Santa Catarina, small-scale shrimp fisheries is a traditional activity and dominates the local fishing economy. By inventorying the accidental bycatch, we provide a preliminary step towards defining intervention measures to reduce or make better use of this bycatch in seabob artisanal fisheries. We have attempted to identify additional threats to vulnerable and endangered species resulting from shrimp trawling.

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inventory

Inventory of Chondrichthyes and Actinopterygii species collected in the central coast of São Paulo State, Brazil

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ROCHA, M.L.F., DIAS, J.F. **Inventory of Chondrichthyes and Actinopterygii species collected in the central coast of São Paulo State, Brazil.** Biota Neotropica. 15(2): e20140136. http://dx.doi.org/10.1590/1676-06032015013614

Abstract: This biodiversity inventory of the central coast of São Paulo State presents species of demersal and pelagic fishes of Santos Bay, Bertioga Channel, and adjacent continental shelf, between São Sebastião and Peruíbe, from the coast till a depth of 100 m. Samples were taken during oceanographic campaigns using otter trawls, between November 2004 and February 2006. A total of 56,095 individuals were collected, belonging to the classes Chondrichthyes (three orders and fourteen species) and Actinopterygii (fifteen orders and 141 species). This list adds 27 species to those explicitly cited for the coast of São Paulo state, contributing to the knowledge of this group.

Keywords: *Ichthyofauna, Santos Bay, Bertioga Channel, Continental Shelf, Southeastern Brazilian Coast.*

ROCHA, M.L.F., DIAS, J.F. **Inventário das espécies de Chondrichthyes e Actinopterygii coletadas no litoral central do estado de São Paulo, Brasil.** Biota Neotropica. 15(2): e20140136. http://dx.doi.org/10.1590/1676-06032015013614

Resumo: Este inventário comentado da biodiversidade do litoral central do estado de São Paulo apresenta as espécies de peixes demersais e pelágicas da baía de Santos, do canal de Bertioga e da plataforma continental adjacente, entre Peruíbe e São Sebastião, da costa até 100 m de profundidade. Os exemplares foram capturados durante campanhas oceanográficas, utilizando-se redes de arrasto de fundo com portas, entre novembro de 2004 e fevereiro de 2006. Foram capturados um total de 56.095 indivíduos pertencentes às Classes Chondrichthyes (três ordens e quatorze espécies) e Actinopterygii (quinze ordens e 141 espécies). Esta lista amplia em 27 espécies as explicitamente citadas para o litoral do estado de São Paulo, contribuindo para o conhecimento do grupo.

Palavras-chave: *Ictiofauna, baía de Santos, canal de Bertioga, plataforma continental adjacente, costa sudeste brasileira.*

Introduction

Species lists are important tools in biodiversity and fish community structure studies, not only to evaluate current and past ichthyofauna records and richness but also as a reference document to environmental agencies and consultancies. Considering these different purposes and the poor environmental quality of the coastal areas, fish have also been used to assess the ecological status of marine environments (Henriques et al. 2008).

Some ichthyofaunistic surveys have been conducted in the central coast of São Paulo state; among these surveys, we can highlight Vazzoler (1970), Paiva-Filho et al. (1987), Giannini & Paiva-Filho (1990), and Graça-Lopes et al. (1993) for the Santos Bay and Barbanti et al. (2013) for the Bertioga Channel. Although already investigated, little information has been published about the ichthyofauna inventory of the continental shelf ecosystem (Vazzoler et al. 1982, Fachinni, 1999). However, this lack of information is not restricted to the coast of São Paulo. Most of ichthyofauna information is found in academic products (Dissertations and Theses). One of the major surveys was the "Program of Evaluation of the Sustainable Potential for Living Resources in the Exclusive Economic Zone (Programa de Avaliação do Potencial Sustentável de Recursos Vivos na Zona Econômica Exclusiva – REVIZEE)", which was carried out between Cabo Frio (22°52'S) and Chuí (33° 41'S) and which resulted in a series of technical documents and available information; however, this campaigns occurred in deeper waters than those examined in the present study, between 100 and 1,000 meters.

Menezes (2011) published a checklist of marine fishes for the state of São Paulo, which was based on the Catalog of Marine Fish Species of Brasil that he and colleagues published in 2003.

The purpose of this article is to present an updated species list, based on the current knowledge of the biodiversity fish in the central coast of São Paulo state.

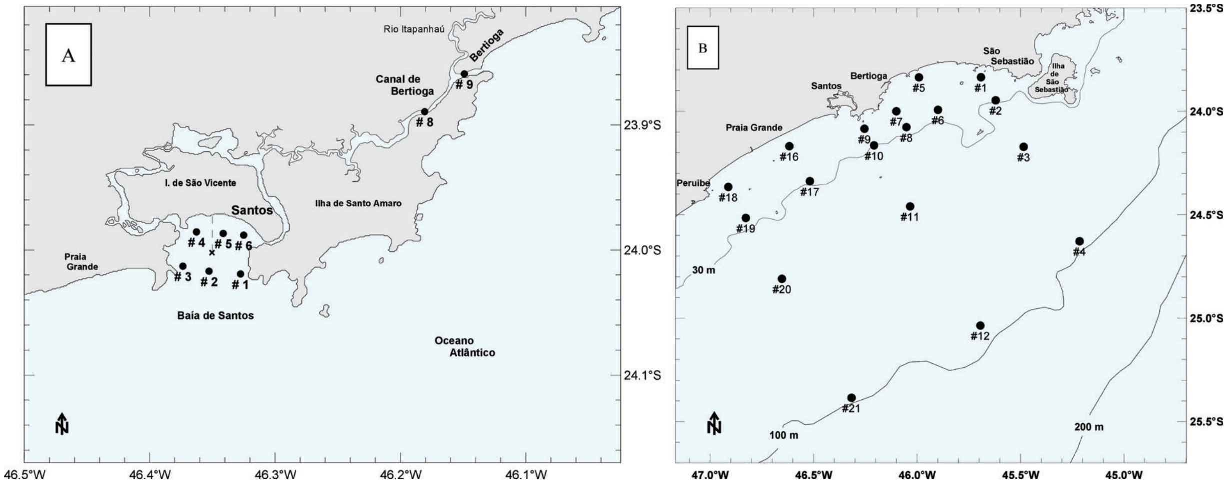

Figure 1. Maps of Santos Bay, Bertioga Channel (A) and adjacent Continental Shelf in the central coast of the state of São Paulo (B), with collection stations of the ichthyofauna.

Material and Methods

The sampled areas are part of the Santos-São Vicente estuarine system, including the adjacent continental shelf (Fig. 1). The Santos Bay (23.98°-24.04°S; 46.4°-46.3°W) is a semi-sheltered bay, with depths ranging from 5 to 15 m. It is bordered by beaches and two natural channels (Santos and São Vicente) to the north and by the Atlantic Ocean to the south. It has an outfall sewer. The sediment type from Santos Bay was classified as very fine sand at the western side and clay and silt in the central-eastern area.

The Bertioga Channel is located at the eastern end of the Santos region (23.85-23.60°S; 46.18-46.25°W) and is considered a secondary connection to the ocean of the estuarine system of Santos - São Vicente. The channel is 25 km long with an average depth between 3 and 6 m and width ranging from 200 to 700 m. The sediment types were classified as clay and medium silt along the channel and fine sand on both borders.

On the continental shelf adjacent to the estuarine system, the sampling area was concentrated between São Sebastião (23°45°S) and Peruíbe (24°19°S) at depths shallower than 100 m. In this region, the sediment types were classified as sand for all coastal areas up to 80 m, a transition from sandy silt to silt-clay type sediment occurred between 80 and 100 m.

In the Santos Bay, specimens were caught monthly at six oceanographic stations, between November 2004 and December 2005 (except for the month of December 2004), three along the entrance of the bay and three along the beaches (stations 1 to 6; Fig. 1A). In the internal stations, the local depth varied between 5.7 and 9.9 m, while it varied between 10 and 14.3 m in the external stations. In the Bertioga Channel, samples were collected monthly from September to December 2005 in two channel points (stations 8 and 9; Fig. 1A), one more internal (between the bar and Largo do Candinho) and another more external point close to channel north mouth. An otter-trawl was used to collect fish in these areas, with a mesh size of 40 mm in the arms and 30 mm in the bagger; the otter-trawl was 11 m long. The effort unit was a 10-min tow at a speed of two knots.

Two expeditions were made at the continental shelf, one in the winter of 2005 (August/September) and another in the summer of 2006 (February), totaling 38 oceanographic stations at depths varying between 14 and 94 m (Fig. 1B). An otter-trawl with 17 m length, and a mesh size of 60 mm in the arms and 25 mm in the bagger was used. The effort unit was a 30-minute tow at an average speed of two knots.

The caught specimens were sacrificed by cooling, sorted and identified based on Figueiredo & Menezes (1978, 1980, 2000), Menezes & Figueiredo (1980, 1985) manuals; Marceniuk (2005) and Gomes et al. (2010) identification keys, and additional taxonomic information of Nelson (2006). Data of total length and standard length (in mm) were taken for each specimen. After identification and data recording on board, all Chondrichthyes specimens were immediately released to the sea while still alive.

The Menezes *et al.* (2003) catalog, the Websites Catalog of Fishes (CAS), FishBase, Advanced Search Report (ITIS), and World Register of Marine Species (WorMS); and Marceniuk & Menezes (2007) and Menezes et al. (2015) publications were utilized to update the nomenclature. The testimony specimens are frozen at ECORREP (Reproductive Ecology and Recruitment Laboratory - Oceanographic Institute-University of São Paulo) and will be added to the ColBIO (Coleções Biológicas Prof. Edmundo Ferraz Nonato-IOUSP).

Results

The collected species are presented in phylogenetic order according to Menezes et al. (2003), and the lists are separated per area. The minimal and maximal lengths per species are also shown. If the caudal fin was damaged or absent, the standard length of the species was provided.

1. Santos Bay

The Santos Bay was represented by 94 species of Actinopterygii and by only one species of Chondrichthyes (Rajiformes) (Table 1).

2. Bertioga Channel

The Bertioga Channel contained 50 species, all belonging to Actinopterygii (Table 2).

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Table 1. List of species collected at Santos Bay between November 2004 and December 2005, with respective total maximum (TL max) and minimum (TL min) lengths in millimeters. In case of a single specimen, its length is shown at "TL max" column. SL = standard length.

Order	Family	Species	TL min	TL max
Rajiformes	Rhinobatidae	*Rhinobatos percellens* (Walbaum, 1792)	235	540
Anguilliformes	Ophichthidae	*Ophichthus gomesii* (Castelnau, 1855)	503	600
Clupeiformes	Engraulidae	*Anchoa filifera* (Fowler, 1915)	72	105
		Anchoa januaria (Steindachner, 1879)	65	92
		Anchoa marinii Hildebrand, 1943	64	95
		Anchoa spinifer (Valenciennes, 1848)	60	180
		Anchoa tricolor (Spix & Agassiz, 1829)		69
		Anchovia clupeoides (Swainson, 1839)		66
		Anchoviella brevirostris (Gunther, 1868)		49
		Anchoviella lepidentostole (Fowler, 1911)	52	165
		Lycengraulis grossidens (Agassiz, 1829)	60	135
	Pristigasteridae	*Chirocentrodon bleekerianus,* (Poey, 1867)	56	61
		Pellona harroweri (Fowler, 1917)	24	142
	Clupeidae	*Harengula clupeola* (Cuvier, 1829)	67	187
		Opisthonema oglinum (Lesueur, 1818)	80	95
		Platanichthys platana (Regan, 1917)		63
Siluriformes	Ariidae	*Aspistor luniscutis* (Valenciennes, 1840)	60	335
		Bagre bagre (Linnaeus, 1766)	65	246
		Cathorops spixii (Agassiz, 1829)	41	366
		Genidens barbus (Lacepède, 1803)	55	255
		Genidens genidens (Cuvier, 1829)	171	313
		Notarius grandicassis (Valenciennes, 1840)	70	139
Aulopiformes	Synodontidae	*Synodus foetens* (Linnaeus, 1766)	45	203
Gadiformes	Phycidae	*Urophycis brasiliensis* (Kaup, 1858)		131
Batrachoidiformes	Batrachoididae	*Porichthys porosissimus* (Cuvier, 1829)	32	237
Lophiiformes	Ogcocephalidae	*Ogcocephalus vespertilio* (Linnaeus, 1758)		67
Scorpaeniformes	Scorpaenidae	*Scorpaena brasiliensis* Cuvier, 1829		206
	Triglidae	*Bellator brachychir* (Regan, 1914)		91
		Prionotus punctatus (Bloch, 1793)	35	160
Perciformes	Centropomidae	*Centropomus parallelus* Poey, 1860	243	540
	Serranidae	*Diplectrum radiale* (Quoy & Gaimard, 1824)	107	218
		Rypticus randalli Courtenay, 1967	103	204
		Rypticus sp. Cuvier & Valenciennes, 1829		128
	Carangidae	*Chloroscombrus chrysurus* (Linnaeus, 1766)	37	105
		Hemicaranx amblyrhynchus (Cuvier, 1833)	77	115
		Oligoplites saliens (Bloch, 1793)	119	167
		Selene setapinnis (Mitchill, 1815)	3	235
		Selene vomer (Linnaeus, 1758)	27	152
		Trachinotus carolinus (Linnaeus, 1766)	51	201
	Gerreidae	*Diapterus auratus* Ranzani, 1842	119	130
		Diapterus rhombeus (Cuvier, 1829)	100	198
		Eucinostomus argenteus Baird & Girard, 1855	100	141
		Eucinostomus gula (Quoy & Gaimard, 1824)	104	180
		Eucinostomus melanopterus (Bleeker, 1863)	122	194
	Haemulidae	*Conodon nobilis* (Linnaeus, 1758)	70	182
		Genyatremus luteus (Bloch, 1790)	90	194
		Orthopristis ruber (Cuvier, 1830)	140	302
		Pomadasys corvinaeformis (Steindachner, 1868)	64	102
	Polynemidae	*Polydactylus oligodon* (Gunther, 1860)	164	167
		Polydactylus virginicus (Linnaeus, 1758)		156
	Sciaenidae	*Bairdiella ronchus* (Cuvier, 1830)	61	261
		Ctenosciaena gracilicirrhus (Metzelaar, 1919)	89	107
		Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	39	164
		Cynoscion leiarchus (Cuvier, 1830)	40	68
		Cynoscion sp. Gill, 1861	25	51
		Cynoscion virescens (Cuvier, 1830)	66	331

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Table 1. Continued.

Order	Family	Species	TL min	TL max
		Isopisthus parvipinnis (Cuvier, 1830)	20	181
		Larimus breviceps Cuvier, 1830	47	222
		Macrodon atricauda (Gunther, 1880)	22	355
		Menticirrhus americanus (Linnaeus, 1758)	63	410
		Menticirrhus littoralis (Holbrook, 1847)	80	142
		Micropogonias furnieri (Desmarest, 1823)	40	478
		Nebris microps Cuvier, 1830	35	290
		Ophioscion punctatissimus Meek & Hildebrand, 1925	99	144
		Paralonchurus brasiliensis (Steindachner, 1875)	44	240
		Stellifer brasiliensis (Shultz, 1945)	36	222
		Stellifer rastrifer (Jordan, 1889)	32	220
		Stellifer sp. Oken, 1817	40	137
		Stellifer stellifer (Bloch, 1790)	42	201
		Umbrina canosai Berg, 1895	88	151
		Umbrina coroides Cuvier, 1830	125	151
	Ephippidae	*Chaetodipterus faber* (Broussonet, 1782)	52	233
	Stromateidae	*Peprilus paru (*Linnaeus, 1758)	29	125
Pleuronectiformes	Paralichthyidae	*Citharichthys dinoceros* Goode & Bean, 1886		139
		Citharichthys macrops Dresel, 1885		116
		Citharichthys spilopterus Gunther, 1862	83	130
		Etropus crossotus Jordan & Gilbert, 1882	63	118
		Etropus longimanus Norman, 1933		93
	Achiridae	*Achirus declivis* Chabanaud, 1940	81	143
		Achirus lineatus (Linnaeus, 1758)	64	139
		Catathyridium garmani (Jordan, 1889)		62
		Trinectes paulistanus (Miranda Ribeiro, 1915)	58	205
	Cynoglossidae	*Symphurus jenynsi* Evermann & Kendall, 1906		SL 120
		Symphurus tessellatus (Quoy & Gaimard, 1824)	61	177
		Symphurus trewavasae Chabanaud, 1948	123	147
Tetraodontiformes	Monacanthidae	*Monacanthus ciliatus* (Mitchill, 1818)		26
		Stephanolepis hispidus (Linnaeus, 1766)	24	25
	Tetraodontidae	*Lagocephalus laevigatus* (Linnaeus, 1766)	34	115
		Sphoeroides greeleyi Gilbert, 1900	35	177
		Sphoeroides spengleri (Bloch, 1785)		90
		Sphoeroides testudineus (Linnaeus, 1758)	43	260
	Diodontidae	*Chilomycterus spinosus* (Linnaeus. 1758)	56	162

3. *Continental shelf*

One hundred fifteen species occurred on the continental shelf, 14 of which belong to Chondrichthyes (Squaliformes, Squatiniformes, and Rajiformes Orders), and the remainder belong to Actinopterygii (Table 3).

Discussion

Menezes (2011) refers to 594 species of marine fish in the coast of São Paulo state based on the "Catalog of Marine Fish Species of Brazil". In the present study, 154 species were caught in the central coast, which represents approximately 26% of the total evaluated species. This number is expressive when considering that the investigated areas were restricted to soft bottoms and that a single fishing gear was utilized. In general, the restriction to depths lower than 100 m eliminates mesopelagic fish, such as Myctophidae, Stomiidae, and Sternoptychidae; the oceanic Xiphidae, Scombridae, Gempylidae, and Echeneidae; the larger Carangidae, and many Elasmobranchii species. The species associated with rocky or coralline sea bottoms, such as Serranidae, Haemulidae, Labridae, Labrisomidae, Pomacanthidae, Pomacentridae, Scorpaenidae, and Scaridae; and those of very shallow areas, such as Gobiidae and Blenniidae, also were not caught. Moreover, the stations were widely spaced in the case of continental shelf, and only two sampling seasons were utilized.

Despite the above restrictions and considering the three sampled areas, this inventory adds 27 species to the checklist published by Menezes (2011), which reports the ichthyofauna of all coastal areas in São Paulo state (Tab. 4).

Comparing the current inventory, in which 95 species are recorded for the Santos Bay, with the list of species collected by the end of the 1980s in the same area (Ribeiro Neto, 1989) some important differences may be noticed. Some groups, such as Serranidae, Haemulidae, and top predators like rays, morays, barracudas, and common snooks, were not captured. Conversely, ten different species of soles and two species of puffers appear in this inventory and were not part of the fauna 25 years ago. Despite the differences and environmental degradation,

Table 2. List of species collected at Bertioga Channel between September and December 2005, with respective total maximum (TL max) and minimum (TL min) lengths in millimeters. In case of a single specimen, its length is shown at “TL max” column.

Order	Family	Species	TL min	TL max
Clupeiformes	Engraulidae	*Anchoa januaria* (Steindachner, 1879)		77
		Anchoviella lepidentostole (Fowler, 1911)	70	180
		Cetengraulis edentulus (Cuvier, 1829)	137	182
		Lycengraulis grossidens (Agassiz, 1829)	160	246
	Pristigasteridae	*Pellona harroweri* (Fowler, 1917)	54	134
	Clupeidae	*Harengula clupeola* (Cuvier, 1829)	56	187
		Opisthonema oglinum (Lesueur, 1818)	77	102
Siluriformes	Ariidae	*Aspistor luniscutis* (Valenciennes 1840)	109	370
		Cathorops spixii (Agassiz, 1829)	80	240
		Genidens barbus (Lacepède, 1803)	113	289
		Genidens genidens (Cuvier, 1829)	110	294
Aulopiformes	Synodontidae	*Synodus foetens* (Linnaeus, 1766)		190
Mugiliformes	Mugilidae	*Mugil curvidens* Valenciennes 1836		222
Scorpaeniformes	Triglidae	*Prionotus punctatus* (Bloch, 1793)	43	141
Perciformes	Centropomidae	*Centropomus parallelus* Poey, 1860	185	266
		Centropomus undecimalis (Bloch, 1792)	810	1080
	Serranidae	*Diplectrum radiale* (Quoy & Gaimard, 1824)	81	190
		Rypticus sp. Cuvier & Valenciennes, 1829		132
	Carangidae	*Chloroscombrus chrysurus* (Linnaeus, 1766)	49	100
		Selene vomer (Linnaeus, 1758)	44	478
	Gerreidae	*Diapterus auratus* Ranzani, 1842		231
		Diapterus rhombeus (Cuvier, 1829)		198
		Eucinostomus gula (Quoy & Gaimard, 1824)		133
	Haemulidae	*Pomadasys corvinaeformis* (Steindachner, 1868)	90	159
	Sciaenidae	*Bairdiella ronchus* (Cuvier, 1830)	138	216
		Isopisthus parvipinnis (Cuvier, 1830)	120	195
		Larimus breviceps (Cuvier, 1830)		152
		Menticirrhus americanus (Linnaeus, 1758)	70	193
		Micropogonias furnieri (Desmarest, 1823)	70	243
		Ophioscion punctatissimus Meek & Hildebrand, 1925		142
		Paralonchurus brasiliensis (Steindachner, 1875)		58
		Stellifer rastrifer (Jordan, 1889)	68	133
		Stellifer stellifer (Bloch, 1790)	76	143
	Ephippidae	*Chaetodipterus faber* (Broussonet, 1782)	77	490
	Trichiuridae	*Trichiurus lepturus* Linnaeus, 1758	116	577
Pleuronectiformes	Paralichthyidae	*Citharichthys spilopterus* Gunther, 1862	73	157
		Etropus crossotus Jordan & Gilbert, 1882	70	121
	Achiridae	*Achirus declivis* Chabanaud, 1940		92
		Achirus lineatus (Linnaeus, 1758)	68	135
		Trinectes paulistanus (Miranda Ribeiro, 1915)		80
	Cynoglossidae	*Symphurus tessellatus* (Quoy & Gaimard, 1824)	111	172
Tetraodontiformes	Monacanthidae	*Stephanolepis hispidus* (Linnaeus, 1766)		50
	Tetraodontidae	*Lagocephalus laevigatus* (Linnaeus, 1766)	38	112
		Lagocephalus lagocephalus (Linnaeus, 1758)	49	121
		Sphoeroides greeleyi Gilbert, 1900	58	114
		Sphoeroides spengleri (Bloch, 1785)		111
		Sphoeroides testudineus (Linnaeus, 1758)	193	210
		Sphoeroides tyleri Shipp, 1972		106
	Diodontidae	*Chilomycterus spinosus* (Linnaeus, 1758)	105	164

Schmidt & Dias (2012) assumed that at least the Sciaenid fish assemblage has been stable in the Santos Bay for more than 20 years.

Although a single type of gear was used in the Bertioga Channel, this study adds 15 species to the ichthyofauna inventory of Barbanti et al. (2013), whose captures utilized ten different fishing gears over a longer sampling period.

Examples, such as those of the Santos Bay and Bertioga Channel, suggest that the respective sampling sufficiency was not achieved for both areas, as the ichthyofauna has not been adequately sampled.

Table 3. List of species collected at Continental Shelf, in the 2005 winter and 2006 summer, with respective total maximum (TL max) and minimum (TL min) lengths in millimeters. In case of a single specimen, its length is shown at "TL max" column.

Order	Family	Species	TL min	TL max
Squaliformes	Squalidae	*Squalus* group *megalops/cubensis**	458	477
Squatiniformes	Squatinidae	*Squatina argentina* (Marini, 1930)	267	557
Rajiformes	Narcinidae	*Narcine brasiliensis* (Olfers, 1831)		237
	Rhinobatidae	*Rhinobatos horkelii,* Muller & Henle 1841	250	756
		Rhinobatos percellens (Walbaum, 1792)	204	286
	Rhinobatidae	*Zapteryx brevirostris* (Muller & Henle, 1841)	123	493
	Rajidae	*Atlantoraja castelnaui* (Miranda Ribeiro, 1907)	256	852
		Atlantoraja cyclophora (Regan, 1903)	122	591
		Atlantoraja sp. Menni, 1972		454
		Psammobatis extenta (Garman, 1913)	87	276
		Psammobatis rutrum Jordan,1891	77	283
		Rioraja agassizii (Muller & Henle, 1841)	175	560
	Dasyatidae	*Dasyatis hypostigma* (Santos & Carvalho, 2004)		449
	Myliobatidae	*Myliobatis freminvillei* Lesueur, 1824		?
Anguilliformes	Muraenidae	*Gymnothorax ocellatus* (Agassiz, 1831)	279	580
	Congridae	*Ariosoma opistophthalmus* (Ranzini, 1839)		293
		Conger orbignianus Valenciennes, 1837		286
Clupeiformes	Engraulidae	*Anchoa januaria* Hildebrand, 1943	83	168
		Anchoa spinifer (Valenciennes, 1848)	128	148
		Anchoviella lepidentostole (Fowler, 1941)	61	129
		Centegraulis edentulus (Cuvier, 1829)	87	90
		Engraulis anchoita Hubbs & Marini, 1935	86	104
		Lycengraulis grossidens (Agassiz, 1829)		200
	Pristigasteridae	*Chirocentrodon bleekerianus* (Poey, 1867)	60	113
		Pellona harroweri (Fowler, 1919)	34	152
	Clupeidae	*Harengula clupeola* (Cuvier, 1829)	91	186
		Sardinella brasiliensis (Steindachner, 1879)	70	98
Siluriformes	Ariidae	*Bagre bagre* (Linnaeus, 1766)		271
		Genidens genidens (Cuvier, 1829)		285
Aulopiformes	Synodontidae	*Saurida brasiliensis* Norman, 1935	48	140
		Synodus foetens (Linnaeus, 1766)	85	538
Ophidiiformes	Ophidiidae	*Raneya brasiliensis* (Kaup, 1856)	194	215
Gadiformes	Phycidae	*Urophycis brasiliensis* (Kaup, 1858)	85	395
	Merlucciidae	*Merluccius hubbsi* Marini, 1933	82	340
Batrachoidiformes	Batrachoididae	*Porichthys porosissimus* (Cuvier, 1829)	61	332
Lophiiformes	Lophiidae	*Lophius gastrophysus* Miranda Ribeiro, 1915	83	436
	Ogcocephalidae	*Ogcocephalus vespertilio* (Linnaeus, 1758)	54	142
Zeiformes	Zeidae	*Zenopsis conchifer* (Lowe, 1852)		132
Gasterosteiformes	Fistulariidae	*Fistularia petimba* Lacepède, 1803	295	970
Scorpaeniformes	Dactylopteridae	*Dactylopterus volitans* (Linnaeus, 1758)	63	310
	Scorpaenidae	*Scorpaena brasiliensis* Cuvier, 1829		134
	Triglidae	*Bellator brachychir* (Regan, 1914)	51	71
		Prionotus nudigula Ginsburg, 1950	40	212
		Prionotus punctatus (Bloch, 1793)	45	380
Perciformes	Acropomatidae	*Synagrops spinosus* Schultz, 1940	60	95
	Serranidae	*Diplectrum formosum* (Linnaeus, 1766)	90	237
		Diplectrum radiale (Quoy & Gaimard, 1824)	82	240
		Dules auriga Cuvier, 1829	59	163
	Priacanthidae	*Priacanthus arenatus* Cuvier, 1829	66	264
	Pomatomidae	*Pomatomus saltatrix* (Linnaeus, 1766)		343
	Carangidae	*Caranx crysos* (Mitchill, 1815)		255
		Chloroscombrus chrysurus (Linnaeus, 1766)	41	206
		Decapterus punctatus (Cuvier, 1829)		97
		Oligoplites saliens (Bloch, 1793)	110	478
		Selene setapinnis (Mitchill, 1815)	36	263
		Selene vomer (Linnaeus, 1758)	50	236
		Trachinotus carolinus (Linnaeus, 1766)	275	286
		Trachurus lathami Nichols, 1920	46	158

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Table 3. Continued.

Order	Family	Species	TL min	TL max
	Gerreidae	*Diapterus rhombeus* (Cuvier, 1829)	115	207
		Eucinostomus argenteus Baird & Girard, 1855	125	212
		Eucinostomus gula (Quoy & Gaimard, 1824)		108
		Eucinostomus melanopterus (Bleeker, 1863)	138	204
	Haemulidae	*Conodon nobilis* (Linnaeus, 1758)	69	236
		Orthopristis ruber (Cuvier, 1830)	138	296
		Pomadasys corvinaeformis (Steindachner, 1868)	77	214
	Sparidae	*Pagrus pagrus* (Linnaeus, 1758)	40	218
	Sciaenidae	*Ctenosciaena gracilicirrhus* (Metzelaar, 1919)	51	180
		Cynoscion acoupa (Lacepède, 1801)		196
		Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	70	382
		Cynoscion leiarchus (Cuvier, 1830)		242
		Cynoscion virescens (Cuvier, 1830)	70	435
		Isopisthus parvipinnis (Cuvier, 1830)	40	160
		Larimus breviceps (Cuvier, 1830)	49	215
		Macrodon atricauda (Gunther, 1880)	50	311
		Menticirrhus americanus (Linnaeus, 1758)	56	292
		Micropogonias furnieri (Desmarest, 1823)	189	523
		Nebris microps Cuvier, 1830	101	169
		Paralonchurus brasiliensis (Steindachner, 1875)	50	227
		Stellifer brasiliensis (Shultz, 1945)	50	153
		Umbrina canosai Berg, 1895	115	156
		Umbrina coroides Cuvier, 1830	191	269
	Mullidae	*Mullus argentinae* Hubbs & Marini, 1933	62	225
		Upeneus parvus Poey, 1852	54	232
	Labridae	*Halichoeres sazimai* Luiz, Ferreira & Rocha, 2009		43
	Pinguipedidae	*Pseudopercis semifasciata* (Cuvier, 1829)		280
	Percophidae	*Bembrops heterurus* (Miranda Ribeiro, 1903)	88	182
		Percophis brasiliensis Quoy & Gaimard, 1825	143	193
	Ephippidae	*Chaetodipterus faber* (Broussonet, 1782)	266	362
	Sphyraenidae	*Sphyraena guachancho* Cuvier, 1829	98	228
		Sphyraena sp Klein, 1778	163	180
		Sphyraena tome Fowler, 1903		186
	Trichiuridae	*Trichiurus lepturus* Linnaeus, 1758	168	922
	Stromateidae	*Peprilus paru* (Linnaeus, 1758)	34	160
Pleuronectiformes	Paralichthyidae	*Citharichthys dinoceros* Goode & Bean, 1886		170
		Citharichthys macrops Dresel, 1885	74	177
		Citharichthys sp. Bleeker, 1872	86	190
		Citharichthys spilopterus Gunther, 1862		128
		Cyclopsetta chittendeni Bean, 1895		250
		Etropus crossotus Jordan & Gilbert, 1882	97	164
		Etropus longimanus Norman, 1933	58	126
		Paralichthys isosceles Jordan, 1891	88	345
		Paralichthys patagonicus Jordan, 1889	186	264
		Paralichthys sp. Girard, 1858	60	295
		Syacium micrurum Ranzani, 1842	135	196
		Syacium papillosum (Linnaeus, 1758)	70	246
		Syacium sp. Ranzani, 1842	75	298
		Verecundum rasile Jordan, 1891	80	265
	Cynoglossidae	*Symphurus tessellatus* (Quoy & Gaimard, 1824)	115	200
Tetraodontiformes	Balistidae	*Balistes capriscus* Gmelin, 1789	186	247
	Monacanthidae	*Aluterus monocerus* (Linnaeus, 1758)	298	377
		Stephanolepis hispidus (Linnaeus, 1766)	40	226
	Tetraodontidae	*Lagocephalus laevigatus* (Linnaeus, 1766)	39	168
		Sphoeroides spengleri (Bloch, 1785)		91
	Diodontidae	*Chilomycterus spinosus* (Linnaeus, 1758)	35	221
		Diodon hystrix (Linnaeus, 1758)		31

*According to Gomes et al., 2010.

Table 4. Species added to the fish fauna of the coastal area of São Paulo state, presented in Menezes (2011).

Order	Family	Species
Squaliformes	Squalidae	*Squalus* group *megalops/cubensis**
Clupeiformes	Engraulidae	*Anchoa filifera* (Fowler 1915)
		Anchoa spinifer (Valenciennes 1848)
		Anchoa tricolor (Spix & Agassiz 1829)
		Anchovia clupeoides (Swainson 1839)
		Anchoviella brevirostris (Gunther 1868)
	Pristigasteridae	*Chirocentrodon bleekerianus* (Poey 1867)
Siluriformes	Ariidae	*Aspistor luniscutis* (Valenciennes 1840)
		Cathorops spixii (Agassiz 1829)
		Genidens barbus (Lacepède 1803)
		Notarius grandicassis (Valenciennes 1840)
		Potamarius grandoculis (Steindachner 1877)
Mugiliformes	Mugilidae	*Mugil curvidens* Valenciennes 1836
Gasterosteiformes	Fistulariidae	*Fistularia tabacaria* Linnaeus 1758
Batrachoidiformes	Batrachoididae	*Porichthys porosissimus* (Cuvier 1829)
Perciformes	Acropomatidae	*Synagrops spinosus* Schultz 1940
	Haemulidae	*Pomadasys corvinaeformis* (Steindachner 1868)
	Sciaenidae	*Cynoscion leiarchus* (Cuvier 1830)
		Cynoscion virescens (Cuvier 1830)
		Nebris microps Cuvier 1830
		Stellifer stellifer (Bloch 1790)
	Labridae	*Halichoeres sazimai* Luiz, Ferreira & Rocha 2009
Pleuronectiformes	Paralichthyidae	*Citharichthys dinoceros* Goode & Bean 1886
		Cyclopsetta chittendeni Bean 1895
		Paralichthys isosceles Jordan 1891
		Syacium micrurum Ranzani 1842
Tetraodontiformes	Tetraodontidae	*Lagocephalus lagocephalus* (Linnaeus 1758)

*According to Gomes et al., 2010.

The results obtained show that part of the region of the Santos-São Vicente estuarine system and adjacent continental shelf present high richness, despite suffering intense pressure from pollution, significant *habitat* alteration and loss, overfishing, and an important capture of juveniles as bycatch of shrimp fishing. In addition, this study expands the previously reported knowledge of the ichthyofauna in the central coast of São Paulo state.

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article

Barn Owl pellets (Aves: *Tyto furcata*) reveal a higher mammalian richness in the Restinga de Jurubatiba National Park, Southeastern Brazil

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Abstract: The northern coast of the state of Rio de Janeiro harbors the largest coastal sandy plains (*restingas*) of southeastern Brazil, severely threatened due to recent human occupation. In this context, mammal inventories becomes urgent to support biodiversity conservation and management policies. This paper aims to update the knowledge on the mammalian species richness of Restinga de Jurubatiba National Park by analyzing pellets of the Barn owl *Tyto furcata*. The analyses of 4745 mammalian bone fragments (1739 individuals) revealed the occurrence of 17 species belonging to the orders Rodentia (9 spp.), Didelphimorphia (2 spp.) and Chiroptera (6 spp.). The rodents *Mus musculus* and *Cerradomys goytaca* accounted for 77.2% of the total individuals preyed, suggesting that the Barn owl hunts in both disturbed and natural open shrub formations. A compilation of previous records, together with those provided in the present study, indicates the occurrence of 44 species of mammals in the Restinga de Jurubatiba National Park, of which six (13.6%) were exclusively detected in pellets. These new records include species adapted to open formations of the interior of Brazil that were not previously reported in *restingas* on the basis of voucher-specimens, such as the rodents *Necromys lasiurus* and *Calomys tener*, the latter being recorded for the first time in the littoral of Rio de Janeiro state. This study underscores the importance of owl pellet analysis as a complementary and indispensable method for inventorying mammals. The results highlight the Restinga de Jurubatiba National Park as one of the *restingas* in Southeastern Brazil with the highest number of mammal species.

Keywords: *restingas, species richness, inventory methods, new records, geographic distribution.*

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Resumo: O litoral norte do estado do Rio de Janeiro possui a maior planície deltaica recoberta por restingas do sudeste brasileiro, porém sob intensa ameaça devido à ocupação humana recente. Neste contexto, a realização de inventários torna-se urgente para fortalecer políticas de manejo e conservação ambiental. Esse trabalho teve como objetivo complementar inventários mastofaunísticos do Parque Nacional da Restinga de Jurubatiba através da utilização de pelotas da coruja suindara *Tyto furcata*. A análise de 4745 fragmentos ósseos de mamíferos (1739 indivíduos) revelou a ocorrência de 17 espécies pertencentes às ordens Rodentia (9 spp.), Didelphimorphia (2 spp.) e Chiroptera (6 spp.). Os roedores *Mus musculus* e *Cerradomys goytaca* foram responsáveis por 77,2% do total de indivíduos predados, sugerindo que a suindara caça tanto em ambientes peridomiciliares perturbados como em formações naturais arbustivas da restinga. A compilação de registros anteriores com os fornecidos pelo presente estudo indica a ocorrência de 44 espécies de mamíferos no Parque Nacional da Restinga de Jurubatiba, dentre as quais seis (13.6%) foram exclusivamente detectadas em pelotas. Dentre estes novos registros, destaca-se a presença de espécies adaptadas a formações abertas do interior do Brasil que não tinham sua ocorrência documentada em restingas a partir de espécimes-testemunho, como os roedores *Necromys lasiurus* e *Calomys tener*, esta última registrada pela primeira vez no litoral do estado do Rio de Janeiro. Esse estudo corrobora a importância das análises de pelotas de coruja como método complementar e imprescindível em inventários de mamíferos, além de destacar o Parque Nacional da Restinga de Jurubatiba como uma das restingas mais ricas em espécies de mamíferos do sudeste brasileiro.

Palavras-chave: *restingas, riqueza de espécies, métodos de inventário, novos registros, distribuição geográfica.*

Introduction

Mammalian diversity in the Brazilian Atlantic forest is relatively high in comparison to those found in other biomes in Brazil, being distributed throughout a wide range of physiognomies that includes dense and humid forests to coastal sandy plains covered by shrublands and dry forests (Paglia et al. 2012). These coastal sandy plains, commonly termed *restingas*, are discontinuously distributed along the Brazilian littoral near river mouths or zones of past marine transgressions, harboring varied biotas, lagoons and vegetation types, some of which adapted to dry or arid conditions (Cerqueira 2000, Esteves 2011). Most restingas are intensively threatened by urban, rural and industrial occupation and development, especially in the northern littoral of Rio de Janeiro state, where most of the Brazilian petroleum exploitation has been based (Bergallo et al. 2009, Esteves 2011).

Despite recent transformations, the northern littoral of Rio de Janeiro state still harbors the most expressive *restingas* in Southeastern Brazil, with 14,860 hectares of these areas protected by the Restinga de Jurubatiba National Park (Rocha et al. 2007). Zoological studies on the mammals of this region have been carried out only recently but promptly reveal a rich mammalian fauna (Bergallo et al. 2004, Pessoa et al. 2010), with a number of new occurrences of bats, rodents and marsupials with poorly known distributions (Luz et al. 2011, Mangolin et al. 2007, Pessôa et al. 2010), and of recently described endemic species (Tavares et al. 2011). As many mammal species act as important seed dispersers, hosts, preys, predators and invasive taxa (Grenha et al. 2010, Martins-Hatano et al. 2011, Raíces & Bergallo 2010), basic knowledge on the composition of local mammalian faunas is important not only to fill in distribution gaps, but also to assess the integrity of ecological processes. Given the increasing impacts in the northern littoral of Rio de Janeiro state, such knowledge becomes timely and urgent in the Restinga de Jurubatiba National Park, which may serve as a reference in conservation and biogeographic studies of *restingas* owing to its large size, location and level of protection. However, reasonably complete mammal inventories are difficult to achieve even at local scales due to the rarity, difficult detection and varied ecology of species-rich groups, such as rodents, marsupials and bats, often requiring long-term combined use of different sampling methods (Umetsu et al. 2006).

Valuable information on the local abundance and richness of small mammals in several tropical ecosystems have been obtained from skull, mandibles and bone fragments found in Barn owl pellets (*Tyto furcata*, Strigidae) (Bonvicino & Bezerra 2003, Scheibler & Christoff 2007, Rocha et al. 2011). Barn owls are adapted to nocturnal-hunting in open areas (Taylor 1994), preying primarily on small mammals, many of which rarely recorded by usual trapping methods (Bonvicino & Bezerra 2003). The undigested parts of their prey, such as bones and hairs, are regurgitated in the form of small pellets near their nests, and most mammalian skulls, mandibles and teeth can be taxonomically identified, providing a complementary assessment of the local small mammal species (Moojen 1943). Despite its advantages and low cost, the analysis of owl pellets has been rarely included in mammal inventories in *restingas*, especially in the Rio de Janeiro state, where most assessments have been exclusively based on live-trapping methods (Moura et al. 2008).

In this paper, we analyzed a collection of bone fragments recovered from Barn owl pellets in the Restinga de Jurubatiba National Park in order to update the mammal species richness and composition recorded in this region and to evaluate the complementarity of this type of evidence to local inventories, discussing the ecological and biogeographic implications of novel species records.

Material and Methods

This study was conducted in the Restinga de Jurubatiba National Park, located in the northern Rio de Janeiro littoral between latitudes 22° 08' and 22° 19'S and longitudes 41° 17' and 41° 43'W, encompassing the municipalities of Quissamã, Carapebús and Macaé. The Park protects 14,860 hectares (62.2%) of the largest continuous *restinga* remnant in Southeastern Brazil (23,884 hectares) (Rocha et al. 2004a, 2007), being the sole National Park exclusively devoted to the preservation of coastal sandy plain ecosystems. The climate is classified as tropical rainy (Aw of the Köppen system), generally exhibiting a rainy season between October and April and a dry season between May and September. The accumulated annual rainfall between 1992 and 2013 varied between 626.6 mm and 1593.6 mm. The monthly temperature averages 21.6°C in June and 27.4°C in January (INMET 2014).

In August 2011 a nest of *Tyto furcata* was found in an abandoned rural habitation (22°16'35"S, 41°40'10"W, 5 m) located in an open shrub formation surrounded by several vegetation formations (dry forests, seasonally flooded forests, marshes and coconut plantations mixed with exotic grasses), all within the coastal sandy plain area. Several pellets and disaggregated bone fragments were collected at this occasion, but in November 2011 all the skeletal material found at the nesting site was collected with the aid of a shovel and broom, filling two 60L buckets. Since then, the accumulation of additional pellets was monitored each trimester, from February 2012 to March 2013.

All pellets and bone fragments collected were screened for small mammals separating them from hairs, arthropods and non-mammalian skeletal remains (birds, reptiles and amphibians). Species identifications were based on complete and fragmented skulls and mandibles. Identifiable skull fragments comprised parts of maxillary with or without teeth, zygomatic plates, interorbits and nearly complete skulls lacking few structures. Each skeletal element or bone fragment identified counted as one unit of the number of identified specimens (NISP), and we used the most commonly occurring bone fragment or element of a given taxon to estimate its minimal number of individuals (MNI), interpreted as a proxy of the taxon frequency in the pellet collection (Lyman 2008). Cranial and dental characters were compared to identified specimens housed at the mammal collections of NUPEM/UFRJ (NPM) and Museu Nacional (MN) at Universidade Federal do Rio de Janeiro, which contain relevant series of topotypes of *Cerradomys goytaca* Tavares, Pessôa and Gonçalves, 2011 and of voucher specimens (skins, skulls, tissues and cells) of other small mammal species with regional occurrence. In addition to direct comparisons with reference collections, we also studied original or emended cranial and dental descriptions of each taxon available in the taxonomic literature (Voss & Carleton 1993, Steppan 1995, López-González 2005, Voss & Jansa 2009, Tavares et al. 2011). We also compiled information on mammal species richness and composition in the Restinga de Jurubatiba National Park, revising previous inventory studies carried out by live-trapping, mistnets and other methods (Bergallo et al. 2004, Pessôa et al. 2010, Luz et al. 2011). All specimens identified in the pellets and analyzed in this study are deposited in the mammal collection of NUPEM/UFRJ (lots NPM 176, 934–987).

We assessed completeness and sampling sufficiency of the pellet inventory by means of cumulative species curves. Two cumulative curves were constructed by rarefaction, one including all mammalian taxa identified in the owl pellets (Volant and non-volant) and the other including only non-volant taxa. In both analyses the cumulative mean number of species expected by the number of sampled individuals and the respective unconditional variances were calculated (standard-deviation and 95% confidence interval) (Colwell et al. 2012; Colwell 2013). The asymptotic behavior of the cumulative curves was examined in order to evaluate the completeness of species number estimates based on owl pellets. All cumulative curves and rarefaction procedures were performed on EstimateS 9.1 (Colwell 2013).

Results

Approximately 10 Kg of material was collected in the *Tyto furcata* nesting site, containing 4745 mammalian bone fragments (specimens) of at least 1739 individuals belonging to 17 small mammal species of the orders Rodentia, Chiroptera and Didelphimorphia (Table 1). The order Rodentia was the most representative in both species number and relative frequency of individuals preyed, comprising nine species and 98% of the specimens identified in owl pellets, with *Mus musculus* and *Cerradomys goytaca* being by large the two most preyed species. The order Chiroptera was second to rodents in species number, represented by six species, but accounting for less than 1% of the specimens identified, with *Carollia perspicillata* and *Eptesicus* sp. being the most representative bats in the pellets (0.4% for both, Table 1). The marsupials of the order Didelphimorphia were represented by only two species, accounting for 2% of the examined sample, with both species being equally represented in the sample (0.9%, Table 1).

The cumulative curves of species number constructed for the two datasets (all taxa vs non-volant) differed in their asymptotic behavior (Figure 1). The cumulative curve for all species did not stabilize at an asymptote throughout the 1739 individuals sampled in this study, exhibiting relatively large standard-deviations (1.61 to 2.11 species) around the expected mean number of species. This reduced precision in the richness estimates for all taxa was due to the number of singleton species (represented by a single individual), which in this case comprised the four bat species. When bats were excluded, the cumulative curve stabilized at an asymptote around 700 sampled specimens, resulting in very precise estimates of species richness (standard-deviations 0.06 to 0 species) throughout the first 1063 individuals of non-volant mammals sampled. No singleton species occurred among the non-volant taxa.

Six species represented in the owl pellets are new to the Restinga de Jurubatiba National Park (Figure 2). *Calomys tener* is recorded for the first time in the littoral of Rio de Janeiro state, while *Necromys lasiurus* is reported for the first time in *restingas*. Few species identifications were not conclusive due to pending taxonomic issues regarding species diagnoses (e.g. *Monodelphis* aff. *iheringi*) or lack of taxonomically informative characters in the single skull fragment preserved in owl pellets (e.g. *Eptesicus*). Given the information compiled from previous mammal inventories in the Restinga de Jurubatiba National Park (Bergallo et al. 2004, Pessôa et al. 2010, Luz et al. 2011), the new occurrences of mammal species provided by owl pellets increase the local mammal richness to 44 species (Table 2). Owl pellet records accounted for 38.6% of the total mammal species richness, with 13.6% of this richness being exclusively recorded by this method (Table 2). When only rodents and marsupial species are considered, pellets are even more complementary, exclusively recording 31.6% of the species of these two groups in the Restinga de Jurubatiba National Park.

Table 1. Mammal species found in Barn owl pellets in the Restinga de Jurubatiba National Park, with their respective number of identified specimens (NISP) and minimal number of individuals (MNI), also provided as percent (%) of the total MNI.

Taxa	NISP	MNI	(%)
Rodentia			
Cricetidae			
Cerradomys goytaca Tavares et al., 2011	1810	654	37.6
Necromys lasiurus (Lund, 1840)	385	139	8.0
Holochilus brasiliensis (Desmarest, 1819)	180	64	3.7
Nectomys squamipes (Brants, 1827)	125	57	3.3
Akodon cursor (Winge, 1887)	19	12	0.7
Calomys tener (Winge, 1887)	15	7	0.4
Muridae			
Mus musculus Linnaeus, 1758	1889	688	39.6
Rattus rattus (Linnaeus, 1758)	202	69	4.0
Caviidae			
Cavia fulgida Wagler, 1831	19	8	0.5
Didelphimorphia			
Didelphidae			
Monodelphis aff. *iheringi*	40	15	0.9
Marmosa paraguayana (Tate, 1931)	39	15	0.9
Chiroptera			
Phyllostomidae			
Carollia perspicillata (Linnaeus, 1758)	10	4	0.2
Glossophaga soricina (Pallas, 1766)	1	1	0.1
Artibeus obscurus (Schinz, 1821)	1	1	0.1
Vespertilionidae			
Eptesicus sp.	6	3	0.2
Lasiurus cinereus (P. Beauvois, 1796)	3	1	0.1
Myotis nigricans (Schinz, 1821)	1	1	0.1
17 species	4745	1739	100

Discussion

The sample of 1739 individuals analyzed in this study is three times larger than the minimum sample sizes suggested by Torre et al. (2004) for reliable small mammal species richness estimates. Indeed, the cumulative curve of species richness obtained for non-volant species was very precise and asymptotic, as also obtained in other owl pellet studies (Rocha et al. 2011). Richness estimates become less precise only when bats are included, owing to their rarity in Barn Owl pellets (Escarlate-Tavares & Pessôa 2005, Scheibler & Christoff 2007).

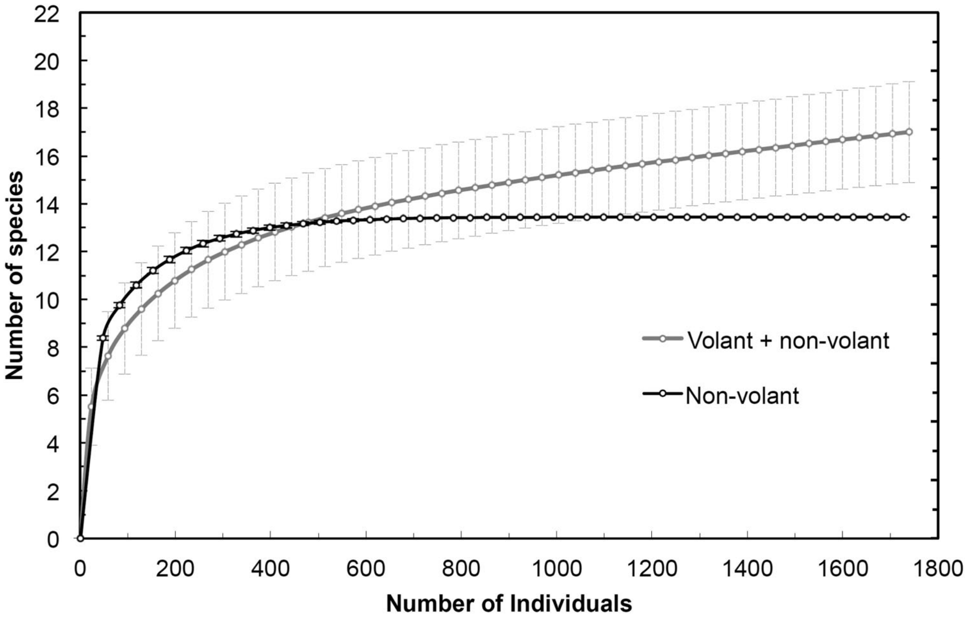

Figure 1. Cumulative curves of mean species richness of mammals recorded in Barn owl pelletsin the Restinga de Jurubatiba National Park including all (grey circles) and only non-volant species (black circles). Bars represent standard deviations.

The exotic mouse *Mus musculus* was the most frequently preyed species, despite its rarity in previous trapping studies in the study area (Bergallo et al. 2004, Pessôa et al. 2010), suggesting that the Barn owl hunts near farms, villages, roads and other altered restinga habitats found within the Restinga de Jurubatiba National Park. Our data suggests that the Barn owl also hunts extensively in preserved restinga habitats, given the high frequency of the endemic Goytacá rat *Cerradomys goytaca* among the preyed mammals. *Cerradomys goytaca* preferentially occupies open shrub formations that are broadly distributed in the study area, rarely occurring in forests or altered habitats where exotic species would be more common (Bergallo et al. 2004, Tavares et al. 2011). Barn owls usually travel distances of up to 1km (seldom exceeding 2km) from the nesting site to foraging areas (Taylor 1994). Given that an area with a 1km radius around the nesting site studied do not include habitats outside the coastal sandy plain, it's reasonable to assume that the local Barn owl foraging area is mostly included within the *restinga*, as also suggested by the high frequency of the endemic *C. goytaca* in the pellet sample.

The owl pellet data also revealed a number of new occurrences at local and regional scales, complementing information on the mammalian fauna composition in northern Rio de Janeiro littoral and filling distribution gaps. The record of the rodent *Calomys tener*, for instance, is new for restinga habitats in Southeastern Brazil and also represents the first occurrence of the species in the littoral of Rio de Janeiro state. This species inhabits dry and open vegetation formations in central Brazil, and its marginal records in Southeastern Brazil did not include littoral zones or coastal localities east to the Serra do Mar (Almeida et al. 2007; Bonvicino et al. 2010), despite its widespread occurrence in the coast of Southern Brazil (Quintela et al. 2014). The most coastal localities reported for this species in Southeastern Brazil were the municipalities of Santa Tereza, in Espírito Santo state, and Itapetininga, in São Paulo state (Bonvicino et al. 2010). Rocha et al. (2004b) listed *C. tener* among the mammals of Rio de Janeiro state, but no information on voucher-specimens, collecting localities or type of record was provided for this species, and its occurrence in the state was so far poorly known. We examined the collection of Museu Nacional and could confirm only one additional locality of occurrence for *C. tener* in Rio de Janeiro state, in the municipality of Comendador Levy Gasparian, bordering the state of Minas Gerais and far from the littoral (Figure 3). The two geographically distant records of *C. tener* reported here thus suggest that this species might be widespread in the state though rarely recorded in mammal inventories.

A second species reported for the first time in restingas was the rodent *Necromys lasiurus*. Nearby coastal records in grasslands and marshes in Campos dos Goytacazes (Rio de Janeiro state) and in semideciduous forests in Rio das Ostras (Rio de Janeiro state) already suggested the potential occupation of *restingas* by this species (Figure 3), given its widespread distribution throughout open areas (Bonvicino et al. 2008, D'Elía et al. 2008, Pessôa et al. 2010). Gatti et al. (2006) mentioned an unidentified species of the genus *Necromys* (= *Bolomys*) in the restingas of Paulo Cesar Vinha State Park, in Espírito Santo state, based on carnivore scat samples (*Bolomys* sp. in Gatti et al. 2006: Table 1). As the scat material was not referenced by voucher-specimens deposited in collections, we could not examine the *Necromys* sp. specimen analyzed by Gatti et al. (2006) to identify it at species level and preferred to maintain this record at genus level, as originally published. Therefore, the owl pellet material analyzed in this study is the first to provide unequivocal novel records of *C. tener* and *N. lasiurus* in *restingas* of Southeastern Brazil.

The replacement of original Atlantic forests by exotic grasslands in the last decades (Ribeiro et al. 2009) might have facilitated the recent dispersal of both *C. tener* and *N. lasiurus* to the littoral. On the other hand, the *restingas* biota in the northern Rio de Janeiro littoral shares similarities with the biotas of Cerrado and Caatinga as a putative result of past biogeographic connections among these three biotas

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Figure 2. Skulls, mandible and respective molariform teeth of six new species records in the Restinga de Jurubatiba National Park found in Barn owl pellets: (a, g) *Cavia fulgida*, (b, h) *Holochilus brasiliensis*, (c, i) *Necromys lasiurus* (d, j) *Monodelphis* aff. *iheringi*, (e, k) *Calomys tener* and (f, l) *Eptesicus* sp.

(Tavares et al. 2011). Assuming this latter hypothesis, the occurrence of *C. tener* and *N. lasiurus* in *restingas* could be relictual and more ancient than that postulated by recent dispersion due to habitat modification. Genetic data would be needed to test among these hypotheses.

The aperea *Cavia fulgida* and the marsh rodent *Holochilus brasiliensis* also comprise novel records for the Restinga de Jurubatiba National park, despite their wider distribution in the Atlantic forest (Bergallo et al. 2004, Bonvicino et al. 2008, Pessôa et al. 2010). These folivorous rodents are rarely attracted to conventionally baited live-traps (Alho 2005) and their preferred habitats include marshes and marginal aquatic vegetation, sites with difficult access for trapping but frequently used by the Barn owl for hunting, judging by the moderate frequencies of

Table 2. Mammal species from the Restinga de Jurubatiba National Park, including information from previous inventory studies and from the owl pellet samples analyzed in the present study. Records in previous studies were based on live-trapping (Traps) and direct observation of animals or tracks (Obs). Sources: (1) Gonzaga & Rajão (2001), (2) Bergallo et al. (2004), (3) Mangolin (2007), (4) Pessôa et al. (2010), (5) Luz et al. (2011), and this study.

Taxa	Traps	Obs.	Owl pellets
Didelphimorphia			
Didelphidae			
Caluromys philander (Linnaeus, 1758)	2		
Didelphis aurita (Wied-Neuwied, 1826)	2, 4		
Marmosa paraguayana (Tate, 1931)	2, 4		present study
Metachirus nudicaudatus (É. Geoffroy, 1803)	4		
Monodelphis* aff. *iheringi			present study
Philander frenatus (Olfers, 1818)	2, 4		
Cingulata			
Dasypodidae			
Dasypus novemcinctus Linnaeus, 1758		2	
Pilosa			
Myrmecophagidae			
Tamandua tetradactyla (Linnaeus, 1758)		4	
Primates			
Callitrichidae			
Callithrix jacchus (Linnaeus, 1758)		2	
Rodentia			
Cricetidae			
Akodon cursor (Winge, 1887)	2, 6		present study
***Calomys tener* (Winge, 1887)**			present study
Cerradomys goytaca Tavares et al. 2011	2, 4		present study
***Holochilus brasiliensis* (Desmarest 1819)**			present study
***Necromys lasiurus* (Lund, 1840)**			present study
Nectomys squamipes (Brants, 1827)	2, 4		present study
Oxymycterus dasytrichus (Schinz, 1821)	2, 4		
Muridae			
Mus musculus Linnaeus, 1758	2		present study
Rattus rattus (Linnaeus, 1758)	2		present study
Erethizontidae			
Coendou spinosus (F. Cuvier, 1823)		2, 4	
Caviidae			
Hydrochoerus hydrochaeris (Linnaeus, 1766)		4	
***Cavia fulgida* Wagler, 1831**			present study
Echimyidae			
Trinomys eliasi (Pessôa and Reis, 1993)	2		
Chiroptera			
Phyllostomidae			
Artibeus lituratus (Olfers, 1818)	2, 5		
Artibeus fimbriatus Gray, 1838	5		
Artibeus obscurus (Schinz, 1821)	5		present study
Carollia brevicauda (Schinz, 1821)	4		
Carollia perspicillata (Linnaeus, 1758)	2, 5		present study
Chiroderma vilossum Peters, 1860	2, 5		
Diaemus youngi (Jentink, 1893)	2, 5		
Desmodus rotundus (É. Geoffroy, 1810)	4		
Glossophaga soricina (Pallas, 1766)	2, 5		present study
Lophostoma brasiliense Peters, 1866	3, 5		
Platyrrhinus lineatus (É. Geoffroy, 1810)	2, 5		
Platyrrhinus recifinus (Thomas, 1901)	5		
Uroderma magnirostrum Davis, 1968	5		
Noctilionidae			
Noctilio leporinus (Linnaeus, 1758)	5		

Continued on next page

Table 2. Continued.

Taxa	Traps	Obs.	Owl pellets
Vespertilionidae			
***Eptesicus* sp.**			present study
Lasiurus cinereus (Palisot de Beauvois, 1796)	5		present study
Myotis nigricans (Schinz, 1821)	5		present study
Carnivora			
Felidae			
Puma yagouaroundi (É. Geoffroy, 1803)		2	
Canidae			
Cerdocyon thous (Linnaeus, 1766)		2	
Mustelidae			
Galictis cuja (Molina, 1782)		4	
Procyonidae			
Potos flavus (Schreber, 1774)		1, 4	
Procyon cancrivorus (G. Cuvier, 1798)		2, 4	

these taxa in the pellets (Table 1). Consequently, records of these species are highly dependent on the analyses of owl pellets and inventories exclusively based on live-trapping records will frequently fail to detect them (Escarlate-Tavares & Pessôa 2005, Scheibler & Christoff 2007, Bonvicino & Bezerra 2003).

The record of the mouse opossum *Monodelphis* aff. *iheringi* is also unprecedented in *restingas*. Species of *Monodelphis* are commonly recorded in mammal inventories in Atlantic forest using pitfall traps (Moura et al. 2008), but the implementation of this trapping method in the study area yielded no samples this genus (Pessôa et al. 2010). This species might be locally rare or present only in semideciduous forests contiguous to the coastal sandy plain in the Restinga de Jurubatiba National Park.

The Vespertilionid bats *Myotis nigricans* and *Lasiurus cinereus* identified in the owl pellets had already been reported for the Restinga de Jurubatiba National Park using mistnets (Luz et al. 2011), but the genus *Eptesicus* is reported for the first time, despite its common occurrence in other *restingas*

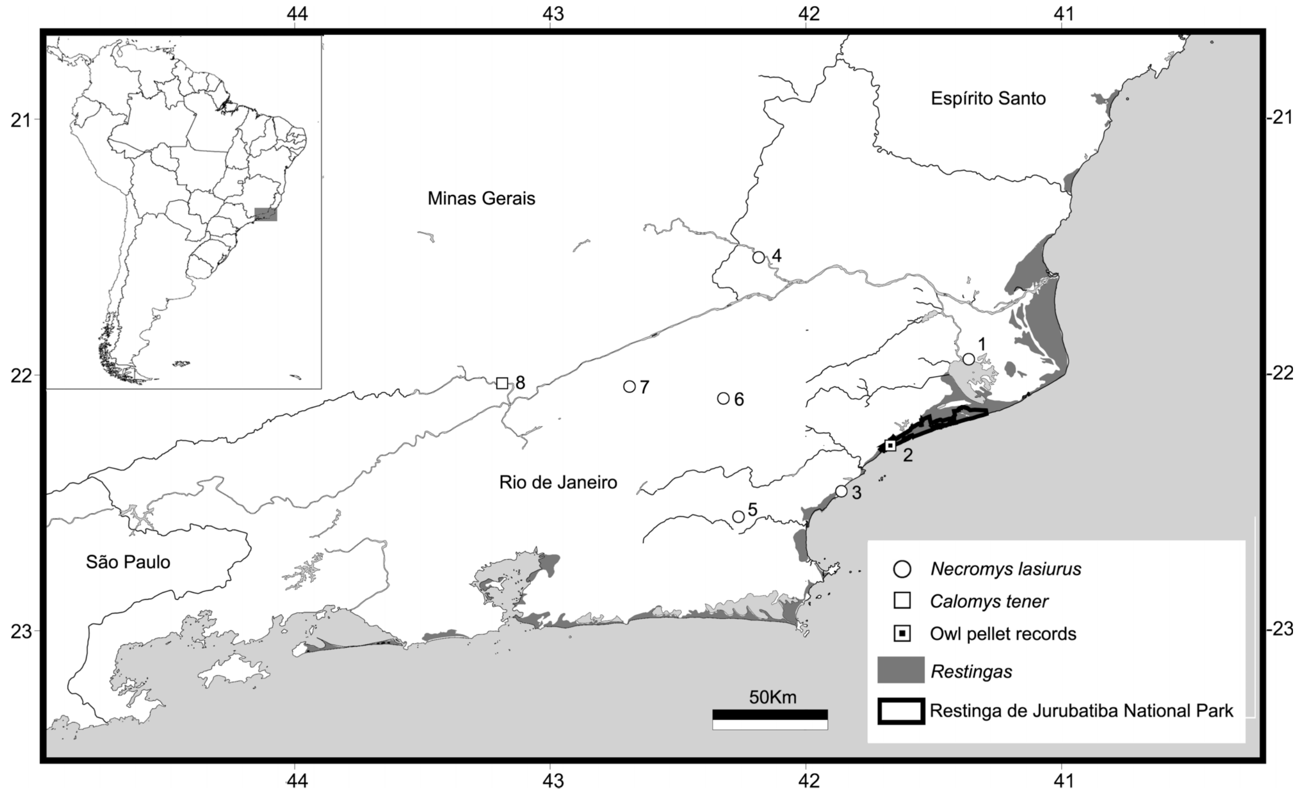

Figure 3. Collecting localities of voucher-specimens of *Calomys tener* and *Necromys lasiurus* in the Rio de Janeiro state: 1 – Lagoa Feia/Ponta Grossa, Campos dos Goytacazes (MN49734); 2 – Restinga de Jurubatiba National Park, Carapebus (NPM944, 953, 957, 960, 969, 973, 982); 3 – Mar do Norte, Rio das Ostras (MN24565-24567); 4 – Santo Antônio de Pádua (MN72744); 5 – Reserva Biológica de Poço das Antas, Silva Jardim (MN42882, 66174); 6 – Fazenda Independência, Cordeiro (MN75286, 75290); 7 – Sumidouro (MN24568, 43756); 8 – Fazenda Amazonas, Comendador Levy Gasparian (MN43888, 43893, 55710-55712).

(Nogueira et al. 2010). Vespertilionids are rarely sampled by conventional methods as they forage for insects on open areas relying on high-sensitivity echolocation that may detect mistnets (Esbérard & Bergallo 2008). The use of owl pellet records in this case should be combined with mistnet methods, even though bats are expected to be rarer than rodents in Barn owl prey items.

In summary, the records reported in this study corroborate the use of owl pellets as important complementary evidence for mammal inventories, especially regarding species that are difficult to detect by conventional live-trapping methods or are locally rare. The novel records also put the Restinga de Jurubatiba National Park as one of the richest coastal sandy plains for mammals (44 species) in Southeastern Brazil, second only to the Paulo César Vinha State Park (Venturini et al. 1996, Oprea et al. 2009) in Espírito Santo state. The updated local richness accounts for 23.8% of the mammals of Rio de Janeiro (Rocha et al. 2004b) and is nearly as high as those found in some well-preserved coastal humid montane areas, such as the Bocaina National Park (48 species, Delciellos et al. 2012). Given the current state of degradation of *restingas* in Rio de Janeiro state (Rocha et al. 2007), the high species richness found in the Restinga de Jurubatiba National Park is remarkable and might be related to its relatively large size, level of protection and variety of habitats, among other evolutionary and ecological factors. This local richness is suggestive of an important diversity hotspot in the northern Rio de Janeiro littoral, as already pointed out by bat, lizard and amphibian community comparisons (Oprea et al. 2009, Rocha et al. 2005), urging the expansion of the few existing protected areas in this region and the creation of new ones to protect the last *restinga* remnants in Southeastern Brazil.

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Bat fauna of Mato Grosso do Sul, southwestern Brazil

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Abstract: Bats have been increasingly studied in the last 15 years in Mato Grosso do Sul, and several records were not yet considered in reviews of South American bat distributions. Here, we present the bat species and their distributions in Mato Grosso do Sul based mainly on data compilation from literature, but also on complementary information from zoological collections, and our and colleagues' unpublished records. We found 74 species of bats within 42 genera and seven families already reported in Mato Grosso do Sul. Bat species in this state represent 44% of the Brazilian's bat species ($\approx$ 169) and 7% of the world's bat richness ($\approx$ 1120). Phyllostomidae (42) and Molossidae (17) were the richest families. Four species formerly cited for Mato Grosso do Sul are not supported by our compilation, and other 15 species recorded in the vicinity are listed as potential occurrences in this state. We additionally found controversial traits for specimens of *Platyrrhinus helleri*, and report *Eumops dabbenei* for the first time in Brazil. Most species were recorded in the regions of Cerrado (60) or Pantanal (57) in Mato Grosso do Sul, but only 16 in the Atlantic Forest. Records of Phyllostomidae species were mostly found in Cerrado and those of Molossidae, in Pantanal. Records in Mato Grosso do Sul determine edges of distribution for at least 22 species of South American bats. The overall known chiropteran fauna of Mato Grosso do Sul is highly diverse and new findings are expected through additional surveys.
Keywords: *Cerrado, Chiroptera, geographic distribution, Eumops dabbenei, Pantanal, Platyrrhinus helleri.*

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Resumo: Morcegos têm sido estudados intensivamente em Mato Grosso do Sul nos últimos 15 anos, e vários registros ainda não foram considerados em revisões sobre a distribuição de morcegos sul-americanos. Apresentamos aqui as espécies de morcegos e suas distribuições em Mato Grosso do Sul principalmente com base em dados compilados da literatura, mas também com base em dados complementares de coleção zoológica, e de registros inéditos nossos e de colegas. Encontramos 74 espécies de morcegos pertencentes a 42 gêneros e sete famílias em Mato Grosso do Sul. A riqueza de morcegos nesse estado representa 44% das espécies brasileiras de morcegos ($\approx$ 169) e 7% da riqueza mundial de morcegos ($\approx$ 1120). Phyllostomidae (42) e Molossidae (17) foram as famílias mais ricas. Quatro espécies reportadas anteriormente para Mato Grosso do Sul não são sustentadas com base em nossa compilação, e outras 15 espécies registradas na vizinhança são listadas como ocorrências potenciais no estado. Adicionalmente, encontramos características controversas em espécimes de *Platyrrhinus helleri*, e reportamos *Eumops dabbenei* pela primeira vez no Brasil. A maioria das espécies foi registrada nas regiões de Cerrado (60) ou Pantanal (57) em Mato Grosso do Sul, e apenas 16 em Mata Atlântica. Registros de Phyllostomidae foram encontrados principalmente em Cerrado e de Molossidae, no Pantanal. Sítios em Mato Grosso do Sul determinam limites de distribuição para pelo menos 22 espécies de morcegos sul americanos. A fauna de morcegos conhecida em Mato Grosso do Sul é bastante diversa, e novos registros são esperados por meio de inventários adicionais.
Palavras-chave: *Cerrado, Chiroptera, distribuição geográfica, Eumops dabbenei, Pantanal, Platyrrhinus helleri.*

Introduction

Although there are some old reports on bat occurrences in Mato Grosso do Sul (e.g. Vieira 1945), almost all knowledge about the chiropteran fauna in this state has 30 years of history, and most records have been reported in the last 10-15 years (e.g. Pulchério-Leite et al. 1998, Taddei & Uieda 2001, Camargo & Fischer 2005, Bordignon 2006, Santos et al. 2010, Silveira et al. 2011). Luiz Onofre Irineu de Souza has provided the first noticeable impetus to the knowledge of bats in Mato Grosso do Sul. He has begun in 1982 the section of chiropterans of the zoological collection of the Universidade Federal de Mato Grosso do Sul (UFMS), and has incorporated 82 specimens of 21 species over a decade. This was the foremost collection of Mato Grosso do Sul's bat fauna in 1997, when Valdir Antônio Taddei has initiated a second pronounced impetus to the knowledge of bats in the state, founding the chiropteran collection of the Universidade para o Desenvolvimento do Estado e da Região do Pantanal (UNIDERP-Anhanguera). Thereafter, supported by these two collections of bats that include more than 5000 specimens today, the bat fauna has been increasingly investigated in Mato Grosso do Sul.

As the knowledge is quite recent, several records of bats in Mato Grosso do Sul have not yet been considered for South American bat distributions (e.g. Gardner 2008) nor included in reviews of the Brazilian bat fauna (Bianconi & Pedro 2007, Fabian & Gregorin 2007, Nogueira et al. 2007a, 2007b, Peracchi & Nogueira 2007, Zortéa 2007). For instance, the most recent review of the Brazil's bat fauna (Tavares et al. 2008) did not include 37 of the 74 species that we list here for Mato Grosso do Sul. The Pantanal and the midwestern Brazil are regions still identified as gaps of data on bat species occurrences (Tavares et al. 2008, Bernard et al. 2011), a condition that has been reversed. Here, we review the known chiropteran species and their distributions in Mato Grosso do Sul, and add unpublished data which include the first record of *Eumops dabbenei* (Molossidae) in Brazil. The large number of species found and the distribution of study sites show that the knowledge on Mato Grosso do Sul's bat fauna is not incipient, though recent.

Methods

The state of Mato Grosso do Sul in central South America comprises the borders of the major continental morfoclimatic domains of Cerrado and Atlantic Forest, and the transitional morfoclimatic zone of Pantanal (Ab'Saber 2000). Environmental differences among Cerrado, Pantanal and Atlantic Forest can determine floristic and faunal variations (e.g. Alho et al. 2011a), thus we present records of bats according to these domains. We formerly searched for records of bat species in Mato Grosso do Sul reported in the literature, using as keywords the names of species and families, and combinations of the words (in English and Portuguese): bats, Chiroptera, distribution, occurrence, Cerrado, Chaco, Mato Grosso, Pantanal. Searches included databases of Scielo, Web of Science and Google. We then selected only records described as geographic coordinates or by names of places which allowed geographical identification. Complementary, we looked for additional records in zoological collections through the *species*Link (http://splink.cria.org.br/) and in the UFMS collection (ZUFMS), and ultimately among our unpublished data and on those kindly offered by the colleagues Alan Eriksson, Gustavo Graciolli, Nayara F. Carvalho, Paulo R. de Souza, and Wilson Uieda. Bat species nomenclature follows Simmons (2005), except *Artibeus planirostris* and *Natalus macrourus* that follow Lim et al. (2004) and Garbino & Tejedor (2012) respectively. We conservatively used *Platyrrhinus helleri* sensu Simmons (2005) because specimens collected in Mato Grosso do Sul differed from the expected according to Velazco et al. (2010a). Thus we described some traits of two *P. helleri* specimens and compared with those described by Velazco et al. (2010a). We also described traits of one *Eumops dabbenei* specimen, identified based on Kiser (1995), Barquez et al. (1999), Gregorin & Taddei (2002) and Eger (2007).

For preparation of distribution maps we used geographic coordinates described in the published studies or collection records, and centroids when the information consisted of names of farms, towns, or villages. We cited geographic coordinates for unpublished records included in the maps (Appendix 1). In cases of species registered twice or more in a same site or nearby ($<$ 20 km), we cited one or two sources in the following order: records published in scientific journals, thesis or dissertations, specimens in zoological collections, and unpublished data. Point size in the distribution maps covers a circular area of 9.3 km of radius. Overlapping points of different species in a same map were slightly dislocated to improve visualization. Maps show some points out of Mato Grosso do Sul when part of studies cited as sources for sites in the state. We finally plotted all sites of bat records surrounded by an arbitrary buffer area of 20 km to provide a roughly notion of the states' territory uncovered for bat surveys.

Results and discussion

Bat species of Mato Grosso do Sul

We compiled 74 species of bats within 42 genera and seven families already registered in the state of Mato Grosso do Sul (Table 1). This number of species is 20% higher than that listed some years ago (Cáceres et al. 2008), and close to the richness of bats reported for other Brazilian states with longer history of bat surveys, as Paraná (64; Passos et al. 2010), Rio de Janeiro (77; Peracchi & Nogueira 2010), São Paulo (79; Vivo et al. 2011), and Minas Gerais (80; Tavares et al. 2010). Most species (62) were found in two or more sites, whereas the remaining 12 species were recorded in one site only: eight phyllostomids (*Micronycteris sanborni*, *Trachops cirrhosus*, *Uroderma bilobatum*, *U. magnirostrum*, *Vampyrodes caraccioli*, *Lonchophylla mordax*, *Lionycteris spurrelli*, and *Rhinophylla pumilio*), three molossids (*Eumops dabbenei*, *E. bonariensis*, and *Tadarida brasiliensis*), and one vespertilionid (*Lasiurus cinereus*). Thus additional records of these species are expected to strengthen their occurrences in this state, mainly *Lionycteris spurrelli*, *Trachops cirrhosus*, and *Tadarida brasiliensis* which were registered only in the state's boundaries (Bordignon 2006, Cunha et al. 2011, Santos & Bordignon 2011). To accept the occurrence of *Rhinophylla pumilio* as valid requires additional records, since there is no information whether the individual was deposited in a collection (Coelho 2005). Additional records are also desirable for *Artibeus fimbriatus*, as the two specimens reported in the central region of Mato Grosso do Sul are not accessible in local collections (Deus et al. 2003, Cáceres et al. 2008), and other individuals were

Table 1. Bat species (n = 74) recorded in the Pantanal (PA), Cerrado (CE), and Atlantic Forest (AF) domains, and references to the figures of distribution, in the State of Mato Grosso do Sul, Brazil.

Families **Subfamilies** **Species**	**Domains**			**Figures of distribution**
	PA	**CE**	**AF**	
Phyllostomidae Gray, 1825				
Phyllostominae Gray, 1825				
Lophostoma brasiliense Peters, 1866	X	X		1 A
Lophostoma silvicolum d'Orbigny, 1836	X	X		1 A
Macrophyllum macrophyllum (Schinz, 1821)		X		1 A
Micronycteris sanborni Simmons, 1996		X		1 B
Micronycteris minuta (Gervais, 1856)	X	X		1 B
Micronycteris megalotis Gray, 1842	X[a]	X		1 B
Chrotopterus auritus (Peters, 1856)	X	X	X	1 C
Lonchorhina aurita Tomes, 1863		X		1 C
Mimon bennettii (Gray, 1838)	X	X		1 D
Mimon crenulatum (E. Geoffroy, 1803)	X			1 D
Phylloderma stenops Peters, 1865	X	X		1 D
Phyllostomus elongatus (E. Geoffroy, 1810)	X[a]	X		1 E
Phyllostomus hastatus (Pallas, 1767)	X	X	X	1 E
Phyllostomus discolor Wagner, 1843	X	X	X	1 E
Tonatia bidens (Spix, 1823)	X	X		1 F
Trachops cirrhosus (Spix, 1823)		X		1 F
Vampyrum spectrum (Linnaeus, 1758)	X			1 F
Stenodermatinae Gervais, 1856				
Artibeus cinereus (Gervais, 1856)		X		2 A
Artibeus fimbriatus Gray, 1838		X	X	2 A
Artibeus planirostris (Spix, 1823)	X	X	X	2 A
Artibeus obscurus (Schinz, 1821)	X[b]	X	X	2 B
Artibeus lituratus (Olfers, 1818)	X	X	X	2 B
Chiroderma villosum Peters, 1860	X	X		2 C
Chiroderma doriae O. Thomas, 1891	X	X	X	2 C
Platyrrhinus helleri (Peters, 1866)	X	X		2 D
Platyrrhinus lineatus (E. Geoffroy, 1810)	X	X	X	2 D
Pygoderma bilabiatum (Wagner, 1843)		X	X	2 E
Uroderma bilobatum Peters, 1866	X			2 E
Uroderma magnirostrum Davis, 1868		X		2 E
Vampyressa pusilla (Wagner, 1843)	X	X		2 E
Vampyrodes caraccioli (Thomas, 1889)	X			2 E
Sturnira lilium (E. Geoffroy, 1810)	X	X	X	2 F
Desmodontinae Bonaparte, 1845				
Desmodus rotundus (E. Geoffroy, 1810)	X	X	X	3 A
Diaemus youngi (Jentink, 1893)	X			3 A
Glossophaginae Bonaparte, 1845				
Anoura geoffroyi Gray, 1838	X	X		3 B
Anoura caudifer (E. Geoffroy, 1818)	X	X		3 B
Glossophaga soricina (Pallas, 1766)	X	X	X	3 C
Lonchophylla dekeyseri Tad.Viz. Saz.,1983		X		3 D
Lonchophylla mordax Thomas, 1903		X		3 D
Lionycteris spurrelli Thomas, 1913		X		3 D
Carolliinae Miller, 1924				
Carollia perspicillata (Linnaeus, 1758)	X	X	X	3 E
Rhinophylla pumilio Peters, 1865		X		3 E
Emballonuridae Gervais, 1855				
Embalonurinae Gervais, 1855				
Peropteryx macrotis (Wagner, 1843)	X[a]	X		3 F
Rhynchonycteris naso (Wied-Neuwied, 1820)	X			3 F

Continued on next page

Table 1. Continued.

Families **Subfamilies** **Species**	**Domains**			**Figures of distribution**
	PA	**CE**	**AF**	
Molossidae Gervais, 1856				
Molossinae Gervais, 1856				
Cynomops abrasus (Temminck, 1827)	X	X		4 A
Cynomops planirostris (Peters, 1865)	X	X		4 A
Eumops dabbenei Thomas, 1914	X			4 A
Eumops bonariensis (Peters, 1874)		X		4 A
Eumops glaucinus (Wagner, 1843)	X	X		4 B
Eumops patagonicus Thomas, 1924	X			4 B
Eumops perotis (Schinz, 1821)	X			4 B
Eumops auripendulus (Shaw, 1800)	X	X[c]		4 B
Molossops temminckii (Burmeister, 1854)	X	X		4 C
Molossus rufus E. Geoffroy, 1805	X	X		4 D
Molossus molossus (Pallas, 1766)	X	X	X	4 D
Molossus pretiosus Miller, 1902	X			4 D
Nyctinomops macrotis (Gray, 1840)		X		4 E
Nyctinomops laticaudatus (E. Geoffroy, 1805)	X	X		4 E
Promops centralis Thomas, 1915	X			4 F
Promops nasutus (Spix, 1823)	X			4 F
Tadarida brasiliensis I. Geoffroy, 1824	X			4 F
Vespertilionidae Gray, 1821				
Vespertilioninae Gray, 1821				
Eptesicus furinalis (d'Orbigny, 1847)				
Eptesicus brasiliensis (Desmarest, 1819)	X	X		5 A
Lasiurus blossevillii (Lesson & Garnot, 1826)		X		5 A
Lasiurus cinereus (Beauvois, 1796)	X	X		5 B
Lasiurus ega (Gervais, 1856)		X[c]		5 B
Myotinae Tate, 1942	X	X		5 B
Myotis nigricans (Schinz, 1821)				
Myotis simus Thomas, 1901	X	X	X	5 C
Myotis riparius Handley, 1960	X			5 D
Myotis albescens (E. Geoffroy, 1806)	X	X		5 D
Mormoopidae Saussure, 1860	X	X		5 D
Pteronotus parnellii (Gray, 1843)				
Noctilionidae Gray, 1821		X		5 E
Noctilio leporinus (Linnaeus, 1758)				
Noctilio albiventris Demarest, 1818	X	X		5 F
Natalidae Gray, 1866	X	X	X	5 F
Natalus macrourus (Gervais, 1856)	X[a]	X		5 E

[a] Occurrence in the Pantanal border.
[b] Occurrence at the southern limit of Pantanal.
[c] In urban zone, Campo Grande.

captured in the limit with Paraná (Ortêncio-Filho et al. 2010, Zanon 2010).

Based on our criteria, five species formerly cited for Mato Grosso do Sul were not included in the present checklist (Table 1). One *Diphylla ecaudata* individual was described without a location (Alho et al. 2011b), so we keep it out of the states' checklist. *Molossus currentium* was listed by Fabian & Gregorin (2007), but it was a mistake since the record is actually 3 km away, in Paraguay (López-Gonzáles & Presley 2001). Likewise, *Myotis ruber* was recorded 1 km away from the state (Coelho 2005). Therefore, *Molossus currentium* and *Myotis ruber* presumably occur in Mato Grosso do Sul in spite they have not yet been recorded. Tavares et al. (2008) pointed out the occurrence of *Tonatia saurophila* based on Williams et al. (1995a); however, it was another mistake because Williams et al. (1995a) cited only *T. bidens* in Mato Grosso do Sul. Thus, the occurrence of *T. saurophila* remains unknown in this state, though expected due to records in Bolivia (Aguirre 2007). One specimen of *Micronycteris schmidtorum* was listed in Cáceres et al. (2008) due to misidentification, reviewed to *M. sanborni* in Santos et al. (2010). Therefore, *M. schmidtorum* follows unreported for Mato Grosso do Sul. Recently, Siles et al. (2013) described the species *Micronycteris yatesi* based on specimens from Bolivia formerly identified as *M. sanborni*. Due to geographical proximity to Bolivia and morphological similarities between both species, the only specimen from Mato Grosso do Sul assigned as *M. sanborni* (Santos et al. 2010) might actually belong to *M. yatesi*. Once confirmed, it would be the first record of *M. yatesi* in Brazil, and this new species would no longer be considered as endemic to Bolivia

Table 2. Five traits of *Platyrrhinus helleri* and *P. incarum* bats (Phyllostomidae) described by Velazco et al. (2010a), and for specimens from Mato Grosso do Sul (MS), Brazil.

Traits	***Platyrrhinus incarum***	***Platyrrhinus helleri***	**Specimens from MS**
Noseleaf vibrissae (n)	8	7	7
Ventral fur color	Bicolor, light brown	Unicolor, light grey	Unicolor, pale
Uropatagium margin	Inverted U-shape	Inverted V-shape	Inverted V-shape
Length of metacarpal III	Longer than metacarpal V	Similar to metacarpal V	Similar to metacarpal V
Dorsal stripe	Narrow	Wide and bright	Wide and bright

(Siles et al. 2013). In addition, if so, *M. yatesi* should substitute *M. sanborni* in the present state's bat checklist.

At least 15 additional species of bats are potentially expected in Mato Grosso do Sul based on their occurrences in the vicinity, in the Paraguay basin or in sites of Cerrado, Atlantic Forest or Chaco: *Glyphonycteris behnii* (Nogueira et al. 2007a, Tavares et al. 2008), *Mesophylla macconnelli* (Aguirre 2007, Tavares et al. 2008), *Artibeus anderseni*, *A. gnomos* (Gonçalves & Gregorin 2004), *A. glaucus* (Aguirre 2007), *Platyrrhinus brachycephalus* (Silva & Marques 2010), *P. masu*, *Choeroniscus minor* (Aguirre 2007), *Saccopteryx bilineata* (Oliveira et al. 2002), *Molossops neglectus* (Bernardi et al. 2007), *Nyctinomops aurispinosus* (Aguirre 2007, Tavares et al 2008), *Eptesicus diminutus*, *Histiotus macrotus* (Willig et al. 2000, Tavares et al. 2008), *Histiotus velatus* (Aguirre 2007, Tavares et al. 2008), and *Pteronotus gymnonotus* (Gonçalves & Gregorin 2004). These potential species summed to *Diphylla ecaudata*, *Molossus currentium*, *Myotis ruber* and *Tonatia saurophila*, indicate that almost one hundred bat species might occur in the state of Mato Grosso do Sul.

Specimens of Platyrrhinus helleri and Eumops dabbenei

Some external traits of two specimens of *Platyrrhinus helleri* (sensu Simmons 2005) from Mato Grosso do Sul (ZUFMS 0241, 0264) match *P. helleri* (sensu Velazco et al. 2010a) rather than *P. incarum* (Table 2), as would be expected. Based on morphological and molecular data, Velazco & Patterson (2008) and Velazco et al. (2010a) proposed *P. incarum* as a valid species whose distribution includes the northern and midwestern Brazil, in the state of Mato Grosso, 387 km north than our northernmost record. They also suggested that *P. helleri* (sensu Velazco et al. 2010a) does not occur in Brazil, and presents the southern edge of distribution in Colombia, Venezuela and Ecuador. Thus far the external traits of specimens from Mato Grosso do Sul may indicate either an unlikely first occurrence of *P. helleri* (sensu Velazco et al. 2010a) in Brazil, or that those external characteristics (Table 2) are not useful to discriminate between *P. incarum* and *P. helleri* (sensu Velazco et al. 2010a), or even an undescribed taxon in the region. Therefore, we highlight that specimens of *P. helleri* (sensu Simmons 2005) in Mato Grosso do Sul deserve a deep taxonomic approach before assign them to a species proposed by Velazco et al. (2010a).

Among bat species found in Mato Grosso do Sul, we report here the first occurrence of *Eumops dabbenei* in Brazil. One adult male was mistnetted at sunset in the edge of a semideciduous forest, in the Pantanal. The specimen presented ears that do not extend over the nose when laid forward, and antitragus shorter than those of *E. perotis* and *E. trumbulli*, the other congeneric species with forearm longer than 70 mm (Barquez et al. 1999, Gregorin & Taddei 2002, Fabián & Gregorin 2007). Twelve traits measured on the male *E. dabbenei* fall within the range reported to the species; other six measures are either larger (breadth across canines and breadth across molars) or shorter (tail length, mandibular length, mandibular toothrow length, and maxillary toothrow length) for *E. dabbenei* from Pantanal than for those from elsewhere (Table 3). *Eumops dabbenei* appears to be rare, with few specimens deposited in zoological collections (Barquez et al. 1999, Tavares et al. 2008). Even so, its occurrence in Brazil, mainly in the southern Pantanal, might be expected due to previous records in Paraguay, 15 to 25 km from Mato Grosso do Sul (Redford & Eisenberg 1992, Gregorin & Taddei 2002, Eger 2007).

Bat distributions in Mato Grosso do Sul

Of the 74 bat species compiled for Mato Grosso do Sul, 60 were found in Cerrado, 57 in Pantanal, and 17 in Atlantic Forest. Fifteen were exclusively registered in Cerrado, 14 solely in Pantanal, and none was found only in Atlantic Forest (Table 1). All five subfamilies of Phyllostomidae were present in the three domains, but low proportions of Phyllostominae and Glossophaginae species (18% and 17%, respectively) were registered in Atlantic Forest; for the other subfamilies this proportion was about 50% (Table 1). Beyond phyllostomids, only *Molossus molossus*, *Myotis nigricans*, and *Noctilio albiventris* were found in Mato Grosso do Sul's Atlantic Forest. This poor bat fauna in this domain may reflect a very low survey effort rather than a region deprived of bat species in Mato Grosso do Sul. The number of species in the states' Atlantic Forest reaches only 14% of those listed for this domain (cf. Paglia et al. 2012). Therefore, even accounting for the relatively small area and the restricted latitudinal range of the Atlantic Forest in Mato Grosso do Sul, increased bat surveys in this region should add several unnoticed species. In contrast, the number of bat species in the states' Cerrado region reaches 60% of that in the whole Brazilian Cerrado, and the number of species in the states' Pantanal region does 95% of that in this domain in Brazil (cf. Paglia et al. 2012). This high proportion of species from Brazilian Pantanal notably occurs because most of this domain is in Mato Grosso do Sul.

Records of Phyllostominae species in Mato Grosso do Sul were mostly distributed in Cerrado rather than in Pantanal. Seven species (*Macrophyllum macrophyllum*, *Micronycteris* spp., *Lonchorhina aurita*, *Mimon bennettii*, and *Trachops cirrhosus*) were mainly recorded in Cerrado, and three (*Lophostoma silvicolum*, *Mimon crenulatum* and *Vampyrum spectrum*) mainly in Pantanal (Figure 1). Likewise, five

Table 3. Measures of one male *Eumops dabbenei* (Molossidae) collected in the Pantanal, Mato Grosso do Sul (MS), Brazil, and range of measurements (or single value if only one available) for this species elsewhere (references: 1 = Barquez et al. 1999; 2 = Souza et al. 2008; 3 = Harrison et al. 1979; 4 = Ochoa & Ibanez 1985; 5 = McWilliams et al. 2002; 6 = Eger 1977; 7 = Redford & Eisenberg 1992).

Traits	Specimen from MS	Range	References
Total body length (mm)	168	145-190	1, 2, 7
Weight (g)	77	74-77	1, 7
Tail length (mm)	54	55-64	1, 2, 7
Braincase length (mm)	30.8	29.6-33.8	1, 2, 3, 4, 5, 6
Braincase breadth (mm)	14.2	12.3-14.2	1, 2
Breadth across canines (mm)	8.5	8.0	1
Breadth across molars (mm)	14.3	13.2-13.7	1, 4
Condylobasal length (mm)	28.3	28.4-30.8	1, 2, 3, 4, 5
Ear length (mm)	24.9	24.0-31.7	1, 2, 7
Interorbital width less (mm)	8.9	6.1-10.8	1, 2, 4
Postorbital constriction (mm)	6.3	5.9-10.8	1, 2, 3, 5, 6
Mandibular length (mm)	23.2	23.6-24.9	1, 3
Mandibular toothrow length (mm)	14.1	14.3-14.9	1, 3
Mastoid breadth (mm)	16.5	16.0-17.1	1, 3, 5, 6
Maxillary toothrow length (mm)	12.1	12.5-13.4	1, 3, 4, 5, 6
Zygomatic breadth (mm)	20.0	16.5-20.4	1, 2, 3, 4, 5, 6
Forearm length (mm)	77.0	75.2-78.5	1, 2, 3, 4, 6, 7
Hind foot length (mm)	13.5	12.0-18.0	2, 3, 7

Stenodermatinae (*Artibeus cinereus*, *A. fimbriatus*, *A. obscurus*, *Pygoderma bilabiatum*, and *Uroderma magnirostrum*) were solely or more commonly registered in Cerrado, and just two rare species (*Uroderma bilobatum* and *Vampyrodes caraccioli*) were found exclusively in the Pantanal (Figure 2). In the other subfamilies, records of *Diaemus youngi* were distributed in Pantanal, whereas *Anoura* spp., *Lonchophylla* spp., *Lionycteris spurrelli*, and *Rhinophylla pumilio* were exclusively or more frequently reported in Cerrado (Figure 3). In total, 18 species of Phyllostomidae appear to have their occurrences somehow favored in Cerrado, and six in Pantanal. Additional 18 phyllostomid species were distributed over both regions without an apparent tendency to either Cerrado or Pantanal.

In contrast to Phyllostomidae, records of Emballonuridae and Molossidae species were largely distributed in Pantanal rather than in Cerrado. Among Emballonuridae, *Rhynchonycteris naso* was recorded only in Pantanal and *Peropteryx macrotis* in both Cerrado and Pantanal (Figure 3F). For Molossidae, 11 species (*Cynomops abrasus*, *Eumops dabbenei*, *E. glaucinus*, *E. patagonicus*, *E. perotis*, *E. auripendulus*, *Molossus pretiosus*, *Nyctinomops laticaudatus*, *Promops centralis*, *P. nasutus*, and *Tadarida brasiliensis*) were mostly or exclusively registered in Pantanal, two species (*Eumops bonariensis* and *Nyctinomops macrotis*) were found in Cerrado only, and four species (*Cynomops planirostris*, *Molossops temminckii*, *Molossus rufus*, and *M. molossus*) did not present a clear tendency of records between Pantanal or Cerrado in Mato Grosso do Sul (Figure 4). Distributions of Vespertilionidae species in Mato Grosso do Sul seem to present opposite tendencies between the subfamilies Vespertilioninae and Myotinae (Figure 5A-D). The former presented two species (*Eptesicus brasiliensis* and *Lasiurus cinereus*) exclusively in Cerrado and one (*Lasiurus ega*) more frequently reported in Pantanal, and the latter presented three species (*Myotis albescens*, *M. riparius*, and *M. simus*) more frequently recorded in Pantanal and none species clearly distributed toward Cerrado. Other Vespertilioninae (*Eptesicus furinalis* and *Lasiurus blossevillii*) and Myotinae (*Myotis nigricans*) showed no tendency of records between domains. In the remaining families, *Pteronotus parnellii* and *Natalus macrourus* were exclusively or more commonly found in Cerrado (Figure 5E), and *Noctilio* spp. in Pantanal (Figure 5F).

Notes on bat distributions in South America

Sites in Mato Grosso do Sul determine boundaries of distributions for several bats in South America. Findings of *Mimon bennettii* in Pantanal expand its distribution westernward, and those of *Micronycteris megalotis* in Serra da Bodoquena fill a gap on its previously known distribution map (Gardner 2008, Eriksson et al. 2011, Oliveira et al. 2011). Records of *Phylloderma stenops* in Mato Grosso do Sul support that its geographical range includes most of the Cerrado domain (Pulchério-Leite et al. 1998, Esbérard & Faria 2006, Alho et al. 2011b). Sites of occurrence for *Vampyrum spectrum* and *Artibeus cinereus* determine the southern and southwestern borders of their distributions, respectively (Gardner 2008, Tavares et al. 2008, Scultori et al. 2009). For *Vampyressa pusilla*, occurrences in Pantanal and in its bordering plateaus (Longo et al. 2007, Camargo et al. 2009) increase the species range northwesternward (Gardner 2008, Tavares et al. 2008). More significantly, records in Mato Grosso do Sul extends the distribution of *Vampyrodes caraccioli* to 1400 km southwesternward from Pará, 1250 km northwesternward from São Paulo coast, and 1060 km southeasternward from north Bolivia (Velazco et al. 2010b).

Likewise, the records in Mato Grosso do Sul mark the southwestern limit of distributions for *Lionycteris spurrelli*, *Lonchorhina aurita*, *Lonchophylla mordax* (Bordignon 2006), *L. dekeyseri* (Cunha et al. 2011), *Micronycteris sanborni* (Santos et al. 2010), *Mimon crenulatum* (Camargo & Fischer 2005), *Phyllostomus elongatus* (Bordignon & França 2009), *Uroderma bilobatum* (present study, Appendix 1), *U. magnirostrum* (Alho et al. 2011b; see Nogueira et al. 2003),

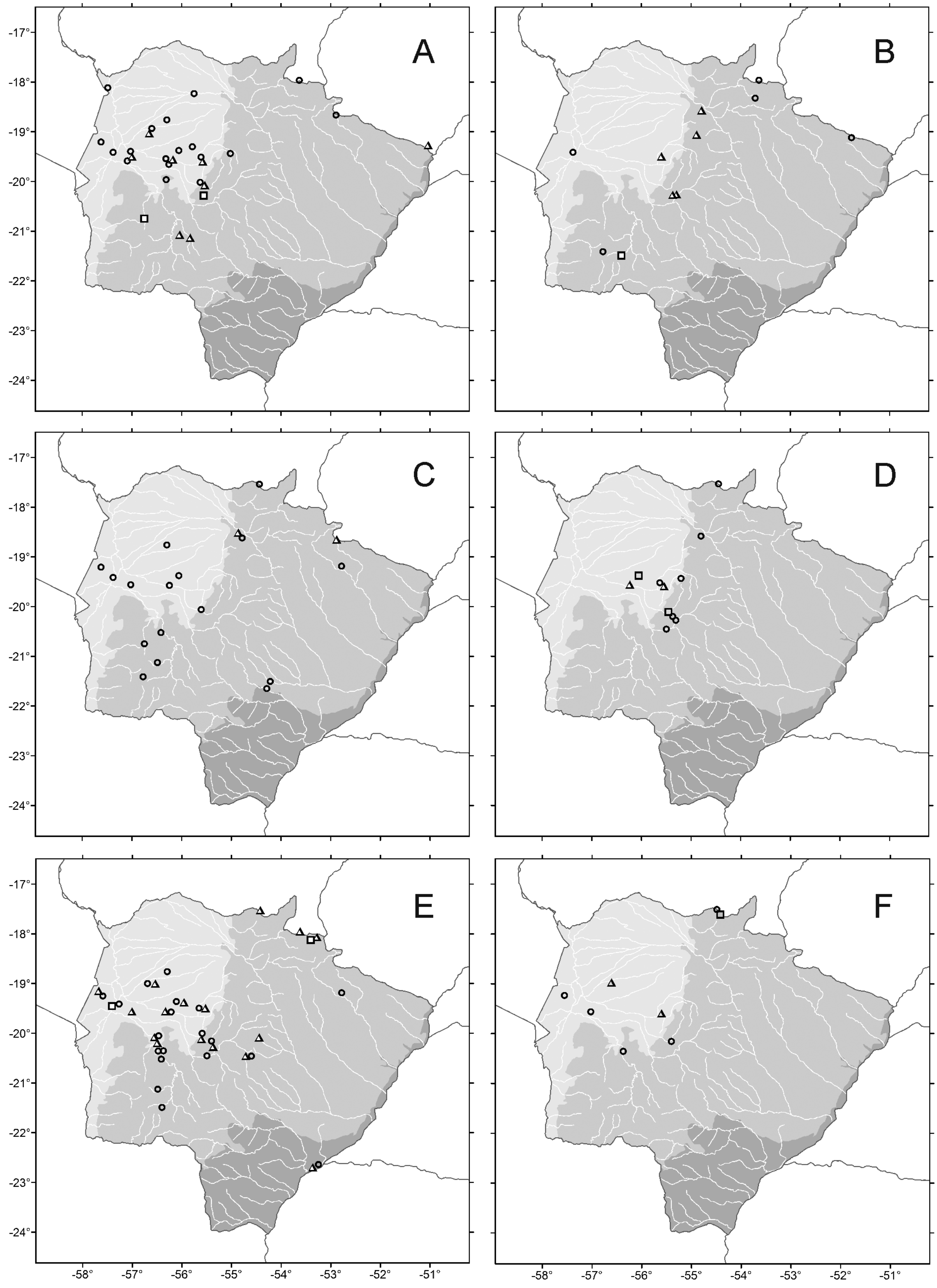

Figure 1. Distribution of Phyllostominae bats in the Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey) in Mato Grosso do Sul, Brazil. [**A**] *Lophostoma brasiliense* (triangle), *L. silvicolum* (circle), *Macrophyllum macrophyllum* (square); [**B**] *Micronycteris sanborni* (square), *M. minuta* (triangle), *M. megalotis* (circle); [**C**] *Chrotopterus auritus* (circle), *Lonchorhina aurita* (triangle); [**D**] *Mimon bennettii* (circle), *M. crenulatum* (triangle), *Phylloderma stenops* (square); [**E**] *Phyllostomus elongatus* (square), *P. hastatus* (circle), *P. discolor* (triangle); [**F**] *Tonatia bidens* (circle), *Trachops cirrhosus* (square), *Vampyrum spectrum* (triangle).

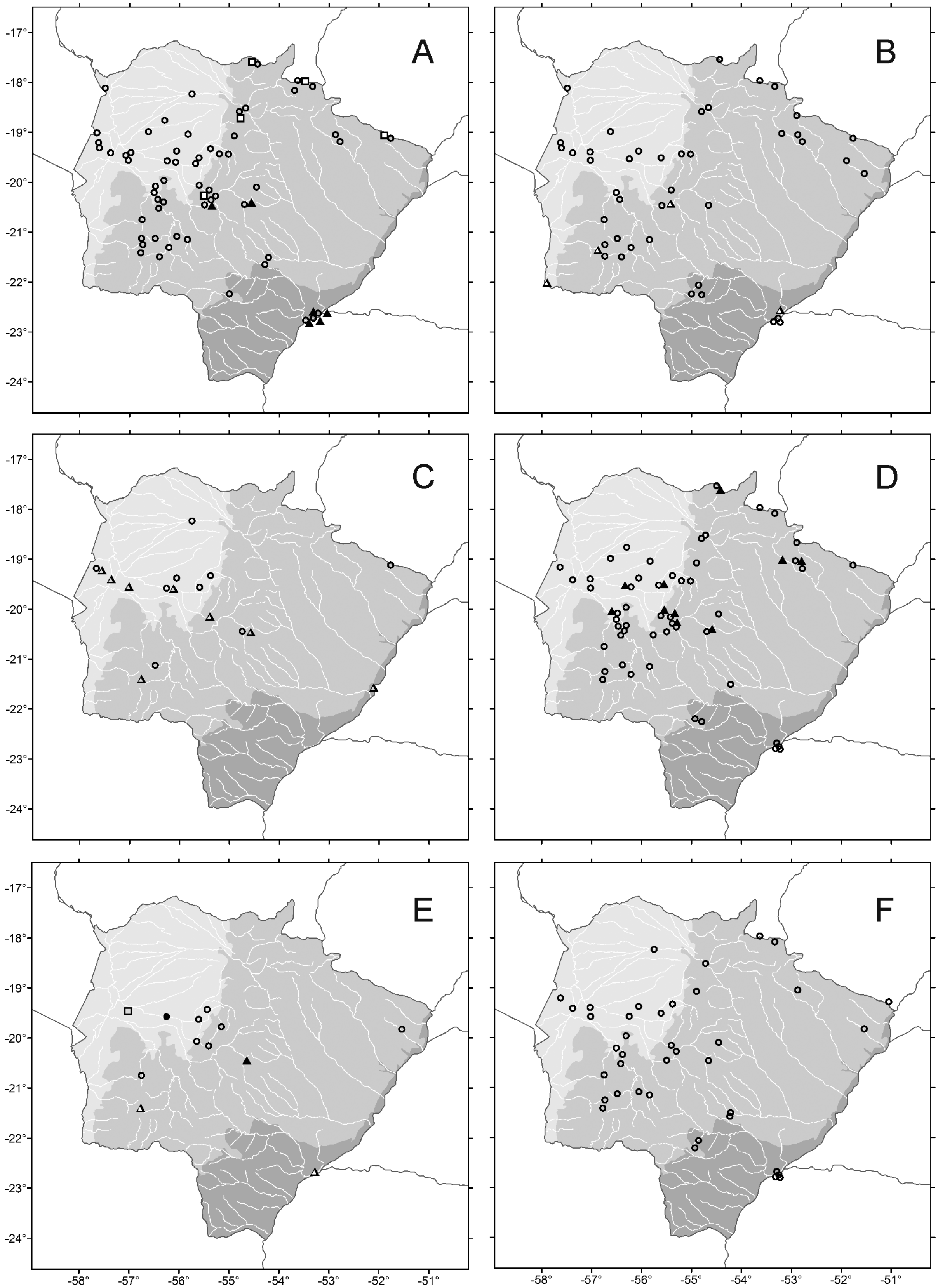

Figure 2. Distribution of Stenodermatinae bats in the Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey) in Mato Grosso do Sul, Brazil. [**A**] *Artibeus cinereus* (square), *A. fimbriatus* (filled triangle), *A. planirostris* (circle); [**B**] *A. obscurus* (triangle), *A. lituratus* (circle); [**C**] *Chiroderma villosum* (circle), *C. doriae* (triangle); [**D**] *Platyrrhinus helleri* (filled triangle), *P. lineatus* (circle); [**E**] *Pygoderma bilabiatum* (triangle), *Uroderma bilobatum* (filled circle), *U. magnirostrum* (filled triangle), *Vampyressa pusilla* (circle), *Vampyrodes caraccioli* (square); [**F**] *Sturnira lilium*.

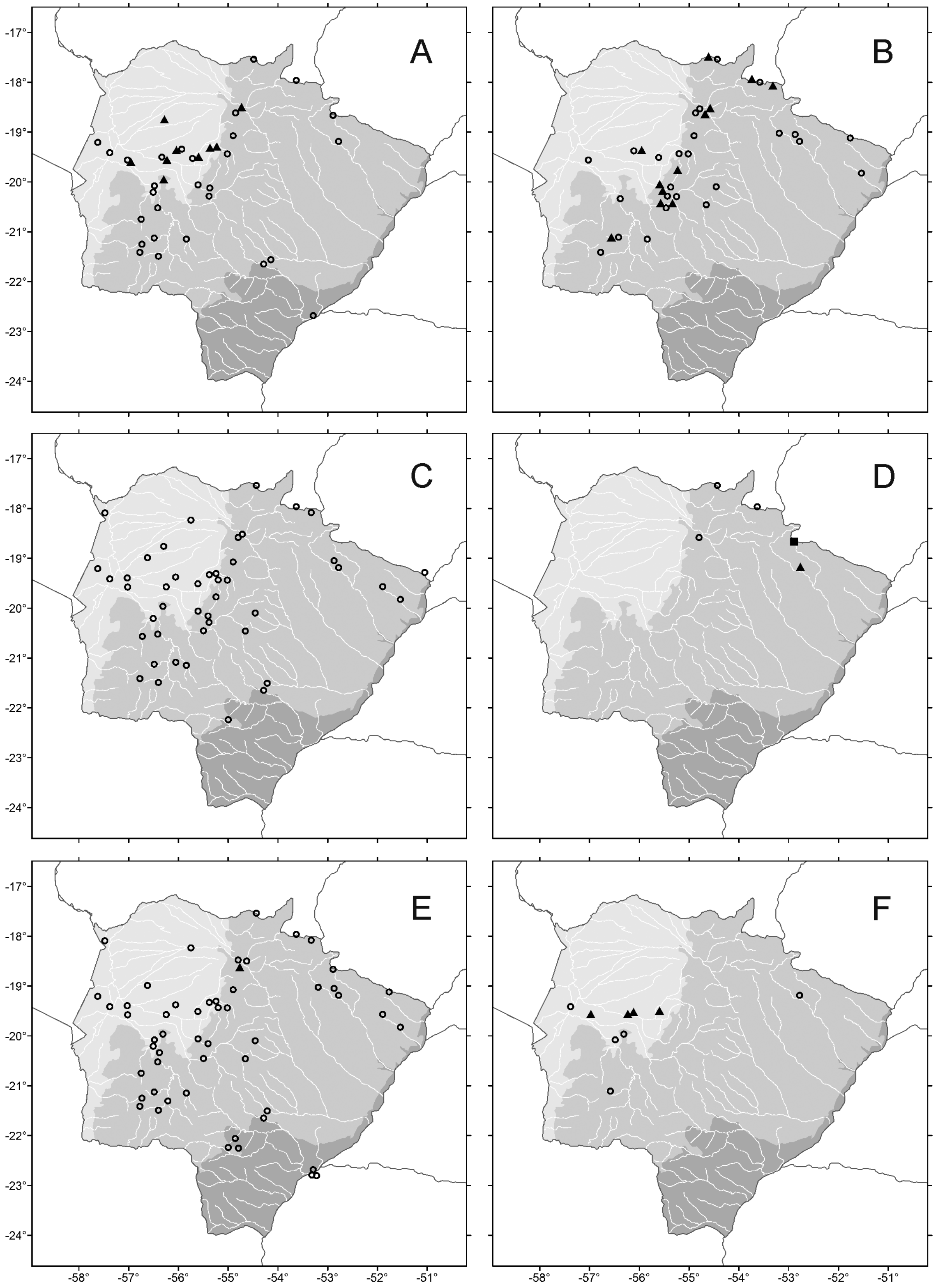

Figure 3. Distribution of Desmodontinae, Glossophaginae, Carolliinae and Emballonurinae bats in the Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey) in Mato Grosso do Sul, Brazil. [**A**] *Desmodus rotundus* (circle), *Diaemus youngi* (filled triangle); [**B**] *Anoura geoffroyi* (filled triangle), *A. caudifer* (circle); [**C**] *Glossophaga soricina*; [**D**] *Lonchophylla dekeyseri* (circle), *L. mordax* (filled triangle), *Lionycteris spurrelli* (filled square); [**E**] *Carollia perspicillata* (circle), *Rhinophylla pumilio* (filled triangle); [**F**] *Peropteryx macrotis* (circle), *Rhynchonycteris naso* (filled triangle).

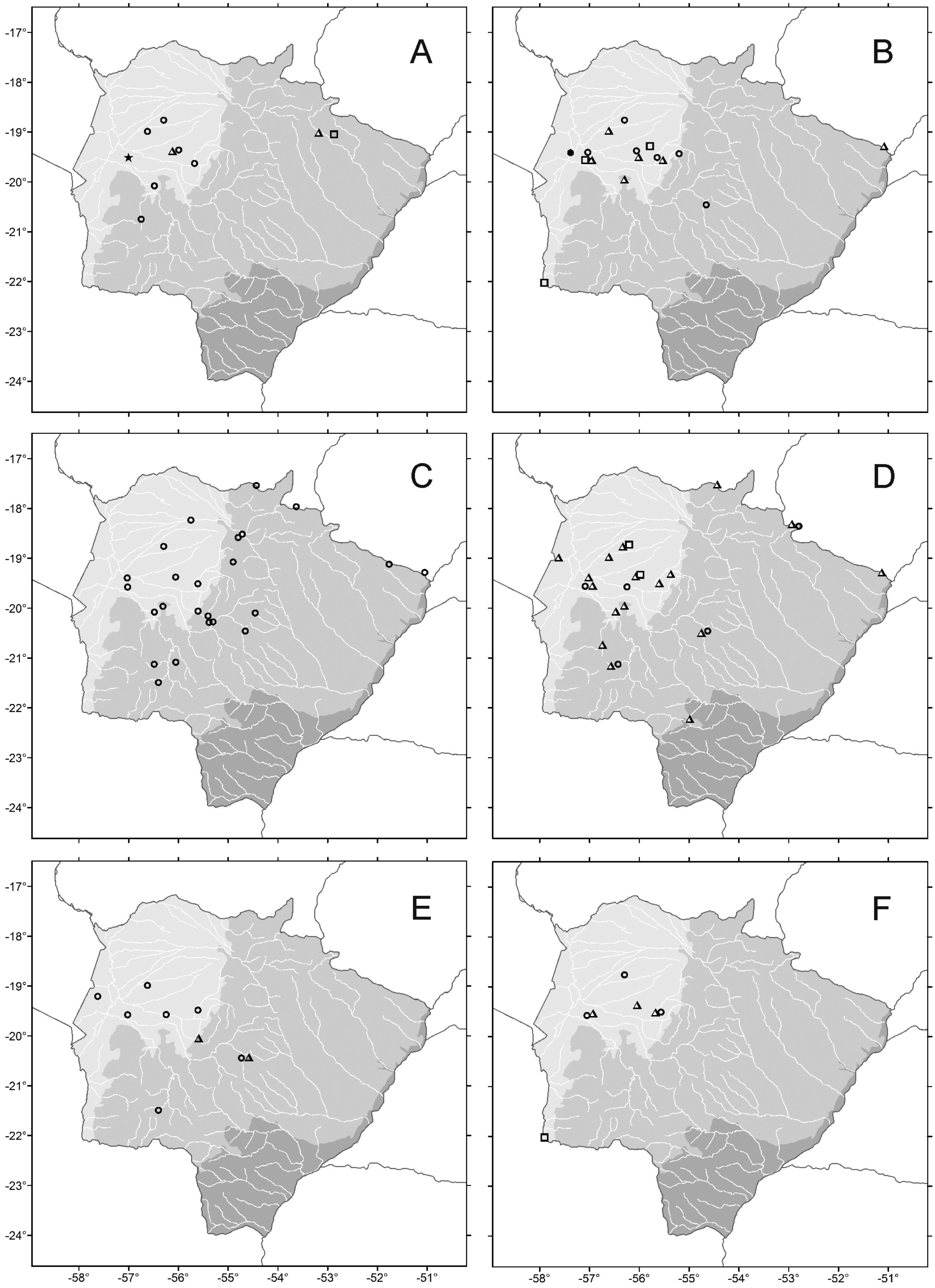

Figure 4. Distribution of Molossinae bats in the Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey) in Mato Grosso do Sul, Brazil. [**A**] *Cynomops abrasus* (circle), *C. planirostris* (triangle), *Eumops dabbenei* (star; first record in Brazil), *Eumops bonariensis* (square); [**B**] *Eumops glaucinus* (triangle), *E. patagonicus* (square), *E. perotis* (filled circle), *E. auripendulus* (circle); [**C**] *Molossops temminckii*; [**D**] *Molossus rufus* (circle), *M. molossus* (triangle), *M. pretiosus* (square); [**E**] *Nyctinomops macrotis* (triangle), *N. laticaudatus* (circle); [**F**] *Promops centralis* (circle), *P. nasutus* (triangle), *Tadarida brasiliensis* (square).

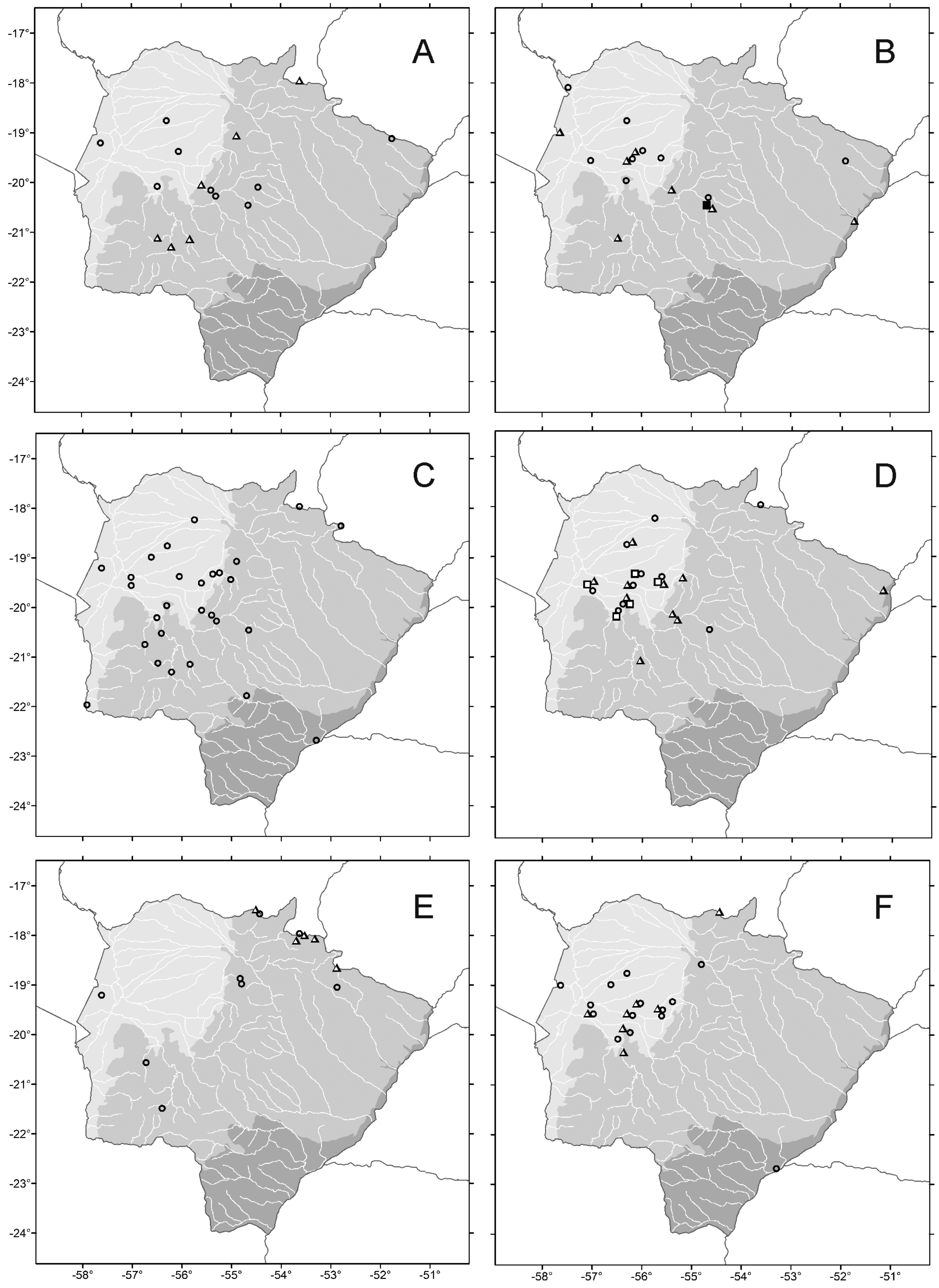

Figure 5. Distribution of Vespertilionidae, Mormoopidae, Natalidae and Noctilionidae bats in the Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey) in Mato Grosso do Sul, Brazil. [**A**] *Eptesicus furinalis* (circle), *E. brasiliensis* (triangle); [**B**] *Lasiurus blossevillii* (triangle), *L. cinereus* (filled square), *L. ega* (circle); [**C**] *Myotis nigricans*; [**D**] *Myotis simus* (square), *M. riparius* (triangle), *M. albescens* (circle); [**E**] *Pteronotus parnellii* (triangle), *Natalus macrourus* (circle); [**F**] *Noctilio leporinus* (triangle), *N. albiventris* (circle).

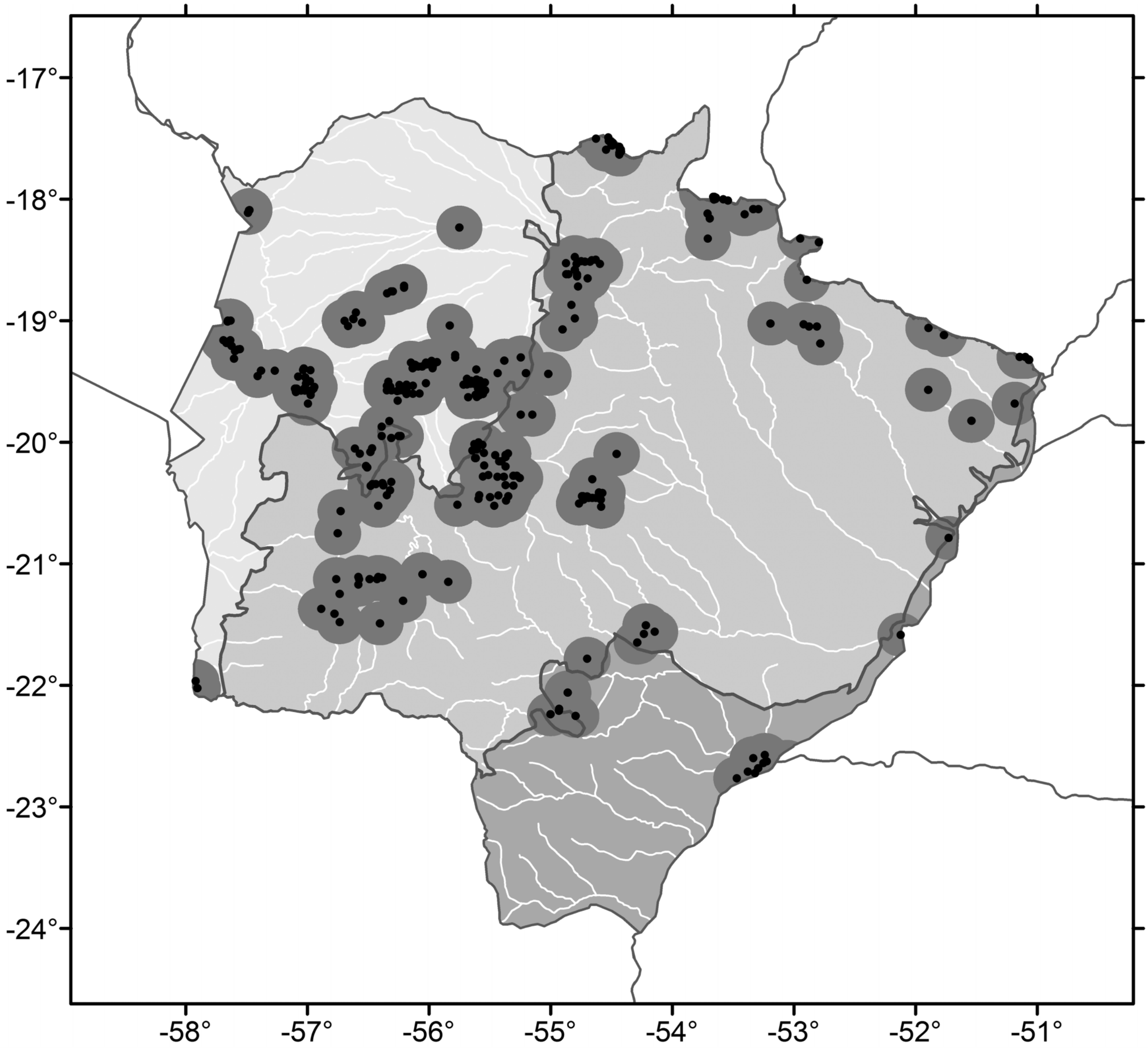

Figure 6. Distribution of sites of bat records (black dots) surrounded by a 20 km buffer zone (dark gray) in the state of Mato Grosso do Sul, Brazil. The total buffer areas account for 78,213 km^2, which comprises 22% of the states' territory. Background gray tones indicate the domains Pantanal (light grey), Cerrado (mid grey) and Mata Atlântica (dark grey).

Rhinophylla pumilio (Coelho 2005; see Rinehart & Kunz 2006), and *Rhynchonycteris naso* (Camargo 2003; present study, Appendix 1). For *Eumops patagonicus*, records in this state extend its geographical distribution northeasternward (Gardner 2008, Bordignon et al. 2011, Waideman et al. 2011; present study, Appendix 1). In addition, occurrences in Mato Grosso do Sul are the southern edges of distribution for *Molossus pretiosus* and *Pteronotus parnellii*; records also support that *M. pretiosus* likely occurs widely in the Pantanal (see Gregorin & Taddei 2000). Occurrences of *Promops centralis* in Mato Grosso do Sul are the first ones in Brazil out of Amazon, and they establish a new species' southeastern limit of distribution (Nogueira & Peracchi 1999, Alho et al. 2011b; present study, Appendix 1). Overall, sites in Mato Grosso do Sul represent the limits of distribution for at least 22 species of bats, 17 Phyllostomidae (eight Phyllostominae, five Stenodermatinae, three Glossophaginae, and one Carolliinae), three Molossidae, one Emballonuridae, and one Mormoopidae. Most of these records have not yet been considered in reviews of South American bat distributions (e.g. Gardner 2008).

Concluding remarks

The chiropteran fauna of Mato Grosso do Sul is highly diverse, and the number of species will likely increase through new inventories across vast areas still unknown regarding to bat occurrences. In addition, as the present data were mostly collected through netting or documentation in roosts, new samplings by records of echolocation calls will probably improve the knowledge on species which roost in less accessible places and are uncommonly mist-netted (Barnett et al. 2006). The general distribution of bat surveyed sites is biased toward the midwestern portion of the Mato Grosso do Sul's territory (Figure 6), in the regions of Miranda and Negro basins, which include part of the Pantanal and Cerrado plateaus, named

Serra da Bodoquena and Serra de Maracaju. Such distribution is likely related to the accessibility via roads, markedly from the capital Campo Grande to Corumbá, Coxim, and towns in the Bodoquena region. In the opposite direction, our compilation also supports that the vast eastern Mato Grosso do Sul is largely unknown about bat occurrences, except by the extreme northeastern (Figure 6). This wide gap comprises all sub-basins of the Paraná river throughout the Cerrado and Atlantic Forest areas in Mato Grosso do Sul. Other relevant gaps of bat surveys are the northwestern Pantanal in the Taquari basin, and the southwestern Pantanal close to the Chaco and to the southern Brazilian Cerrado. In a roughly estimation, discounting a 20 km buffer zone around sites of bat records, 78% of the state's territory is still uncovered for bat occurrences (Figure 6). Unsurvey areas per domain reach 91% in Atlantic forest, 78% in Cerrado, and 71% in Pantanal. Furthermore, the expectation of species increment is not only based on large gap areas. As we included records conservatively, future corrections on the present checklist are prone to add rather than to subtract species. A general relevant issue is that Mato Grosso do Sul comprises a major ecotonal zone in South America. It likely explains the occurrence of species at edges of their distributions, as evidenced by numerous species of bats whose northern, southern, eastern or western geographical limits are in Mato Grosso do Sul; like *Eumops dabbenei* for instance.

Appendix 1. Sources of records included in the distribution maps of bat species, in alphabetical order, in the Mato Grosso do Sul state, Brazil.

Anoura caudifer – LITERATURE: Pulchério-Leite et al. 1998, Camargo 2003, Coelho 2005, Bordignon 2006, Fernandes 2009, Longo 2009, Ferreira et al. 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011; UNPUBLISHED RECORDS: Nicolay Cunha (19°07' S, 51°45' W).

Anoura geoffroyi – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Alho et al. 2011, Cunha et al. 2011; MUSEUM: ZUFMS (0151, 0368, 0454).

Artibeus cinereus – LITERATURE: Coelho 2005, Cunha et al. 2011; MUSEUM: ZUFMS (0360); UNPUBLISHED RECORDS: Nicolay Cunha (19°07' S, 51°45' W).

Artibeus fimbriatus – LITERATURE: Deus et al. 2003, Cáceres et al. 2008, Ortêncio-Filho et al. 2010, Zanon 2010.

Artibeus lituratus – LITERATURE: Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Cunha et al. 2009, Fernandes 2009, Longo 2009, Teixeira et al. 2009, Ferreira et al. 2010, Ortêncio-Filho et al. 2010, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Gonçalves et al. 2012, Munin et al. 2012; MUSEUM: ZUFMS (0577); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (18°06' S, 57°29' W; 19°12' S, 57°37' W); Nayara F Carvalho (22°14' S, 54°59' W; 22°15' S, 54°47' W; 22°03' S, 54°51' W); Nicolay Cunha (19°07' S, 51°45' W).

Artibeus obscurus – LITERATURE: Fernandes 2009, Bordignon & Santos 2010, Zanon 2010, Eriksson et al. 2011.

Artibeus planirostris – LITERATURE: Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Cunha et al. 2009, Fernandes 2009, Longo 2009, Teixeira et al. 2009, Ferreira et al. 2010, Ortêncio-Filho et al. 2010, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Silveira 2011, Munin et al. 2012; MUSEUM: ZUFMS (0382, 0466, 0471, 0578); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Alan Eriksson, Carolina F Santos (18°06' S, 57°29' W; 18°07' S, 57°29' W); Nayara F Carvalho (22°14' S, 55°00' W); Nicolay Cunha (19°07' S, 51°46' W; 21°39' S, 54°17' W; 21°35' S, 54°14' W; 21°36' S, 54°14' W; 21°30' S, 54°13' W; 19°13' S, 57°37' W).

Carollia perspicillata – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Cunha et al. 2009, Fernandes 2009, Longo 2009, Teixeira et al. 2009, Ferreira et al. 2010, Ortêncio-Filho et al. 2010, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0179, 0371, 0372); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Alan Eriksson, Carolina F Santos (18°06' S, 57°29' W; 19°13' S, 57°37' W); Nayara F Carvalho (22°14' S, 55°00' W; 22°13' S, 54°56' W; 22°15' S, 54°48' W; 22°04' S, 54°52' W); Nicolay Cunha (19°07' S, 51°46' W; 21°39' S, 54°17' W; 21°34' S, 54°15' W; 21°35' S, 54°14' W; 21°36' S, 54°14' W; 21°30' S, 54°13' W).

Chiroderma doriae – LITERATURE: Gregorin 1998, Bordignon & França 2009, Ferreira et al. 2010, Alho et al. 2011, Eriksson et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0258); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W); Alan Eriksson (19°34' S, 57°01' W).

Chiroderma villosum – LITERATURE: Pulchério-Leite et al. 1998, Ferreira et al. 2010, Alho et al. 2011; ZUFMS (0158, 0159, 0208, 0209, 0505); UNPUBLISHED RECORDS: Nicolay Cunha (19°07' S, 51°46' W).

Chrotopterus auritus – LITERATURE: Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0109, 0354); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W); Nicolay Cunha (21°39' S, 54°17' W; 21°30' S, 54°13' W).

Cynomops abrasus – LITERATURE: Pulchério-Leite et al. 1998, Camargo et al. 2009, Alho et al. 2011, Silveira 2011; MUSEUM: ZUFMS (0377).

Cynomops planirostris – LITERATURE: Pulchério-Leite et al. 1998, Bordignon 2006; MUSEUM: ZUFMS (0162).

Desmodus rotundus – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Cunha et al. 2009, Longo 2009, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0115, 0121, 0340, 0364); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W); Nicolay Cunha (21°39' S, 54°17' W; 21°35' S, 54°14' W).

Diaemus youngi – LITERATURE: Pulchério-Leite et al. 1998, Alho et al. 2011, Munin et al. 2012; MUSEUM: ZUECMAM (384, 385), ZUFMS (0078, 0164, 0165).

Eptesicus brasiliensis – LITERATURE: Coelho 2005, Cáceres et al. 2007, Longo 2009; MUSEUM: ZUFMS (0160).

Eptesicus furinalis – LITERATURE: Pulchério-Leite et al. 1998, Alho et al. 2011; UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°07' S, 51°46' W; 19°13' S, 57°37' W).

Eumops auripendulus – LITERATURE: Alho et al. 2011; ZUFMS (0146).

Eumops bonariensis – LITERATURE: Bordignon 2006.

Eumops dabbenei – MUSEUM: ZUFMS (1319).

Eumops glaucinus – LITERATURE: Camargo 2003, Bordignon 2006, Alho et al. 2011; MUSEUM: ZUFMS (0145, 0298).

Eumops patagonicus – LITERATURE: Bordignon et al. 2011, Waideman et al. 2011; MUSEUM: ZUFMS (0470).

Eumops perotis – LITERATURE: Bordignon & França 2009; MUSEUM: ZUFMS (0045).

Glossophaga soricina – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Cunha et al. 2009, Fernandes 2009, Longo 2009, Ferreira et al. 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0283, 0344, 0366, 0367, 0369); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W); Nayara F Carvalho (22°14' S, 55°00' W); Nicolay Cunha (19°07' S, 51°46' W; 21°39' S, 54°17' W; 21°35' S, 54°14' W; 21°30' S, 54°13' W); Erich Fischer, Paulo R Souza (18°05' S, 57°29' W).

Lasiurus blossevillii – LITERATURE: Pulchério-Leite et al. 1998, Alho et al. 2011; MUSEUM: ZUEC-MAM (2632), ZUFMS (0134, 0135, 0171, 0252); UNPUBLISHED RECORDS: Wilson Uieda (19°00' S, 57°39' W).

Lasiurus cinereus – LITERATURE: Alho et al. 2011.

Lasiurus ega – LITERATURE: Pulchério-Leite et al. 1998, Camargo 2003, Bordignon 2006, Alho et al. 2011, Oliveira et al. 2011; MUSEUM: ZUFMS (0138, 0176, 0253).

Lionycteris spurrelli – LITERATURE: Bordignon 2006.

Lonchophylla dekeyseri – LITERATURE: Coelho 2005, Cunha et al. 2011.

Lonchophylla mordax – LITERATURE: Bordignon 2006.

Lonchorhina aurita – LITERATURE: Coelho 2005, Bordignon 2006.

Lophostoma brasiliense – LITERATURE: Bordignon 2006, Longo 2009, Alho et al. 2011, Silveira 2011, Munin et al. 2012; MUSEUM: ZUFMS (0113, 0318, 0357).

Lophostoma silvicolum – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Longo 2009, Alho et al. 2011, Silveira 2011, Munin et al. 2012; MUSEUM: ZUFMS (0110, 0181, 0356); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (18°07' S, 57°29' W); Alan Eriksson (19°13' S, 57°37' W).

Macrophyllum macrophyllum – LITERATURE: Camargo et al. 2009; MUSEUM: ZUFMS (0072).

Micronycteris megalotis – LITERATURE: Coelho 2005, Bordignon & França 2009, Eriksson et al. 2011; ZUFMS (0347); UNPUBLISHED RECORDS: Nicolay Cunha (19°07' S, 51°46' W).

Micronycteris minuta – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Longo 2009, Alho et al. 2011.

Micronycteris sanborni – LITERATURE: Santos et al. 2010.

Mimon bennettii – LITERATURE: Coelho 2005, Fernandes 2009, Alho et al. 2011, Oliveira et al. 2011; UNPUBLISHED RECORDS: Nicolay Cunha (17°32' S, 54°27' W).

Mimon crenulatum – LITERATURE: Camargo & Fischer 2005; MUSEUM: ZUFMS (0108).

Molossops temminckii – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Cunha et al. 2009, Longo 2009, Ferreira et al. 2010, Alho et al. 2011, Cunha et al. 2011; MUSEUM: ZUFMS (0147); UNPUBLISHED RECORDS: Nicolay Cunha (19°07' S, 51°46' W).

Molossus molossus – LITERATURE: Bordignon 2006, Camargo et al. 2009, Longo 2009, Alho et al. 2011; MUSEUM: ZUFMS (0271); UNPUBLISHED RECORDS: Nayara F Carvalho (22°14' S, 55°00' W); Nicolay Cunha (17°32' S, 54°27' W); Wilson Uieda (19°00' S, 57°38' W).

Molossus pretiosus – LITERATURE: Alho et al. 2011.

Molossus rufus – LITERATURE: Camargo 2003, Bordignon 2006, Alho et al. 2011; UNPUBLISHED RECORDS: George Camargo, Carolina F Santos (19°34' S, 56°15' W).

Myotis albescens – LITERATURE: Coelho 2005, Alho et al. 2011; MUSEUM: ZUFMS (0141, 0170); UNPUBLISHED RECORDS: George Camargo, Carolina F Santos (19°34' S, 56°15' W).

Myotis nigricans – LITERATURE: Coelho 2005, Bordignon 2006, Camargo et al. 2009, Longo 2009, Ferreira et al. 2010, Zanon 2010, Alho et al. 2011, Moratelli et al. 2011; MUSEUM: ZUFMS (0133, 0137, 0172, 0175, 0203, 0204, 0283, 0378, 0379, 0381); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W).

Myotis riparius – LITERATURE: Camargo 2003, Alho et al. 2011, Moratelli et al. 2011; MUSEUM: ZUFMS (0140).

Myotis simus – LITERATURE: Alho et al. 2011, Moratelli et al. 2011; MUSEUM: ZUFMS (0006).

Natalus macrourus – LITERATURE: Taddei & Uieda 2001, Coelho 2005, Bordignon 2006, Cunha et al. 2009, 2011; MUSEUM: ZUFMS (0329, 0330, 0331).

Noctilio albiventris – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Gonçalves et al. 2007, Longo 2009, Zanon 2010, Alho et al. 2011; MUSEUM: ZUFMS (0365); UNPUBLISHED RECORDS: Wilson Uieda (19°00' S, 57°38' W).

Noctilio leporinus – LITERATURE: Alho et al. 2011; MUSEUM: ZUFMS (0143); UNPUBLISHED RECORDS: Nicolay Cunha (17°32' S, 54°27' W); Carolina F Santos (19°34' S, 56°15' W).

Nyctinomops laticaudatus – LITERATURE: Cunha et al. 2009, Alho et al. 2011; MUSEUM: ZUFMS (0008, 0012, 0018, 0149, 0305, 0306, 0478); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°34' S, 56°15' W).

Nyctinomops macrotis – LITERATURE: Alho et al. 2011; MUSEUM: ZUFMS (0148).

Peropteryx macrotis – LITERATURE: Bordignon 2005, 2006, Labruna & Venzal 2009, Alho et al. 2011.

Phylloderma stenops – LITERATURE: Pulchério-Leite et al. 1998, Alho et al. 2011.

Phyllostomus discolor – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Longo 2009, Ferreira et al. 2010, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0105, 0155, 0355, 0468).

Phyllostomus elongatus – LITERATURE: Coelho 2005, Bordignon & França 2009.

Phyllostomus hastatus – LITERATURE: Bordignon 2006, Bordignon & França 2009, Cunha et al. 2009, Fernandes 2009, Ferreira et al. 2010, Zanon 2010, Alho et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0106, 0352, 0353); UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W).

Platyrrhinus helleri – LITERATURE: Bordignon 2006, Ferreira et al. 2010, Alho et al. 2011, Cunha et al. 2011, Munin et al. 2012; MUSEUM: ZUFMS (0158, 0361); UNPUBLISHED RECORDS: Carolina F Santos (19°31' S, 55°37' W).

Platyrrhinus lineatus – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Fernandes 2009, Longo 2009, Teixeira et al. 2009, Ferreira et al. 2010, Ortêncio-Filho et al. 2010, Zanon 2010, Alho et al. 2011, Cunha et al. 2011, Eriksson et al. 2011, Munin et al. 2011, 2012; MUSEUM: ZUFMS (0210, 0211, 0212, 0266, 0349, 0370); UNPUBLISHED RECORDS: Nayara F Carvalho (22°15' S, 54°48' W; 22°12' S, 54°56' W); Nicolay Cunha (19°07' S, 51°46' W; 21°30' S, 54°13' W); Carolina F Santos (19°31' S, 55°37' W).

Promops centralis – LITERATURE: Alho et al. 2011; ZUFMS (0021).

Promops nasutus – LITERATURE: Alho et al. 2011; ZUFMS (0039).

Pteronotus parnellii – LITERATURE: Coelho 2005, Bordignon 2006, Cunha et al. 2011; MUSEUM: ZUFMS (0232).

Pygoderma bilabiatum – LITERATURE: Zanon 2010, Eriksson et al. 2011.

Rhinophylla pumilio – LITERATURE: Coelho 2005.

Rhynchonycteris naso – LITERATURE: Camargo 2003; MUSEUM: ZUFMS (0234, 0260, 0261); UNPUBLISHED RECORDS: Nicolay Cunha (19°35' S, 56°15' W); Alan Eriksson (19°32' S, 56°08' W).

Sturnira lilium – LITERATURE: Pulchério-Leite et al. 1998, Coelho 2005, Bordignon 2006, Bordignon & França 2009, Camargo et al. 2009, Fernandes 2009, Longo 2009, Teixeira et al. 2009, Ferreira et al. 2010, Ortêncio-Filho et al. 2010, Zanon 2010, Alho et al. 2011, Eriksson et al. 2011, Oliveira et al. 2011, Munin et al. 2012; UNPUBLISHED RECORDS: Luiz F Carvalho, Nicolay Cunha, Carolina F Santos (19°13' S, 57°37' W); Nayara F Carvalho (22°13' S, 54°56' W; 22°04' S, 54°52' W); Nicolay Cunha (21°35' S, 54°14' W; 21°30' S e 54°13' W).

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Tonatia bidens – LITERATURE: Williams et al. 1995, Camargo 2003, Alho et al. 2011, Cunha et al. 2011.

Trachops cirrhosus – LITERATURE: Cunha et al. 2011.

Uroderma bilobatum – MUSEUM: ZUFMS (0132).

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Vampyrodes caraccioli – MUSEUM: ZUFMS (0129).

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inventory

The stream fish fauna from three regions of the Upper Paraná River basin

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Abstract: This study aimed to conduct an inventory of fish assemblages in small streams that are tributaries of large reservoirs in three previously unstudied regions of the Upper Paraná River basin. We sampled 117 streams from 1st to 3rd order in Araguari (Nova Ponte hydropower plant reservoir), Paranaíba (São Simão reservoir) and Grande (Volta Grande reservoir) drainages. In total, 20,696 specimens belonging to 100 species, 53 genera, 20 families and six orders were collected. Of these, 11,530 specimens and 41 species were recorded in Araguari, whereas 17 were exclusive to this drainage. In Grande drainage, 3,537 individuals belonging to 41 species (11 exclusive) and in Paranaíba, 5,629 specimens and 67 species (38 exclusive) were sampled. The mean richness per stream was 6.7 for Grande, 9.0 for Araguari and 10.9 for Paranaíba drainage. The predominant orders were Characiformes, 48% of the total richness, and Siluriformes, 36%. Three species were diagnosed as new: *Astyanax* sp. 1 (Grande and Paranaíba), *Astyanax* sp. 2 and *Astyanax* sp. 3 (both from Araguari), all from *scabripinnis* group. Another three were considered potentially new: *Characidium* sp. 1, *Characidium* sp. 2 and *Rhamdiopsis* sp. Among all records, eight species are not native from the Paraná basin: the exotics *Oreochromis niloticus* and *Tilapia rendalli* and the allochtonous *Cyphocharax gillii*, *Hoplerythrinus unitaeniatus, Knodus moenkhausii*, *Poecilia reticulata*, *Roeboides descalvadensis* and *Trichomycterus brasiliensis*. This study fills part of the existing knowledge gap about fish from small streams of the Paraná basin. Inventories of the fish fauna from these low-order water courses are important because they highlight their biodiversity relevance, including a significant number of unknown species. Thus, this study contributes to a better knowledge of the stream fish fauna of the upper Paraná River basin, as well as contribute to the establishment of strategies for conservation of this important component of aquatic biodiversity.

Keywords: *fish, species inventory, new species.*

FAGUNDES, D.C., LEAL, C.G., CARVALHO, D.R., JUNQUEIRA, N.T., LANGEANI, F., POMPEU, P.S. **A ictiofauna de riachos de três regiões do alto rio Paraná.** Biota Neotropica. 15(2): e20140187. http://dx.doi.org/10.1590/1676-06032015018714

Resumo: Este trabalho teve como objetivo realizar um inventário das assembleias de peixes em pequenos riachos afluentes de grandes reservatórios do alto rio Paraná, em três regiões até então desconhecidas pela literatura. Foram amostrados 117 riachos de 1ª a 3ª ordens nas bacias dos rios Araguari (na bacia de drenagem do reservatório de Nova Ponte), Paranaíba (reservatório de São Simão) e Grande (reservatório de Volta Grande). No total foram capturados 20.696 exemplares pertencentes a 100 espécies, seis ordens, 20 famílias e 53 gêneros. Destes, 11.530 exemplares e 41 espécies foram registradas na bacia do Araguari, sendo que 17 dessas espécies são exclusivas. Na bacia do rio Grande, foram registrados 3.537 exemplares pertencentes a 41 espécies (11 exclusivas) e na bacia do Paranaíba, foram registrados 5.629 exemplares e 67 espécies (38 exclusivas). A riqueza média por riacho foi de 6.7 para os riachos da bacia do rio Grande, 9.0 para os riachos da bacia do Araguari e 10.9 para os riachos da bacia do rio Paranaíba. As ordens predominantes foram Characiformes, com 48% da riqueza total e Siluriformes, com 36%. Três espécies pertencentes ao grupo *scabripinnis* foram diagnosticadas como novas: *Astyanax* sp. 1 (Grande e Paranaíba), *Astyanax* sp. 2 (Araguari) e *Astyanax* sp. 3 (Araguari). Outras três foram consideradas como potencialmente novas: *Characidium* sp. 1, *Characidium* sp. 2 e *Rhamdiopsis* sp. Entre todos os registros, oito espécies não são nativas da bacia do Paraná: as exóticas

Oreochromis niloticus e *Tilapia rendalli* e as alóctones *Cyphocharax gillii*, *Hoplerythrinus unitaeniatus, Knodus moenkhausii, Poecilia reticulata, Roeboides descalvadensis* e *Trichomycterus brasiliensis*. Este estudo preenche parte da lacuna de conhecimento existente sobre peixes de pequenos riachos da bacia do Paraná. Os inventários sobre a fauna de peixes em riachos de pequena ordem são importantes, pois evidenciam a ocorrência de grande diversidade, incluindo um número significativo de espécies ainda não descritas. Dessa forma, esse estudo contribui para um melhor conhecimento da fauna de peixes de riachos pertencentes à bacia do alto rio Paraná, além de colaborar para o estabelecimento de estratégias para conservação deste importante componente da biodiversidade aquática.

Palavras-chave: *peixes, inventário, espécie nova.*

Introduction

Vertebrates are represented by approximately 55,000 species of which more than 31,000 are fish (IUCN 2008; Froese & Pauly 2009; Eschmeyer & Fong 2010). Neotropical freshwater ecosystems encompass a great part of this diversity, namely 4,475 valid species and about other 1,550 yet to be described (Reis et al. 2003). Therefore this region is considered to have the most diverse freshwater fish fauna in the world (Junk 2007). Brazil covers most of the Neotropical region, and its' ichthyofauna hosts more than 3,000 freshwater species (Froese & Pauly 2014). This is due to, among other factors, the country's vast extension and complex hydrological network including some of the largest river drainages in the world.

The Paraná River basin is the second largest in drainage area in Brazil (Latrubesse et al. 2005). The upper portion of the basin is considered the best studied region in terms of its ichthyofauna, however this knowledge is still insufficient and several regions remain completely unknown. Therefore the present study aimed to present the results of an inventory conducted in small streams draining to three large reservoirs in the Upper Paraná, in areas thus far unstudied. The information presented here can be used to inform management and conservation strategies.

Materials and Methods

1. Study Area

The Upper Paraná River encompasses the Paraná River basin upstream the former Salto de Sete Quedas (Bonetto 1986). This portion of the basin represents 891.000 km^2 (10.5% of Brazil's total area) (Agostinho et al. 2003) and includes important tributaries such as the Araguari, Grande, Paranaíba, Paranapanema and Tietê, and the first three were included in the present study. The Araguari River is a left bank tributary of the Paranaíba River and has its headwaters in the Parque Nacional da Serra da Canastra, São Roque de Minas municipality, Minas Gerais state. This tributary is 475 km of length and covers 21, 856 km^2 of drainage area (Baccaro et al. 2004). The headwaters of the Grande River are in the Serra da Mantiqueira, Bocaina de Minas municipality. Approximately 86,500 km^2 of its total 143,000 km^2 drainage area is within Minas Gerais state limits. The Paranaíba has its headwaters in the Serra da Mata da Corda, 1,100 m above sea level and its drainage area encompasses 222,711 km^2, with ca 30% in Minas Gerais state. Together, the rivers Paranaíba and Grande form the Paraná River.

This study was carried out in 117 streams of 1^{st} to 3^{rd} order (according to Sthraler 1957) belonging to Araguari (38 streams), Paranaíba (39 streams) and Grande river (40 streams) drainages (Figure 1).

1.1. Fish Sampling and Identification. Stream sampling was carried out during the dry season, in September 2009 (Araguari), 2011 (Grande), 2012 (Paranaíba) and 2013 (resampling of Araguari streams). The length of each stream site sampled was 40 times its mean width, with a minimum length of 150 m (Kaufmann et al. 1999). Each stream was sampled for two hours by three people using mainly semicircular hand nets (80 cm of diameter, 1 mm of mesh size) and seines when possible (4 m long, 2 m high, 5 mm of mesh size). All catches were made during daylight hours. Specimens were killed in an anesthetic solution of clove oil and then fixed in 10% formalin. In the laboratory, all sampled fishes were transferred to 70° GL alcohol and identified to species level, by means of identification key (Graça & Pavanelli 2007) and expert (Francisco Langeani). Voucher specimens of all species are deposited at the following fish collections: Coleção de Ictiologia da Universidade Federal de Lavras (CIUFLA), Coleção do Departamento de Zoologia da Universidade Estadual Paulista, São José do Rio Preto campus (DZSJRP), Museu de Ciências e Tecnologia da PUCRS (MCP), Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu Paraense Emilio Goeldi (MPEG) and Coleção Ictiológica do Nupélia (NUP), Universidade Estadual de Maringá (Table 1).

Results and Discussion

In total we collected 20,696 specimens belonging to 100 species, 53 genus, 20 families and six orders. Araguari accounted for 11,530 specimens and 41 species whereas 17 species were exclusive to this drainage. Grande drainage was represented by 3,537 individuals belonging to 41 species (11 exclusive) and the Paranaíba by 5,629 specimens and 67 species (38 exclusive). Paranaíba showed the highest mean richness per stream, 10.9, followed by Araguari, 9.0 and Grande, 6.7 (Table 1)

Characiformes and Siluriformes orders represented the majority of the species richness, 48% and 36% respectively, reflecting a well known pattern recognized for South American rivers (Lowe-McConnell 1987). Langeani et al. (2007) recorded 310 species included in 11 orders for the Upper Paraná basin, with 80% represented by Characiformes and Siluriformes, a number similar to our findings. Likewise Alves et al. (2007) found a predominance of Characiformes (47%) and Siluriformes (32%) in the Minas Gerais portion of the Upper Paraná basin.

At the family level, the Characidae was the best represented in this study. Other studies also found the same pattern (Castro et al. 2003; 2004; Shibatta et al. 2007). The Characidae is one of the richest families among the Neotropical freshwater fish fauna (Reis et al. 2003), and present a wide range of feeding habits and habitat uses (Kavalco & Pazza 2007).

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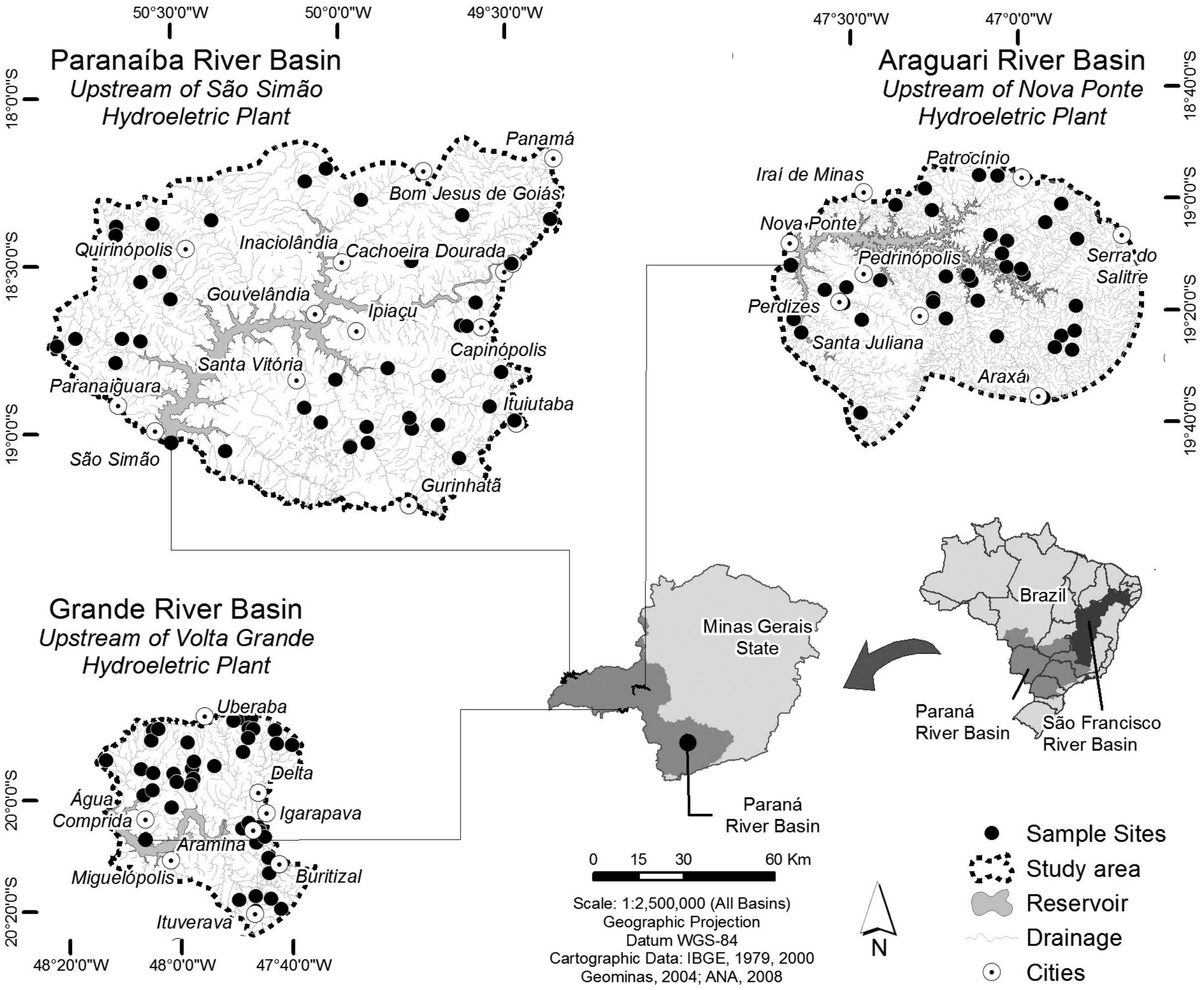

Figure 1. Map of the study area showing the location of the 117 streams in the Upper Paraná River basin.

The *Astyanax scabripinnis* group is particularly abundant and widespread in small streams in several Brazilian river basins (Bertaco & Lucena 2006), including the Upper Paraná River basin (Castro & Casatti 1997; Pavanelli & Caramaschi 1997). In the present study three species within the *scabripinnis* group were identified as probably new: *Astyanax* sp. 1 (Grande and Paranaíba), *Astyanax* sp. 2 (Araguari) and *Astyanax* sp. 3 (Araguari). Besides these, another three species were considered potentially new: *Characidium* sp. 1, *Characidium* sp. 2 e *Rhamdiopsis* sp.

Besides being a well studied region, the Upper Paraná still hosts several new species, some of them recently discovered and described. Langeani et al. (2007) listed 50 new species for the region, whereas 16 were formally described since then and another 34 await the same process (*Leporinus piavussu* Britski, Birindelli & Garavello 2012; *Astyanax bockmanni* Vari & Castro 2007; *Hemigrammus parana* Marinho, Carvalho, Langeani & Tatsumi 2008; *Characidium heirmostigmata* Graça & Pavanelli 2008; *Characidium xanthopterum* Silveira, Langeani, Graça, Pavanelli & Buckup 2008; *Apteronotus acidops* Triques 2011; *Gymnorhamphichthys britskii* Carvalho, Ramos & Albert 2011; *Rhinolekos britskii* Martins, Langeani & Britskii 2011; *Hypostomus multidens* Jerep, Shibatta & Zawadzki 2007; *Harttia absaberi* Oyakawa, Fichberg & Langeani 2013; *Neoplecostomus corumba* Zawadzki, Pavanelli & Langeani 2008; *Neoplecostomus selenae* Zawadzki, Pavanelli & Langeani 2008; *Neoplecostomus yapo* Zawadzki, Pavanelli & Langeani 2008; *Phalloceros harpagos* Lucinda 2008; *Phalloceros reisi* Lucinda 2008; *Laetacara araguaiae* Ottoni & Costa 2009). In addition to the new species mentioned by Langeani et al. (2007), another 29 were also described for the region (*Hyphessobrycon uaiso* Carvalho & Langeani 2013; Hyphessobrycon vinaceus Betarco, Malabarba & Dergam 2007; *Corumbataia britskii* Ferreira & Ribeiro 2007; *Hisonotus piracanjuba* Martins & Langeani 2012; *Microlepidogaster dimorpha* Martins & Langeani 2011; *Microlepidogaster arachas* Martins, Calegari & Langeani 2012; *Microlepidogaster longicolla* Calegari & Reis 2010; *Otothyropsis biamnicus* Calegari, Lehmann & Reis 2013; *Otothyropsis Polyodon* Calegari, Lehmann & Reis 2013; *Rhinolekos schaeferi* Martins & Langeani 2011; *Rhinolekos garavelloi* Martins & Langeani 2011; *Hypostomus denticulatus* Zawadzki, Weber & Pavanelli 2008; *Hypostomus heraldoi* Zawadzki, Weber & Pavanelli 2008; *Neoplecostomus bandeirante* Roxo, Oliveira & Zawadzki 2012; *Neoplecostomus botucatu* Roxo, Oliveira & Zawadzki 2012; *Neoplecostomus langeanii* Roxo, Oliveira & Zawadzki 2012; *Iheringichthys syi* Azpelicueta & Britskii 2012; *Trichomycterus perkos* Datovo, Carvalho & Ferrer 2012; *Trichomycterus pirabitira* Barbosa & Azevedo Santos 2012; *Trichomycterus piratymbara* Katz, Barbosa & Costa 2013; *Trichomycterus septemradiatus* Katz,

Table 1. Fish species sampled in Upper Paraná River basin streams. N = number of individuals, CI-UFLA = voucher specimens deposited at Coleção de Peixes da Universidade Federal de Lavras (UFLA), DZSJRP = Coleção do Departamento de Zoologia de São José do Rio Preto, MCP = Museu de Ciências e Tecnologia da PUCRS, MPEG = Museu Paraense Emilio Goeldi, MZUSP = Museu de Zoologia da Universidade de São Paulo, NUP = Coleção ictiológica do Nupélia. * = allochtonous species, ** = exotic species, *** = migratory species, **** = probably nem species, X = specimens that couldn't be deposited in a scientific collection because they were used in stable isotopes study, in this case they were identified through photos taken in the field.

TAXON (Catalog of Fishes)	**Upper Paraná River basin**			**Collection**	**Voucher**
CHARACIFORMES	**Araguari**	**Grande**	**Paranaíba**		
Acestrorhynchidade					
Acestrorhynchus lacustris (Lütken, 1875)	1	-	5	CIUFLA	0460/X
Anostomidae					
Leporinus friderici (Bloch, 1794) ***	-	-	1		X
Leporinus lacustris Amaral Campos, 1945	-	-	1		X
Leporinus microphthalmus Garavello, 1989	26	-	3	CIUFLA	0483/0841
Leporinus octofasciatus Steindachner, 1915	-	-	2	CIUFLA	0842
Leporinus paranensis Garavello & Britski, 1987	-	-	2	CIUFLA	0843
Leporinus piavussu Britski, Birindelli & Garavello, 2012	-	-	1		X
Leporinus striatus Kner, 1858	-	-	2	CIUFLA	0844
Characidae					
Aphyocharax dentatus Eigenmann & Kennedy, 1903	-	-	5		X
Astyanax altiparanae Garutti & Britski, 2000	44	29	95	CIUFLA	0464/0769/0749/0807
Astyanax bockmanni Vari & Castro, 2007	-	67	156	CIUFLA	0750/0808
Astyanax fasciatus (Cuvier, 1819)	31	18	315	CIUFLA	0770/0751/0809
Astyanax sp. 1****	-	838	192	CIUFLA	0752/0810
Astyanax sp. 2****	1002	-	-	CIUFLA	0463/0771
Astyanax sp. 3****	3347	-	-	CIUFLA	0465/0772
Bryconamericus cf. *stramineus* Eigenmann, 1908	-	1	-	CIUFLA	0881
Bryconamericus stramineus Eigenmann, 1908	5	12	4	CIUFLA	0467/0773/0754/0812
Bryconamericus turiuba Langeani, Lucena, Pedrini & Tarelho-Pereira, 2005	61	110	-	CIUFLA	0774/0755
Brycon orbignyanus (Valenciennes, 1850) ***	-	3	1	CIUFLA	0753/0811
Glandulocaudinae sp.	1	-	-	MZUSP	114314
Hasemania sp.	2	-	32	CIUFLA	0783/822
Hemigrammus parana Marinho, Carvalho, Langeani & Tatsumi, 2008	308	-	-	CIUFLA	0784
Hyphessobrycon eques (Steindachner, 1882)	-	-	8	CIUFLA	0826
Knodus moenkhausii (Eigenmann & Kennedy, 1903) *	528	18	2517	CIUFLA CIUFLA	0481/0789/ 0734/0839
Moenkhausia intermedia Eigenmann, 1908	-	-	1	CIUFLA	0845
Moenkhausia sanctaefilomenae (Steindachner, 1907)	-	-	14	CIUFLA	0846
Oligosarcus cf. *planaltinae*	6	-	-	CIUFLA	0486/0792
Oligosarcus pintoi Amaral Campos, 1945	-	17	-	CIUFLA	0736
Piabina argentea Reinhardt, 1867	142	24	145	CIUFLA DZSJRP	0489/0795/0738/0849 20030/20031
Roeboides descalvadensis Fowler, 1932*	-	-	5	CIUFLA	0855
Serrapinus sp. 1	-	-	40	CIUFLA DZSJRP	0861 18692/18696
Serrapinus sp. 2	-	-	127	CIUFLA DZSJRP	0862 18709
Triportheus nematurus (Kner, 1858)	-	-	12	CIUFLA	0858
Crenuchidae					
Characidium cf. *zebra* Eigenmann, 1909	4	-	-	CIUFLA	0776
Characidium gomesi Travassos, 1956	30	41	45	CIUFLA	0777/0757/0814
Characidium sp. 1****	-	76	-	CIUFLA	0863
Characidium sp. 2****	141	-	-	CIUFLA	0469/0778
Characidium xanthopterum Silveira, Langeani, da Graça, Pavanelli & Buckup, 2008	20	-	-	CIUFLA	0471

Continued on next page

Table 1. Continued.

TAXON (Catalog of Fishes)	**Upper Paraná River basin**			**Collection**	**Voucher**
CHARACIFORMES	**Araguari**	**Grande**	**Paranaíba**		
Characidium zebra Eigenmann, 1909	-	-	306	CIUFLA	0815
Curimatidae					
Cyphocharax gilli Eigenmann & Kennedy, 1903*	-	-	4		X
Steindachnerina insculpta (Fernández-Yépez, 1948)	-	-	10	CIUFLA	0856
Erythrinidae					
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)*	-	1	-	CIUFLA	0766
Hoplias aff. *malabaricus* (Bloch, 1794)	6	-	1	CIUFLA	0476/0785/0825
Hoplias intermedius (Günther, 1864)	3	3	3	CIUFLA	0475/0763/0824
Lebiasinidae					
Pyrrhulina australis Eigenmann & Kennedy, 1903	-	12	4	CIUFLA	0740/0852
Parodontidade					
Apareiodon cf. *piracicabae* Eigenmann, 1907	-	-	5	CIUFLA	0804
Apareiodon ibitiensis Amaral Campos, 1944	158	32	119	CIUFLA	0461/0768/0747/0805
Parodon nasus Kner, 1859	6	-	-	CIUFLA	0487/0793
CYPRINODONTIFORMES					
Poeciliidae					
Phalloceros harpagos Lucinda, 2008	2017	2	-	CIUFLA	0488/0794/0737
Poecilia reticulata Peters, 1859*	43	532	112	CIUFLA	0490/0796/0739/0851
Rivulidae					
Rivulus apiamici Costa, 1989	-	-	11	CIUFLA	0854
GYMNOTIFORMES					
Gymnotidae					
Gymnotus carapo Linnaeus, 1758	-	-	1	CIUFLA	0820
Gymnotus cf. *inaequilabiatus* Valenciennes, 1839	-	1	-	CIUFLA	0760
Gymnotus sylvius Albert & Fernandes-Matioli, 1999	16	16	3	CIUFLA	0474/0782/0761/0821
Sternopygidae					
Eigenmannia trilineata López & Castello, 1966	-	-	7	CIUFLA	0818
Eigenmannia virescens (Valenciennes, 1836)	-	-	3	CIUFLA	0819
Sternopygus macrurus (Bloch & Schneider, 1801)	-	-	1		X
PERCIFORMES					
Cichlidae					
Cichlasoma paranaense Kullander, 1983	9	2	10	CIUFLA	0779/0765/0816
Crenicichla jaguarensis Haseman, 1911	-	-	2	CIUFLA	0817
Geophagus brasiliensis (Quoy & Gaimard, 1824)	47	13	-	CIUFLA	0473/0781/0759
Laetacara araguaiae Ottoni & Costa, 2009	-	-	29	CIUFLA	0840
Oreochromis niloticus (Linnaeus, 1758) **	-	-	81	CIUFLA	0847
Tilapia rendalli (Boulenger, 1897) **	-	1	-	CIUFLA	0744
SILURIFORMES					
Auchenipteridae					
Tatia neivai (Ihering, 1930)	-	1	1	CIUFLA	0764/X
Callichthydae					
Aspidoras fuscoguttatus Nijssen & Isbrücker, 1976	-	22	208	CIUFLA	0748/0806
Corydoras difluviatilis Britto & Castro, 2002	70	2	-	CIUFLA	0472/0780/0758
Cetopsidae					
Cetopsis gobioides Kner, 1858	-	-	1		X
Heptapteridae					
Cetopsorhamdia iheringi Schubart & Gomes, 1959	45	60	20	CIUFLA	0468/0775/0756/0813
Imparfinis borodini Mees & Cala, 1989	-	3	7	CIUFLA	0732/0836
Imparfinis cf. *schubarti* Gomes, 1956	-	-	2	CIUFLA	0837
Imparfinis longicauda (Borodin, 1927)	-	-	5		X
Imparfinis schubarti (Gomes, 1956)	3	11	65	CIUFLA	0480/0788/0733/0838
Phenacorhamdia cf. *unifasciata* Britiski, 1996	-	-	8	CIUFLA	0848
Pimelodella gracilis (Valenciennes, 1835)	-	-	36	CIUFLA	0850
Rhamdia quelen (Quoy & Gaimard, 1824)	37	44	21	CIUFLA	0491/0797/0741/0853
Rhamdiopsis sp. ****	72	13	-	CIUFLA	0479/0798/0742

Continued on next page

Table 1. Continued.

TAXON (Catalog of Fishes)	**Upper Paraná River basin**			**Collection**	**Voucher**
CHARACIFORMES	**Araguari**	**Grande**	**Paranaíba**		
Loricariidae					
Hisonotus piracanjuba Martins & Langeani, 2012	-	-	183	CIUFLA	0823
Hisonotus francirochai (Ihering, 1928)	-	98	-	CIUFLA	0762
				MUP	48252/48253/48254/48255/48256/48257/48258/48259
Hypostomus aff. *nigromaculatus* Schubart, 1964	-	235	89	CIUFLA	0864/0834
				NUP	16115/16117/16126/16130/16132
Hypostomus ancistroides (Ihering, 1911)	-	499	59	CIUFLA	0865/0827
				NUP	16426/16427/16428/16429/ 16430/16431/16432/16434/16435/16436/16437/16438
Hypostomus cf. *paulinus* Ihering, 1905	-	-	56	CIUFLA	0828
Hypostomus cf. *topavae* Godoy, 1969	-	-	45	CIUFLA	0829
Hypostomus nigromaculatus (Schubart, 1964)	-	198	-	NUP	16112/16113/16114/16116/16118/16124/16128/16129/16131/16134/16135/16136
Hypostomus sp. 1	741	-	-	CIUFLA	0477/0786
Hypostomus sp. 2	109	-	-	CIUFLA	0478/0787
Hypostomus sp. 3	-	-	82	CIUFLA	0830
Hypostomus sp. 4	-	-	148	CIUFLA	0831
Hypostomus sp. 5	-	-	94	CIUFLA	0832
Hypostomus sp. 6	-	-	26	CIUFLA	0833
Hypostomus strigaticeps (Regan, 1908)	-	6	26	CIUFLA	0835
				NUP	16123/16127/16133/16433
Microlepidogaster arachas Martins, Calegari & Langeani, 2013	512	-	-	CIUFLA	0484/0790
Neoplecostomus paranensis Langeani, 1990	-	13	-	CIUFLA	0735
Neoplecostomus sp.	79	-	-	CIUFLA	0485/0791
Trichomycteridae					
Trichomycterus aff. *brasiliensis* Lütken, 1874	-	176	-	CIUFLA	0745
				MPEG	24986
Trichomycterus brasiliensis Lütken, 1874*	258	-	-	CIUFLA	0800
Trichomycterus candidus (Miranda Ribeiro, 1949)	-	284	-	CIUFLA	0746
				MPEG	24979
Trichomycterus sp. 1	1418	-	-	CIUFLA	0493/0801
Trichomycterus sp. 2	177	-	-	CIUFLA	0732/0802
Trichomycterus sp. 3	2	-	-	CIUFLA	0803
SYNBRANCHIFORMES					
Synbranchidae					
Synbranchus marmoratus Bloch, 1795	3	3	4	CIUFLA	0492/0799/0743/0857
Total abundance	11530	3537	5629		
Total richness	41	41	67		
Mean richness per stream	8.97	6.73	10.85		
Exclusive species	17	11	38		

Barbosa & Costa 2013; *Pituna brevirostrata* Costa 2007; *Melanorivulus faucireticulatus* Costa 2007; *Melanorivulus illuminatus* Costa 2007; *Rivulus giarettai* Costa 2008; *Rivulus formosensis* Costa 2008; *Simpsonichthys margaritatus* Costa 2011; *Simpsonichthys nigromaculatus* Costa 2007; *Australoheros tavaresi* Ottoni 2012 and Pimelodus britskii Garavello & Shibatta 2007.

Among all recorded species, six are considered allochtonous, *i.e.* native to other Neotropical river basins and introduced in the upper Paraná basin. Of these six species, *Cyphocharax gillii* and *Roeboides descalvadensis* were collected only in the Paranaíba basin, *Hoplerythrinus unitaeniatus* in the Grande basin and *Trichomycterus brasiliensis* in Araguari basin. On the other hand *Poecilia reticulata* and *Knodus moenkhausii* occurred in each of the drainages. The most abundant allochtonous species, *K. moenkhausii* (especially in the Paranaíba basin) is an opportunistic species that invests much of its energy in reproduction and colonize several environments, including the most degraded (Ceneviva-Bastos & Casatti 2007). *Poecilia reticulata* (the second most abundant allochthonous species) is native to northwestern America (Bisazza 1993) and has been introduced in several regions of the world because of its potential for mosquito control (Araújo et al. 2009). This species also has great ability to increase its population in harsh environments, and is therefore indicative of poor water quality (Araújo 1983).

The two exotic species (i.e. native to other continents) recorded in our study area, *Oreochromis niloticus* and *Tilapia rendalli* occurred only in one of the studied drainages each, Grande and Paranaíba respectively. Both species are of medium size and have great commercial value, which probably motivated their introduction. *Oreochromis niloticus* is native to the Nile River basin, East Africa but is largely introduced in tropical and subtropical regions (Carvalho 2006). It was first introduced in northeast Brazil in the 1970s, through the Departamento Nacional de Obras Contra a Seca (DNOCS), and subsequently spread throughout the whole country (Castagnolli 1996). It is classified as a pest and its introduction has a well known negative impact to the aquatic ecosystems (Froese & Pauly 2010).

Two migratory species were recorded, *Brycon orbignyanus* (piracanjuba) and *Leporinus friderici* (piau-três-pintas), both represented by few individuals. Migratory species in the adult stage are mostly residents of larger streams or rivers, being occasionally found in these low-order streams when in their young stage (Pompeu & Godinho 2003). *Brycon orbignyanus* is considered endangered in Minas Gerais state, according to the IUCN Red Data List (Machado et al 2005; Alves et al 2007), due to habitat degradation especially driven by clearance of the riparian vegetation, pollution and construction of hydropower plants (Santos 2010).

This study fills part of the knowledge gap about fish from small streams of the Paraná basin by presenting the species list of regions unstudied until this moment. Inventories of the fish fauna from these low-order water courses are important because they highlight their biodiversity relevance, including a significant number of new species. As such, our findings can help inform future conservation and/or management strategies in the studied landscape.

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short communication

Effect of temperature on the life cycle of *Acanthagrion* Selys, 1876 (Insecta: Coenagrionidae) under artificial conditions

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Abstract: The goal of this study was to investigate the effect of temperature on the life cycle of *Acanthagrion* nymphs sampled in a stream in the southern state of Amazonas. Altogether, 50 nymphs (10 in each of the five treatments) with ambient temperatures of 16, 20, 24, 28 and 32°C and water temperatures of 18, 22, 26, 30 and 34°C, respectively, were used. The only treatment that had a hatching adult was at a temperature of 28°C, identified in a single species, *Acanthagrion apicale*. In all other treatments (16, 20, 24 and 32°C), all nymphs died, respectively 1, 1, 3 and 2 days. We conclude from the results of this study that controlling water temperature near 28°C was the most efficient for obtaining adult *A. apicale,* and that this temperature was close to the average temperature where the nymphs were sampled, indicating that the control of this variable in artificial conditions is extremely important to obtain adults from nymphs.

Keywords: *Insecta, nymphs, temperature.*

FULAN, J.A., ANJOS, M.R., MACHADO, N.G. **Efeito da temperatura sobre o ciclo de vida de Acanthagrion Selys, 1876 (Insecta: Coenagrionidae).** Biota Neotropica. 15(2): e20140169. http://dx.doi.org/10.1590/1676-06032015016914

Resumo: O objetivo deste trabalho foi investigar o efeito da temperatura sobre o ciclo de vida das ninfas de *Acanthagrion* amostradas em um igarapé no sul do estado do Amazonas. Ao todo foram utilizadas 50 ninfas (10 em cada um dos cinco tratamentos) com temperaturas ambiente de 16, 20, 24, 28 e 32°C e temperaturas da água de 18, 22, 26, 30 e 34°C, respectivamente. O único tratamento em que houve a eclosão do adulto foi à temperatura de 28°C e foi identificada uma única espécie *Acanthagrion apicale*. Em todos os outros tratamentos (16, 20, 24 e 32°C) todas as ninfas morreram, respectivamente, em 1, 1, 3 e 2 dias. Concluímos a partir dos resultados deste estudo que o controle de temperatura da água próximo a 28°C foi o mais eficiente para obtenção do adulto de *A. apicale* e que esta temperatura ficou próxima da temperatura média do local onde as ninfas foram amostradas indicando que o controle desta variável em condições artificiais é extremamente importante para a obtenção dos adultos a partir das ninfas.

Palavras-chave: *Insecta, ninfas, temperatura.*

Introduction

Studies involving Odonata have become very common in recent years (Corbet 1999). Odonata are commonly observed in aquatic ecosystems, however, the rearing of nymphs in the laboratory allows researchers to control environmental variables such as temperature, which is difficult to monitor in natural conditions (Locklin et al. 2012).

The effect of temperature on Odonata is well known (Hassall & Thompson 2008). The temperature limits their distribution and also changes their behavior (Corbet 1999). Some Odonata species exhibit temperature adaptations and are able to maintain their temperature constant, in comparison to the environment, showing certain endothermic regulation (May 1976).

Laboratory experiments conducted at constant temperatures showed success in the rearing of *Anax junius* (Drury 1770) nymphs (Trottier 1971). The rearing of Odonata nymphs in laboratory experiments is essential to obtain adults and species identification. In Brazil, there are very few studies involving the life cycles of species, especially in Amazonas species.

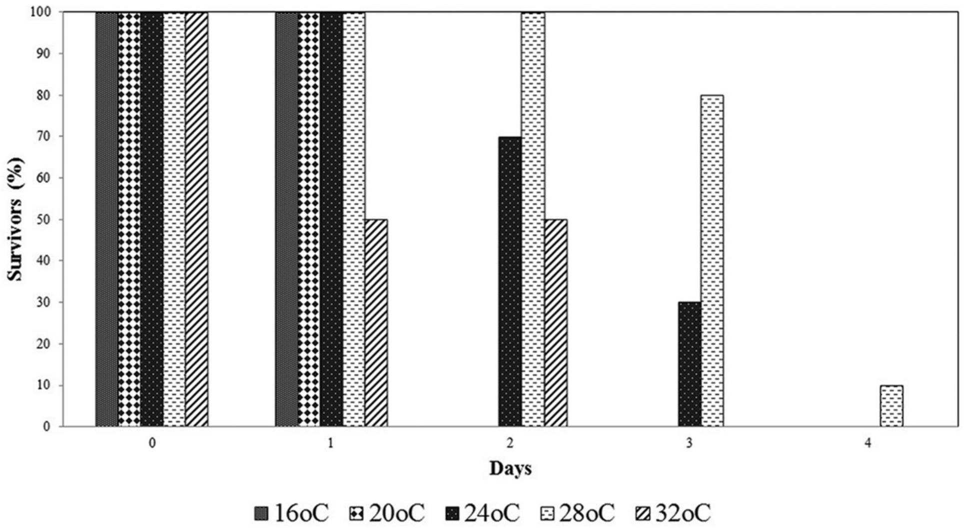

Figure 1.

The objective of this study was to investigate the effects of the temperature on the life cycle of *Acanthagrion* Selys 1876 reared in laboratory conditions in order to identify the most suitable temperature for the attainment of adults, thereby increasing efficiency in the creation of the nymphs.

Material and Methods

All nymphs were obtained from the root of aquatic plant *Eichhornia azurea* (Sw.) from July 2013 to August 2013 in a creek in Humaitá, Amazonas State, Brazil (07°31'06"S and 63°00'58"W). Ten nymphs in the penultimate or final instar were used in the experiment in each treatment. The nymphs were fed exclusively on Chironomidae (Diptera). *Acanthagrion* nymphs were grown in plastic trays (30x20x7.5cm) covered by a screen of 0.25 mm and 2 cm of water. Ten trays were used for each treatment and each tray had only one *Acanthagrion* nymph per tray to prevent intraspecific predation. Five treatments were performed in the laboratory with external temperatures of 18, 22, 26, 30 and 34°C.

Results

The average water temperatures in the sites sampled were about 16, 20, 24, 28 and 32°C, and the external temperatures (laboratory) of 18, 22, 26, 30 and 34°C, respectively. The results were discussed in relation to water temperature because this is where the larvae come into direct contact. The only treatment which had the emergence of the adult was at a temperature of 28 C. It was at this temperature that the only adult species, *Acanthagrion apicale* Selys, 1876 was obtained. In all other treatments (16, 20, 24 and 32^{o}C), all nymphs died, respectively 1, 1, 3 and 2 days (Fig. 1).

Discussion

Low water temperatures may increase stress during the development of Odonata nymphs (Chang et al. 2007, Thompson & Hassall 2008). In this work, when we analyzed the water temperature in the different treatments, a higher mortality rate of the *Acanthagrion* nymphs was recorded in temperatures of 16 and 20°C water, showing that warmer temperatures had a negative effect on their life cycle. On the other hand, the higher water temperatures of 32°C in the treatment was also responsible for the death of 100 % of nymphs between the 2nd and 3rd days of the experiment. The negative effect of increased temperature on the physiology of the Odonata nymph as its life cycle, the rate of development of nymphs and its immune system is recognized (Hassall & Thompson 2008). *Acanthagrion* nymphs were sampled in a stream in southern Amazonas where the ambient temperature can reach over 40°C. The water temperature at the sampling nymph site, along with macrophytes, was never higher than 30°C, with an average holding temperature of 28,3°C. Therefore, we must consider that natural environmental refuge conditions, enabled by macrophytes or a high diversity of prey, among other factors, cannot be reproduced in the laboratory. It's important to emphasize that obtaining the only adult in the experiment was in water temperatures of 28°C, which is very close to the average water temperature (28,3°C) where the nymphs were obtained. This result shows the importance of measuring the local temperature where the nymphs are sampled to have success in the creation and acquisition of adult insects. Locklin et al. (2012) succeeded in obtaining *Ischnura ramburii* (Selys) nymphs from adults in an average temperature of 25.4°C. *I. ramburii*, as well as *Acanthagrion,* belong to the same Coenagrionidae family, so at least in artificial conditions, temperatures of 25°C to 28°C seem to be important to complete the life cycle of at least these two genres. However, it is also necessary to consider that the 50 *Acanthagrion* nymphs used in this experiment may be of different species. Unfortunately, it is not possible to identify the species from nymphs, so it is possible that other nymphs of the same genus have different environmental needs which, unfortunately, could not be detected because in this experiment we were only able to identify a single species, *A. apicale*. The nymphs that died during the experiment could not be identified to species level.

We conclude from the results of this study that controlling water temperature to near 28°C was the most efficient for obtaining adult *A. apicale* and that this temperature was close to the average temperature where the nymphs were sampled, indicating that the control of this variable in artificial conditions is extremely important to obtain adults from nymphs.

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Land use change in the Atlantic Forest affects carbon and nitrogen sources of streams as revealed by the isotopic composition of terrestrial invertebrates

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AUGUSTO, F.G., TASSONI FILHO, M., FERREIRA, A., PEREIRA, A.L., CAMARGO, P.B., MARTINELLI, L.A. **Land use change in the Atlantic Forest affects carbon and nitrogen sources of streams as revealed by the isotopic composition of terrestrial invertebrates.** Biota Neotropica. 15(2): e20140188. http://dx.doi.org/10.1590/1676-06032015018814

Abstract: Terrestrial invertebrates link terrestrial systems to aquatic ones, making vegetal material produced in the watershed available to aquatic food webs. In this study, using carbon and nitrogen stable isotopes, we evaluated the importance of introduced C_4 grasses as a source of carbon in aquatic food webs of headwater streams of the coastal Atlantic Forest located on the north coast of the State of São Paulo, in the southeastern region of Brazil. Terrestrial invertebrates were collected in two streams: one where the main land cover was pristine montane Atlantic Forest (forest stream) and another where the main land cover was introduced C_4 forage grasses for livestock (pasture stream). The average $\delta^{13}C$ of terrestrial invertebrates collected in the forest stream ($-26.3 \pm 2.1‰$) was significantly ($p < 0.01$) smaller than the average $\delta^{13}C$ of terrestrial invertebrates collected in the pasture stream ($-15.7 \pm 4.7‰$), denoting a larger contribution of C_4 grasses to terrestrial invertebrates of the pasture stream. The average $\delta^{15}N$ of terrestrial invertebrates of the forest stream ($4.1 \pm 2.4‰$) was significantly ($p < 0.01$) lower than the average $\delta^{15}N$ of terrestrial invertebrates of the pasture stream ($9.5 \pm 2.7‰$). The relative contribution of C_3 and C_4 plants to terrestrial invertebrates was estimated using SIAR. In the forest stream, the C_3 contribution was on average 0.75 (0.72 minimum to 0.79 maximum), and the C_4 contribution was on average 0.25 (0.21 minimum to 0.28 maximum). In the pasture stream, the C_3 contribution decreased to 0.20 (0.14 minimum to 0.26 maximum), and the C_4 contribution increased to 0.80 (0.74 minimum to 0.86 maximum). These results have several implications for the ecosystem functioning as well as for recent changes in environmental policies of Brazil. The lower nutritional value of C_4 grasses may not only decrease invertebrate performance, but also alter the stoichiometry of several components of the aquatic food webs with potential consequence for the whole ecosystem functioning. On the public policy side, recent changes in the Brazilian Forest Act, a series of laws that regulate land cover at the property level, reduced the width of the forested riparian area with potentially dangerous consequences for aquatic ecosystems.

Keywords: *Atlantic Forest, land use, streams, stable isotopes, terrestrial invertebrate.*

AUGUSTO, F.G., TASSONI FILHO, M., FERREIRA, A., PEREIRA, A.L., CAMARGO, P.B., MARTINELLI, L.A. **Mudanças no uso do solo na Mata Atlântica afetam fontes de carbono e nitrogênio em riachos como é revelado através da composição isotópica dos invertebrados terrestres.** Biota Neotropica. 15(2): e20140188. http://dx.doi.org/10.1590/1676-06032015018814

Resumo: Os invertebrados terrestres constituem uma importante ligação entre os sistemas aquáticos e terrestres, disponibilizando o material vegetal produzido no entorno de riachos para as cadeias aquáticas. Nesse estudo, usando isótopos estáveis de carbono e nitrogênio, investigamos a introdução de plantas C_4 como fonte de energia em cadeias alimentares aquáticas em riachos de cabeceira da Mata Atlântica, na costa norte do Estado de São Paulo, região sudeste do Brasil. Os invertebrados foram amostrados em dois riachos: um com cobertura de solo predominante de Floresta Atlântica Montana (riacho da floresta) e outro em que foram introduzidas gramíneas forrageiras para criação de gado (riacho da pastagem). A média dos valores de $\delta^{13}C$ para os invertebrados terrestres coletados no riacho de floresta ($-26,3 \pm 2,1‰$) foi significativamente (p < 0,01) menor que a média dos invertebrados coletados na pastagem (– 15,7 ± 4,7‰), indicando uma maior contribuição de C_4 para os invertebrados terrestres do riacho de pastagem. A média do $\delta^{15}N$ para os invertebrados do riacho da floresta (4,1 ± 2,4‰) foi significativamente (p < 0,01) menor do que a média dos invertebrados na pastagem (9,5 ± 2,7‰). A contribuição relativa de plantas C_3 e C_4 para os invertebrados terrestres foi estimada usando SIAR. No riacho de floresta, a contribuição de C_3 foi em média 0,75 (mínimo de 0,72 e máximo de 0,79) e a contribuição de C_4 foi em média 0,25 (mínimo de 0,21 e máximo de 0,28). No riacho de pastagem, a contribuição C_3 diminuiu para 0,20 (mínimo de 0,14 e máximo de 0,26) e a contribuição C_4 aumentou para 0,80 (mínimo de 0,74 e máximo de 0,86). Esses resultados têm várias implicações para o funcionamento dos ecossistemas, bem como para as mudanças recentes nas políticas ambientais do Brasil. O baixo valor nutricional de gramíneas C_4 pode não só reduzir o desempenho de invertebrados, mas também alterar a estequiometria de vários componentes das cadeias alimentares aquáticas com potencial consequência para todo o funcionamento do ecossistema. Do lado da política pública, as recentes mudanças no Código Florestal brasileiro, uma série de leis que regulam a cobertura da terra no nível da propriedade, reduziu a largura da área de floresta ripária com consequências potencialmente perigosas para os ecossistemas aquáticos.

Palavras-chave: *Mata Atlântica, uso do solo, riachos, isótopos estáveis, invertebrados terrestres.*

Introduction

The coastal Atlantic Forest of Brazil is concentrated mainly in the *Serra do Mar*, and runs parallel to the Brazilian coast for almost 1.000 km from Rio de Janeiro State in the north to Santa Catarina State in the south (Myers et al. 2000, Oyakawa et al. 2006). This biome is one of the richest in terms of number of plants and animals species, considered a hotspot of biodiversity (Myers et al. 2000**)**.

Such richness of life did not prevent its displacement by croplands nor did it prevent unplanned urban sprawl (Monteiro & Kaz 1991/92, Oyakawa et al. 2006, Ribeiro et al. 2009). Currently, only 12% of the 1.5 million km^2 of the original Atlantic Forest remains intact (Ribeiro et al. 2009). Such changes in land use affect not only the structure and functioning of terrestrial ecosystems (Allan 2004), but also affects such characteristics of streams and rivers (Villela et al. 2002, Vanni 2002, Cross et al. 2005, Bukovinszky et al. 2008). There are several studies showing how land use changes affects the whole food web, from insects and benthonic macroinvertebrates (Ometto et al. 2000, Suriano et al. 2011, Colzani et al. 2013, Ligeiro et al. 2013) to fish species (Casatti et al. 2009, Alexandre et al. 2010).

Among lotic systems, the first order streams located in headwaters are the first link between the aquatic and terrestrial environments (Peterson et al. 2001). In these streams the food web encompasses a mixture of autochthonous and allochthonous sources (Pusey & Arthington 2003). In such conditions, Riparian terrestrial ecosystem is an important source of organic matter (e.g. plant material, terrestrial invertebrates) for aquatic communities (Kawaguchi & Nakano 2001, Pusey& Arthington 2003, Barreto & Aranha 2006, Casatti et al. 2009, Teresa & Casatti 2013).

In watersheds, riparian areas assume a very important role as a source of food to lotics systems, especially in headwater streams (Naiman & De' camps 1997, Ward 1998, Fisher et al. 1998, Helfield & Naiman 2001, Pusey & Arthington 2003, Casatti et al. 2012). Despite this importance, the displacement of riparian forests by monoculture and pasture for cattle is one of the main environmental problems in the Atlantic Forest biome (Silva et al. 2007). In Brazil, cultivated C_4-grasses cover approximately 200 million ha (Lapola et al. 2013), and in São Paulo State more than 70% of riparian forests were replaced by C_4-grasses (Silva et al. 2007).

Catford et al. (2013) suggested that climate change would facilitate the invasion of non-indigenous C_4 plants in tropical areas. Dominance of C_4 plants in future land use scenarios is especially important because it can have several ecological effects on tropical ecosystems (see Williams & Baruch 2000 for a review). Particularly important to this study is the lower nutritional quality of C_4 grasses compared with C_3 plants due to the lower level of nutrients, higher fiber contents, and higher leaf toughness (Scheirs et al. 2001, Ehleringer et al. 2002, Clapcott & Bunn 2003, Barbehenn et al. 2004). However, despite these nutritional limitations, it was shown that some insect species are well adapted to grass feeding (Barbehenn 2005). In aquatic food webs, it has been shown that the importance of C_4 grasses seems to depend on the local conditions. For instance, C_4 grass was an important component in small river food webs of the Piracicaba River Basin, located in the southeastern region of Brazil (Ferreira et al. 2012). On the other hand, it seems that C_4 grasses were less important as energy source in large tropical and sub-tropical watersheds of the Paraná River (Manetta et al. 2003, Hoeinghaus et al. 2007), and Amazon River (Araújo-Lima et al. 1986, Forsberg et al. 1993, Oliveira et al. 2006), nor were they important in sub-tropical and tropical watersheds of Australia (Clapcott & Bunn 2003, Bunn et al. 2007).

Based on the discussion above, the main objective of this study was to evaluate the transport of exotic C_4 forage grasses by terrestrial invertebrate to aquatic food webs of headwater streams of the coastal Atlantic Forest. In order to achieve this objective we collected terrestrial invertebrates from two watersheds; one where the dominant cover was Montane Atlantic Forest, and other where the dominant cover, especially in the riparian zone, was C_4 forage grasses.

We analyzed the carbon and nitrogen stable isotopic composition of the terrestrial invertebrates to determine the contribution of C_4 grasses to the aquatic food web. The carbon stable isotopic composition of C_4 grasses is distinct from plants that follow the C_3 photosynthetic pathway (Farquhar et al. 1989). This fact opens up the possibility of using carbon stable isotopic composition to track the fate of terrestrial C_4 grasses in aquatic food webs (Bunn et al. 1997).

Material and Methods

1. Study area

Two headwater streams were selected for this study. The Ombrophyllus Dense Montane Forest (Velloso et al. 1991) dominates the watershed of the stream located in the branch

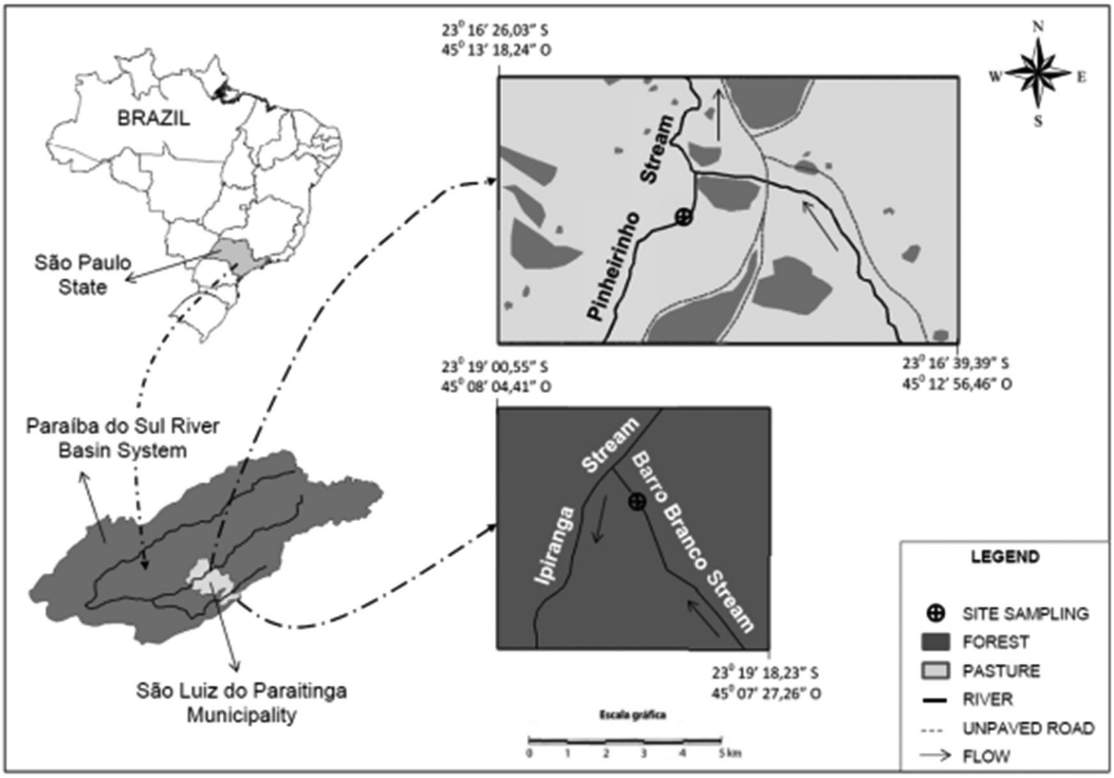

Figure 1. Study area showing the location of the *pasture* stream (Pinheirinho) and *forest* stream (Barro Branco).

Santa Virgínia of the State Park of Serra do Mar, hereafter referred to as "forested stream" (Figure 1). The other stream is dominated by pastures composed mainly of C_4 grasses of the genus *Brachiaria* and is located approximately 30 km from the forested stream, hereafter referred to as "pasture stream" (Figure 1). The annual precipitation of the area is approximately 2.300 mm and the average annual temperature is 16°C. This low average temperature for a sub-tropical area is due to the high elevation of the watersheds, approximately 1.000 m above sea level (Sousa Neto et al. 2008).

2. Sampling

Terrestrial invertebrates were collected in the beginning of the dry season (April of 2009) after the end of the heavy summer rains. Twenty-five floating plastic trays (pan traps) were randomly deployed on the water surface of the streams along a 150 m reach. The pan traps were filled with a mixture of water and 70% alcohol. The sampled invertebrates were fixed in 70% alcohol and transported to the laboratory where they were identified according to order and morph types. After identification, samples were dried at 60°C for 48 hours and sent to analysis. Aquatic insect adults (Ephemeroptera and Trichoptera) were excluded from analyses of the pan trap samples, since our primary focus was on terrestrial invertebrates as allochthonous sources to the streams. Odonatas were included because according to Corbet (1962) the adults phases vary from a few days to months, therefore due to this extended living period it is possible that Odonatas contributes to river and streams trophic chains by transferring carbon from the terrestrial to aquatic systems.

We are aware that the use of alcohol to fix the invertebrates may alter their stable carbon isotopic composition (Ruiz-Cooley et al. 2011, Syväranta et al. 2011, Xu et al. 2011). Additionally, it is difficult to make any correction in this alteration due to its variability; some studies show an increase in the stable carbon isotopic composition, while others show the opposite. However, in general these changes due to the alcohol use are minor, on the order of less than 1‰ (Ruiz-Cooley et al. 2011, Syväranta et al. 2011, Xu et al. 2011), and since in this study we are investigating the use of C_4 and C_3 plants by these animals that have great differences in their stable carbon isotopic composition (more than 10‰) we believe that any alteration due to the alcohol will not affect the main conclusions of this study.

3. Isotopic analysis

Dried samples were crushed to a fine powder and homogenized. Depending on the sample, 0.8 to 2.5 mg of material was encapsulated, and carbon and nitrogen content as well their isotopic composition were determined by combustion an Elemental Analyzer (Carlo Erba, CHN-1100) coupled with a mass spectrometer Thermo Finningan Delta Plus at the Laboratory of Isotope Ecology of CENA-University of São Paulo. The analytical error obtained by the analysis of internal standards was 0.3‰ and 0.5‰ for carbon and nitrogen, respectively. Results were expressed in the classical delta (δ) per mil notation defined as:

$$\delta = (R_{sample}/R_{standard} - 1) \times 1000$$

Where R_{sample} and $R_{standard}$ is the ratio of ^{13}C:^{12}C or ^{15}N:^{14}N of the sample and standard, respectively. The standard for carbon is the Vienna PDB and for nitrogen, the standard is the atmospheric air.

Table 1. Mean and standard deviation (Stdev) of δ^{13}C and δ^{15}N values of order of terrestrial invertebrates collected from floating trays on a forest stream. N denotes the number of samples, and Total denotes the overall mean and standard deviation.

Order	N.	δ^{13}C Mean	Stdev	δ^{15}N Mean	Stdev
Aranae	1	−26.2		4.4	
Coleoptera	4	−25.3	1.7	3.8	1.5
Collembola	3	−25.7	0.8	2.0	0.8
Diptera	44	−26.5	2.4	4.7	2.3
Hemiptera	3	−25.5	1.1	3.0	3.6
Hymenoptera	5	−26.1	1.0	3.8	2.3
Isopoda	2	−27.6	0.3	0.3	0.1
Orthoptera	2	−24.6	1.1	0.8	1.0
Total	64	−26.3	2.1	4.1	2.4

Table 2. Mean and standard deviation (Stdev) of δ^{13}C and δ^{15}N values of order of terrestrial invertebrates collected from floating trays on pasture stream. N denotes the number of samples, and Total denotes the overall mean and standard deviation.

Order	N.	δ^{13}C Mean	Stdev	δ^{15}N Mean	Stdev
Coleoptera	5	−16.3	3.2	11.0	2.4
Collembola	1	−19.0		7.1	
Diptera	32	−18.9	4.3	9.4	2.7
Hemiptera	32	−11.6	2.3	8.6	2.5
Hymenoptera	8	−16.5	3.7	11.7	1.9
Lepidoptera	4	−19.2	5.5	12.4	1.8
Odonata	2	−16.0	1.3	7.0	0.4
Orthoptera	2	−18.4	3.1	8.8	0.1
Total	94	−15.7	4.7	9.5	2.7

4. Sources contribution

The relative contribution of C_4 and C_3 plants to terrestrial invertebrates was estimated using the computational package Stable Isotope Analysis in R (SIAR; Parnell et al. 2010). Terrestrial invertebrates were considered consumers, and C_3 and C_4 plants their food sources. In order to run SIAR, the carbon and nitrogen isotopic composition of the sources, and the isotopic fractionation values between diet-consumer have to be assigned. We assumed the average foliar δ^{13}C (−31.9 ± 1.6‰) and δ^{15}N (2.3 ± 2.0‰) values found among 184 tree specimens collected in the Montane Atlantic Forest a few kilometers from the forest stream (Martinelli LA, non published data). The average δ^{13}C and δ^{15}N for the pasture watershed was assumed to be the average of 28 C_3 plant specimens collected along the pasture stream banks, which were equal to −28.6 ± 1.5‰ and 6.7 ± 1.6‰, respectively (Pereira 2011). For C_4 plants, the δ^{13}C and δ^{15}N were assumed to be the average of six C_4 plants specimens collected along the pasture stream banks, which were equal to −11.9 ± 0.2‰ and 7.8 ± 1.5‰, respectively (Pereira 2011). Finally, the Δ^{13}C and Δ^{15}N was assumed to be +0.5 ± 1.2‰ and +2.3 ± 1.6‰, according to McCutchan et al. (2003).

5. Statistical analysis

The δ^{13}C values did not follow a normal distribution and could not be normalized by transformation. Therefore, the non-parametric Mann-Whitney test was used to compare δ^{13}C and δ^{15}N values of invertebrates collected in the forest and pasture streams. The statistical tests were applied by using STATISTICA12 software and differences were accepted as significant at a 5% level of probability.

Results

The carbon and nitrogen isotopic compositions of 64 and 86 invertebrates were determined in the forest and pasture streams, respectively. Results of these analyses were grouped by order and are shown in Table 1 and 2. The δ^{13}C values of invertebrates in the forest stream varied from −27.6 ± 0.3‰ (Isopoda) to −24.6‰ ± 1.1 (Orthoptera), being the mean equal to −26.3 ± 2.1‰ (Table 1). The δ^{13}C values of invertebrates in the pasture stream varied from −19.2 ± 5.5‰ (Lepidoptera) to −11.6 ± 2.3‰ (Hemiptera), being the mean equal to −15.7 ± 4.7‰ (Table 2), which was significantly higher than the mean value of invertebrates of the forest stream ($p < 0.05$)

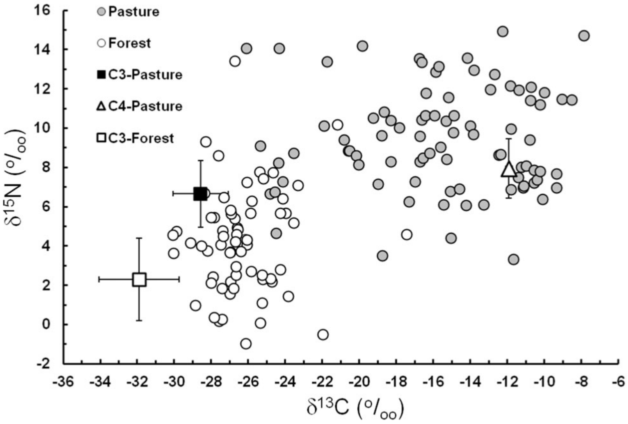

Figure 2. Carbon (δ^{13}C) and nitrogen (δ^{15}N) stable isotope signatures of terrestrial invertebrates collected from floating trays placed in forested (empty circles) and pasture (filled circles) streams and mean isotopic values of C_3 and C_4 plants of pasture and C_3 plants of forest. Bars are standard deviations.

The δ^{15}N values of invertebrates in the forest stream varied from 0.3 ± 0.1‰ (Isopoda) to 4.7 ± 2.3‰ (Lepidoptera), and the mean value was equal to 4.1 ± 2.4‰ (Table 1). The δ^{15}N values of invertebrates of the pasture stream varied from 7.0 ± 0.4‰ (Odonata) to 12.4 ± 1.8‰ (Lepidoptera), and the mean value, equal to 9.5 ± 2.7‰, was significantly higher ($p < 0.05$) than the mean δ^{15}N of invertebrates in the forest stream (Table 2).

In the Figure 2, the δ^{13}C values of invertebrates and plant sources are plotted versus the δ^{15}N values in the so-called δ-space (Newsome et al. 2009). In general, the δ^{13}C and δ^{15}N values of invertebrates of the forest stream were less variable than the pasture stream, and plotted near the C_3 sources in the δ-space (Figure 2). On the other hand, invertebrates of the pasture stream plotted between the C_3 and C_4 sources showed that both types of plant might be contributing to their diets.

The relative proportion of C_3 and C_4 sources to terrestrial invertebrates was estimated using SIAR (Parnell et al. 2010). As expected, in the forest stream, C_3 plants predominate as the main food source of terrestrial invertebrates, the average

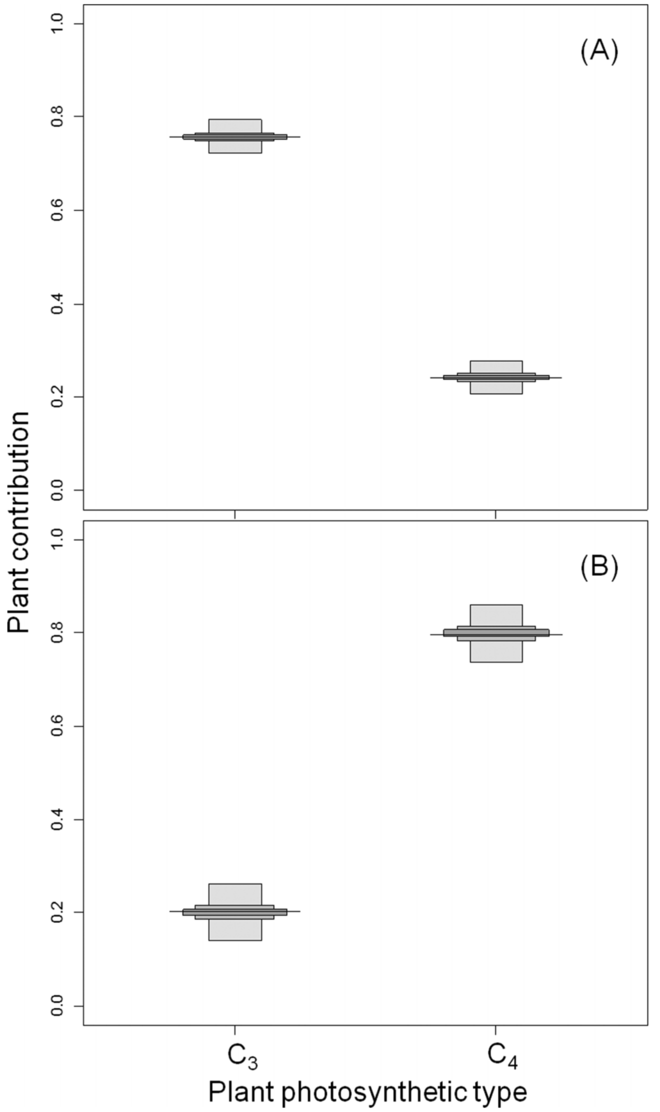

Figure 3. Relative contribution of C_3 and C_4 plants to terrestrial invertebrates in (A) forest stream and (B) pasture stream estimated by the stable isotope analysis in R (SIAR; Parnell et al. 2010) mixing model at 1% 25%, 50% and 99% probability levels.

contribution was 0.75, the minimum 0.72 and the maximum 0.79 (Figure 3). There was also some unexpected C_4 contribution to the forest stream terrestrial invertebrates.

The average C_4 contribution in the forest stream was 0.25, the minimum 0.21 and the maximum 0.28 (Figure 3). In the pasture stream, most of carbon assimilated by the terrestrial invertebrates had a C_4 origin. The average contribution of these plants was 0.80, the minimum 0.74 and the maximum 0.86. The average contribution of C_3 was 0.20, the minimum 0.14 and the maximum 0.26 (Figure 3).

Discussion

Caswell et al. (1973) hypothesized that C_4 plants are avoided by herbivores, especially insects, due to their lower nutritional content compared to C_3 plants. More recently, Barbehenn (2005) showed that leaf-chewing grass-feeding insects such as the grasshopper *Camnula pellucid* and *Melanoplus sanguinipes* are capable of crushing and extracting nutrients from the bundle sheath cells of C_4 grasses, suggesting that these insects may take advantage of the presence of C_4 grasses in the landscape.

We found in this study that the conversion of forest to pasture lands in the coastal Atlantic Forest of Southeastern Brazil influenced the diet composition of terrestrial invertebrates collected on stream surfaces. The contribution of terrestrial C_4 plants to these invertebrates was significantly higher in the pasture than in the forest stream (Figure 3). According to our estimates an average of approximately 78% of the carbon of these invertebrates had a C_4 origin (Figure 3).

It is important to mention that such an estimate has a degree of uncertainty associated with several factors. First, due to logistical constraints our samples of invertebrates were fixed in alcohol, which may especially alter $\delta^{13}C$ values, although this difference seems to be minor, generally between 0.8‰ and 2.5‰ (Ruiz-Cooley et al. 2011, Syväranta et al. 2011, Xu et al. 2011). Regarding this change, it is important to emphasize that in this study, we are evaluating differences in contribution of C_3 and C_4 plants that have a significant differences in their $\delta^{13}C$ value, approximately 17‰ and 19‰ for pasture and forest plants, respectively. Therefore, minor changes in the isotopic composition due to alcohol probably had a minor effect on our results.

Second, we consider constant values for the isotopic fractionation between diet-consumer ($\Delta^{13}C = +0.5‰$ and $\Delta^{15}C = +2.3‰$) according to McCutchan et al. (2003). There are several studies showing that the $\Delta^{13}C$ and $\Delta^{15}C$ may vary due to consumer, and diet characteristics and composition (McCutchan et al. 2003, Codron et al. 2011). As we previously mentioned, the composition and nutritional value of C_3 and C_4 grasses are different (Ehleringer et al. 2002, Barbehenn 2005); this may lead to differences in the $\Delta^{13}C$ and the $\Delta^{15}C$ values for C_3 and C_4 plants; and in this study we assumed the same isotopic fractionation for both types of plants.

In the Neotropics the contribution of C_4 plants to terrestrial invertebrates appears to be a common in large rivers as well as streams. For instance, Adis & Victoria (2001) showed that species of *Tucayaca gracilis* (Orthoptera), *Stenacris f. fissicauda* (Orthoptera), and *Mestosoma hylaeicurn* (Polydesmida) living in the Marchantaria Island, in the Solimões River floodplains had $\delta^{13}C$ values ranging from approximately −14‰ to −11‰, showing the importance of C_4 grasses *Paspalum repens* and *Echinochloa polystachya*, two naturally occurring grasses in the region. Oliveira et al. (2006) working on Camaleão Lake in the same island found that $\delta^{13}C$ values of terrestrial insects collected on C_4 vegetation varied from approximately −13‰ to −17‰, confirming the importance of these plants to the local fauna of insects. Finally, Ferreira et al. (2012), studying watersheds of southeastern Brazil where the original forest was replaced by C_4 forage grasses, also found that that these plants were the most important components of the terrestrial invertebrate diets.

If the C_4 material carried by terrestrial insects enters in aquatic food webs appears to be a function of watershed physical characteristics and the food habits of fish species. For instance, in large watersheds, like those in the Solimões and upper Amazon rivers, Forsberg et al. (1993) found that for most fish species, the contribution of C_4 carbon was low. However, for some species (*Pterygoplichthys diatus, Hydrolycus scomberoides, Heros* sp., *Hypostomus plecostomus* and *Schizodon* *fasciatus*), the C_4 contribution was at least 40%. Likewise, Manetta et al. (2003) found that most fish species had a low contribution of C_4 carbon in lagoons of the Upper Paraná River floodplains; however, two fish species (*Schizodon borellii,* and *Leporinus lacustris*) had a significant contribution from C_4 plants. Also in the Upper Paraná River Basin, Hoeinghaus et al. (2007) showed that only in high-gradient rivers (1.3 $m.km^{-1}$), C_4 carbon made a significant contribution, especially to the species *Schizodon nasutus*. On the other hand, in a small watershed (0.1 to 1 km^2) of southeastern Brazil where the original vegetation was displaced mainly by pastures, the contribution of C_4 carbon for the fish species *Astyanax paranae* and *Bryconamericus iheringii* was higher (60%) than in large tropical watersheds (Ferreira et al. 2012).

An unexpected result was the average contribution of 0.23 (up to 0.27) of C_4 plants to the terrestrial invertebrates of the forest stream. This fact was unexpected because we did not see any C_4 plants along the forest stream banks near the sampling site. Therefore, there are two possibilities to explain the C_4 signal in the terrestrial invertebrates of the forest stream: one is that there are C_4 plants along the forest stream banks that were not observed in our visual inspection or they were located in a distant stream in relation to the sampling site; or a second possibility is that terrestrial invertebrates are feeding on C_4 grasses located on the side of a back road located in the vicinity of our sampling site.

The $\delta^{15}N$ values of terrestrial invertebrates were also significantly higher in the pasture streams compared to forest streams (Figure 2). The main cause of such differences may be due to the higher $\delta^{15}N$ values observed in plants of the pasture stream watershed. However, it is also possible that the trophic position between terrestrial invertebrates of forest and pasture streams are different, since it is well established that $\delta^{15}N$ values increase toward higher trophic levels due to a preferential loss of ^{14}N along the food chain (Post et al. 2000, McCutchan et al. 2003, Martínez del Rio et al. 2009). As we had classified terrestrial invertebrates only to the order level, it is difficult to determine a trophic isotopic fractionation for invertebrates captured in the forest and pasture-streams. Therefore, we cannot provide a more precise cause for the higher $\delta^{15}N$ values observed in invertebrates of the pasture stream.

It is also worth speculating about the ecological implications caused by the entrance of C_4 carbon in aquatic food webs. There are two main aspects to be considered, one is the consequence for terrestrial invertebrates and the other is the consequence for the ecosystem functioning itself. Regarding the first aspect, the plant quality (elemental composition and defense substances) affects the performance of herbivorous insects, including fecundity (Awmack & Leather 2002). Barbehenn et al. (2004) showed that the growth rate of grasshoppers (*Melanoplus sanguinipes*) was approximately 70% higher in C_3-feeding than in C_4-feeding animals. Therefore, it is reasonable to hypothesize that the performance of terrestrial invertebrates may be different in pasture-dominated compared to forest-dominated watersheds. Such differences in performance may be effective not only at the individual but also at population level (Awmack & Leather 2002). Secondly, despite the apparent poor invertebrate performance in C_4-dominated landscapes, it is also important to consider that nutrient ratios (C:N, C:P or N:P) of consumers may change in accordance with the substrate quality, and such changes may affect the whole food chain and ecosystem functioning (Cross et al. 2005, Bukovinszky et al. 2008), since animals, including invertebrates, may greatly affect nutrient dynamics in freshwater systems (Vanni 2002).

Finally, our findings also have important policy implications. The Brazilian Forest Act that regulates land cover at the rural property level was recently changed by the Brazilian Congress. Although there are still pending issues on the final bill, there will be probably a reduction of the extent of the riparian area that has to remain forested. The 30m forested buffer zone established in a longstanding version of the Forest Act will probably be significantly reduced. As we saw in this study, the lack of riparian forest and the implementation of feeding C_4 grasslands to livestock (the largest land use in Brazil) will change the quality of the vegetal material transferred from the terrestrial to aquatic systems by terrestrial invertebrates. As previously mentioned, this change in the substrate quality has the potential to alter not only the performance of terrestrial invertebrates as well as modify the entire food web with consequences for the ecosystem functioning. The maintenance of a 30m-riparian buffer zone would definitely help minimize the effect of upland cropped areas on streams (Ferreira et al. 2012).

There was a major shift from C_3-dominated to C_4-dominated plants in the diet of terrestrial invertebrates of pristine forest to disturbed pasture streams. These major changes in food web fuels may affect not only the performance of terrestrial invertebrates but also may lead to important alterations of the aquatic ecosystem functioning of pasture streams compared to forest streams. These changes may be exacerbated by recent changes in the Brazilian Forest Act, namely a decrease of the riparian buffer zone, one of the most important changes due to its ecological implications.

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Trans-Amazon dispersal potential for *Crotalus durissus* during Pleistocene climate events

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INGENLOFF, K., PETERSON, A.T. **Trans-Amazon dispersal potential for *Crotalus durissus* during Pleistocene climate events.** Biota Neotropica. 15(2): e20130081. http://dx.doi.org/10.1590/1676-06032015008113

Abstract: Two disjunct distributional areas of *Crotalus durissus* (Neotropical rattlesnake) are in open habitats north and south of the Amazon Basin and are presently separated by humid rainforest habitats. We used ecological niche modeling to identify and investigate potential dispersal pathways for this species between the two areas during the late Pleistocene. Niches estimated for the two populations did not differ significantly. Our analyses indicated two possible, but a single most likely, potential routes of dispersal during the last glacial cycle. These results are important to understanding the history of Amazon Basin humid forest biotas, as they suggest agents of isolation among putative humid forest refugia in the form of dry forest and scrub, and associated biotas.
Keywords: *Ecological Niche Modeling, Amazon Basin, Biogeography, Forest Refugia, Last Glacial Maximum.*

INGENLOFF, K., PETERSON, A.T. **Potencial de dispersión trans-Amazónica de Crotalus durissus durante el Pleistoceno.** Biota Neotropica. 15(2): e20130081. http://dx.doi.org/10.1590/1676-06032015008113

Resumen: Actualmente existen dos áreas de distribución disyuntas de la serpiente de cascabel *Crotalus durissus*, afín a hábitats abiertos, al norte y al sur de la cuenca del Río Amazonas, separadas por selvas húmedas. Usamos técnicas de modelado de nicho ecológico para identificar corredores potenciales de dispersión para esta especie entre las dos áreas en el Pleistoceno tardío. Los nichos estimados para las poblaciones de cada una de las áreas de distribución no presentaron diferencias significativas. Nuestros análisis identificaron un corredor de dispersión más probable para esta especie durante el Último Máximo Glaciar. Estos resultados tienen implicaciones para el entendimiento de la historia de las biotas de las selvas húmedas del Amazonas, ya que sugieren causas de aislamiento entre refugios potenciales de selva húmeda, en la forma de selva seca y matorral.
Palavras-chave: *Modelado de Nicho Ecológico, Amazonas, Biogeografía, Refugios Pleistocénicos, Último Máximo Glaciar.*

Introduction

The events leading to the present diversity of species across the Amazon Basin have been pondered since the time of Darwin (Mayr and O'Hara 1986, Nores 1999, Bush and de Oliveira 2006). However, effects of past climate shifts on present-day biotic diversity can be difficult to discern because they depend on complex interactions among multiple biotic and abiotic factors. Earliest assumptions were of stable tropical rainforest ecosystems that had remained largely unchanged since the Cenozoic (Fischer 1960, Bush 1994, Nores 1999). This idea was replaced by the Pleistocene Refugium Hypothesis (PRH) beginning in the late 1960s (Haffer 1969), and gaining considerable popularity thereafter. Given improved understanding of geologic history and impacts on climate and hydrologic systems, the PRH provided a more adequate explanation of the distribution and diversity of modern taxa in the region.

The PRH posits substantial retractions and fragmentation of humid rainforests in the face of advancing savannahs during the cooler, drier climates of the Last Glacial Maximum (LGM, ~21,000–18,000 yr BP) and preceding glacial events. This hypothesis has been resurrected and amended in various forms (Mayr and O'Hara 1986). However, as data from sedimentary core samples from across the Amazon Basin and marine isotope analyses shed light on climatic cycles and likely regional vegetation responses throughout the Quaternary (van der Hammen and Hooghiemstra 2000, Bush 1994, Bush and de Oliveira 2006), researchers have suggested more moderate explanations for Pleistocene range fragmentation, such as increased vegetation heterogeneity in the region, perhaps with dry-forest conditions constituting the cool-climate matrix rather than savannah (Nores 1999, Bonaccorso et al. 2006, Peterson and Nyári 2008, Bush et al. 2011).

The Pleistocene (~2.58 My-11.7 Ky BP) saw a series of global cooling events alternating with warmer periods: temperature fluctuations averaged 4-5°C, and precipitation varied by 50-60% (van der Hammen and Hooghiemstra 2000, Bush and de Oliveira 2006, Lawing and Polly 2011). Paleoreconstuctions of the Last Interglacial period (LIG; ~130,000–116,000 yr BP) indicate climates similar to or possibly even warmer than those of the present day (Otto-Bliesner et al. 2008), whereas the LGM (~21,000-18,000 yr BP) was characterized by cold and dry climates in continental regions worldwide (van der Hammen and Hooghiemstra 2000, Braconnot et al. 2007). Ehlers and Gibbard (2007) suggested at least 20 glacial cycles over the previous 2.6 My BP, most within the last ~900,000 yr.

Ecological niche modeling (ENM), in combination with paleoclimatic reconstructions, provides researchers with a powerful tool with which to "retrodict" potential past distributions of species for key points in time (e.g., LIG, LGM), and can be particularly useful for investigating hypotheses such as the PRH (Waltari et al. 2007, Peterson and Nyári 2008). Availability of climatic reconstructions for the Pleistocene allows exploration of paleo-distributional potential of species, including the location and timing of range disjunctions and potential dispersal routes. Although previous ENM studies of Amazon Basin biotas have indicated that distributions of forest species did fragment owing to climate changes (Bonaccorso et al. 2006, Peterson and Nyári 2008), few have reconstructed the converse phenomenon of broadened distributions of savannah species (Bonaccorso et al. 2006, Collevatti et al. 2012).

Here, we use LGM and LIG paleoclimatic reconstructions in an ENM framework to understand possible effects of Pleistocene climatic shifts on Amazon Basin habitats via analysis of an open-habitat species, the rattlesnake *Crotalus durissus* L., 1758. Despite high diversity of rattlesnakes in North America, *C. durissus* is the only rattlesnake species to have colonized South America broadly (Tozetti and Martins 2008). Populations of this species are found across a broad range in Mesoamerica, and in South America north and south of the Amazon Basin. Though predominantly found in the *cerrado* formations known as *campo cerrado* and *campo sujo*, (Wüster et al. 2005a, Quijada-Mascareñas et al. 2007), *C. durissus* populations are also known from fragmented dry forest habitats and disturbed areas (Bastos et al. 2005, Quijada-Mascareñas et al. 2007, Tozetti and Martins 2008, Tozetti et al. 2009). As a result, a distributional understanding for this species through time may be particularly illuminating as regards the distributional history of Amazonian biotas.

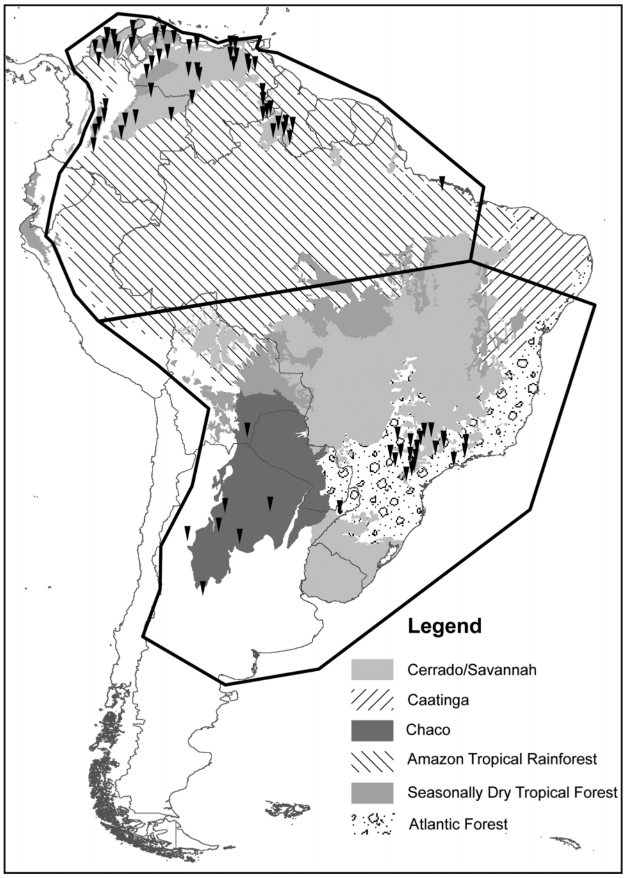

Figure 1. Model calibration regions for *Crotalus durissus* overlaid on a map of ecoregions (Olson et al. 2001). Thick black line delineates training regions (**M**) for northern and southern populations; triangles indicate present-day *C. durissus* occurrence points used in this study.

Materials and Methods

1. Input Data

Occurrence data for six disjunct populations of the *C. durissus* complex across Central and South America were kindly provided by A. Quijada-Mascareñas (pers. comm.). In light of the coarse spatial resolution of available paleoclimatic reconstructions, we focused analyses on the two populations in South America, for which 55 unique occurrences for the northern population and 28 occurrences for the southern population (Figure 1) were available. As these sets of occurrences are distinctly located north and south of the Amazon Basin, their potential for range shifts during Pleistocene cooling events is of particular relevance.

Present-day climatic data were acquired from the WorldClim database (Hijmans et al. 2005). Parallel Late Pleistocene bioclimatic layers (LGM and LIG) were derived from downscaled global climate outputs from the Community Climate System Model (CCSM). LGM data were obtained from the Paleoclimate Modeling Intercomparison Project Phase II (PMIP2, Braconnot et al. 2007); LIG data (~140,000–120,000 yr BP) were kindly made available by C. Ammann (pers. comm.), based on Otto-Bliesner et al. (2006), and downscaled and prepared by R. Hijmans (pers. comm.). As a result, we were able to characterize distributional responses to major climatic events over the past 135,000 yr. Because robustness of ENMs is highly dependent on the complexity of the environmental spaces in which they are calibrated (Peterson and Nakazawa 2008, Peterson et al. 2011), we took care not to calibrate models in highly dimensional spaces. Seven variables showing low correlations (<0.8) were used in ENM calibration (annual mean temperature, mean diurnal range, maximum temperature of the warmest month, minimum temperature of the coldest month, annual precipitation, and precipitation of wettest and driest months). All analyses were conducted at a spatial resolution of 2.5', or ~5 km.

Model calibration regions were delineated carefully, as most presence-only niche modeling algorithms generate background information, or pseudoabsences, based on these areas (Stockwell 1999, Phillips et al. 2006, Pearson et al. 2007, Warren et al. 2010). In this step we followed Barve et al. (2011): we attempted to identify areas that had been accessible to the species over relevant time periods, whether suitable or not, in effect a hypothesis of **M** in the Biotic-Abiotic-Mobility (BAM) framework (Peterson et al. 2011). These hypothesized accessible areas were bounded to the west by the eastern foothills of the Andes and to the east by the Atlantic Ocean.

The calibration area for the northern population extended north to encompass the full extent of the coastline; that of the southern population extended south into north-central Argentina. Designation of the accessible area in the Amazon Basin was chosen arbitrarily at roughly half the distance between the known occurrence points of the two populations (Figure 1). We transferred model results to the whole of South America to allow interpretation of potential dispersal routes at a continental scale during LGM.

2. Niche Similarity

As an initial step, we used ENMTools (Version 1.3, http://enmtools.blogspot.com/) to test hypotheses of niche similarity between the two populations. Described in depth by Warren et al. (2010), the program works in conjunction with Maxent (Phillips et al. 2006) to test whether two populations have environmental characteristics of occurrences more or less similar than random expectations. The "background" area specified in this test for each population is the accessible area (**M**) described above. The program compares niche models via two similarity metrics (Schoener's *D* and *I*) based on known occurrences of one of the two populations with niche models based on points drawn at random from the "background" (**M**) of the other. This process was repeated 1000 times to create a null distribution of background similarity values. ENMs were generated for each population in Maxent, and thresholded to the least training presence value (Pearson et al. 2007). Finally, we compared observed similarity values to the null distribution, rejecting the null hypothesis of similarity if the observed fell below the fifth percentile of the distribution of null values.

3. Ecological Niche Modeling

Because observed values for niche similarity for both similarity metrics were well above the critical values of the null distributions (Figure 2), we were unable to reject the null hypothesis (all $P \geq 0.997$); we thus accepted that no significant dissimilarity exists between niches of northern and southern South American populations of *C. durissus*. In view of these results, occurrences of the two populations were combined (i.e., the two calibration regions and occurrence data) to obtain an overview of likely geographic limits of the distribution of *C. durissus* through time.

Niches were estimated and paleodistributional projections made using two common ENM algorithms: the openModeller (OM-GARP version 1.1, Muñoz et al. 2011) implementation of the Genetic Algorithm for Rule-set Prediction (GARP, Stockwell 1999) and a maximum entropy approach (Maxent, Phillips et al. 2006). Both algorithms were set to 1000 bootstrapped runs for up to 1000 iterations of estimation. GARP models were run to a 1% convergence criterion, with extrinsic testing of omission, a relative omission threshold (20% of the distribution), and a 50% commission threshold (Anderson et al. 2003), producing 100 final models for interpretation, which were summed to produce a single map of model agreement. Maxent was set for 100 bootstrap replicates; all other settings were left at default. Suitability thresholds for interpretation of models from both algorithms were based on least training presence criteria (Pearson et al. 2006), modified to consider possible error rates (*E*) of 0, 1, 5, and 10% (Peterson and Nyári 2008, Peterson et al. 2011).

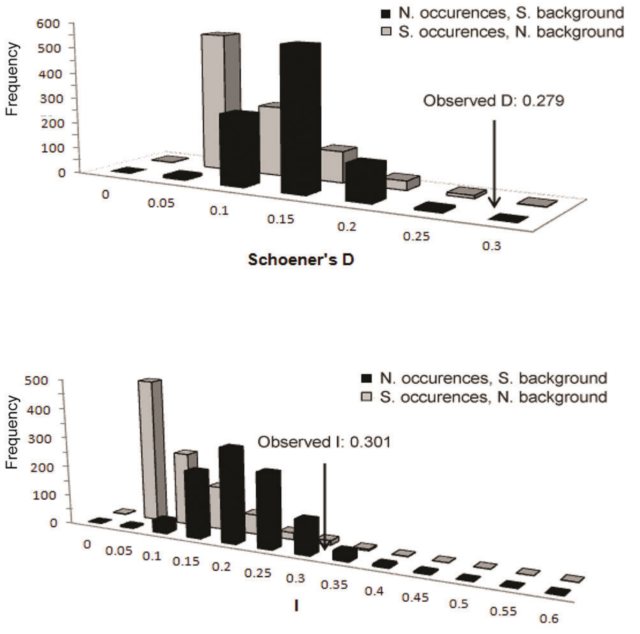

Figure 2. Niche background similarity distributions for one-tailed testing of similarity of niches between northern and southern *Crotalus durissus* populations for *D* and *I* similarity indices. The observed degree of similarity between the two species is shown as a black arrow.

Finally, to explore responses to key climatic parameters, we developed niche visualizations following a modification of the approaches of Elith et al. (2005) and Owens et al. (2013): simple models were constructed based on two generalized bioclimatic variables (mean annual temperature and precipitation) and projected onto a two-dimensional space wherein the *x*-axis equates to a broad spectrum of mean annual temperatures (-100-100°C) and the *y*-axis corresponds to a similar spectrum of mean annual precipitation values (0–15,000 mm; see Owens et al. 2013 for further illustration of this approach). ENMs were calibrated using the pooled *C. durissus* occurrence data and present-day bioclimatic data using GARP and Maxent, as described above.

Results

The niche visualizations (Figure 3) offer a two-dimensional view of temperature and precipitation responses of the species, but also suggest the need for some caution with transferring models onto conditions outside those over which our model was calibrated (Owens et al. 2013). The two models (GARP and Maxent) differed in the response surface shape reconstructed, although which is more "correct" is not clear.

Model projections onto current conditions emphasized the disjunct nature of the present potential distribution of the species (Figure 4). Paleoprojection outputs indicated a climatically suitable dispersal corridor for *C. durissus* across the eastern part of the Amazon Basin during the cooler, drier climates of the LGM (Figure 4). GARP further identified a possible corridor from the northwest south along the eastern foothills of the Andes. Both of these corridors were in areas where projections onto LIG and present-day conditions indicated climatic barriers to trans-Amazonian dispersal (Figure 4). Visually, model outputs for the two algorithms

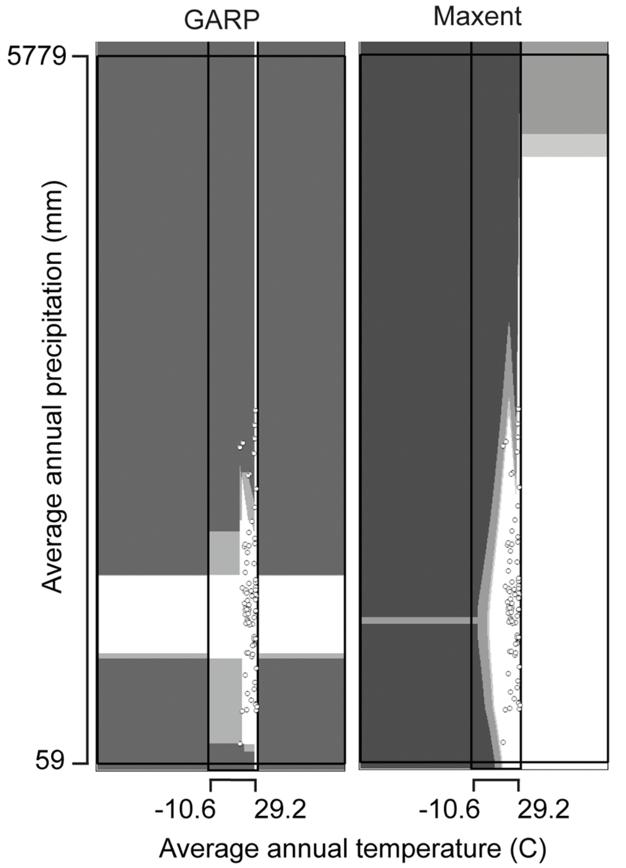

Figure 3. GARP (left) and Maxent (right) projections of *Crotalus durissus* occurrences and ecological niche models visualized using a calibration strip. The *x*-axis expresses mean annual temperature (-100 to 100C) and the *y*-axis shows annual precipitation (0 to 15,000 mm). Circles indicate *C. durissus* occurrences. Boxes indicate ranges of conditions manifested across the combined (north and south) calibration region.

showed high agreement as regards general patterns of bioclimatic suitability shifts across time periods. However, whereas Maxent projections showed broader areas of suitability during the transition from the LIG (22.4%) to the LGM (30.5%), GARP projected decreased suitable area from LIG (30.2%) to LGM (24.9%).

Discussion

Our paleodistributional reconstructions concur with those of prior ENM-based studies indicating LGM expansion of *cerrado* and other dry-habitat biomes (Collevatti et al. 2012, Bonatelli et al. 2014), as well as those which identified LGM barriers for forest that coincide with our reconstructed dispersal corridors for a non-forest species (Bonaccorso et al. 2006, Peterson and Nyári 2008). Although projections from niche modeling algorithms presently provide only a single, generalized snapshot of climatic suitability for a given time slice, they illuminate processes affecting the broader distributional potential of *C. durissus* since the LIG. A variety of studies, including genetic (Wüster et al. 2005a,b, Quijada-Mascareñas et al. 2007), paleoecological (Prado and Gibbs 1993, Pennington et al. 2000, Mayle et al. 2004, Pennington et al. 2004, Anhuf et al. 2006, Cowling 2011, Hannah et al. 2011), and paleoclimatic (Colinvaux and de Oliveira 2001, Wang et al. 2004, 2006, Kanner et al. 2012, Mosblech et al. 2012) analyses, further support for these ideas. These results suggest a stepping-stone-like series of dispersal events across a heterogeneous topography dictated by effects of glacial-interglacial cycles (Vegas-Vilarrúbia et al. 2012) and strongly influenced by the North Atlantic climate (Fritz et al. 2010).

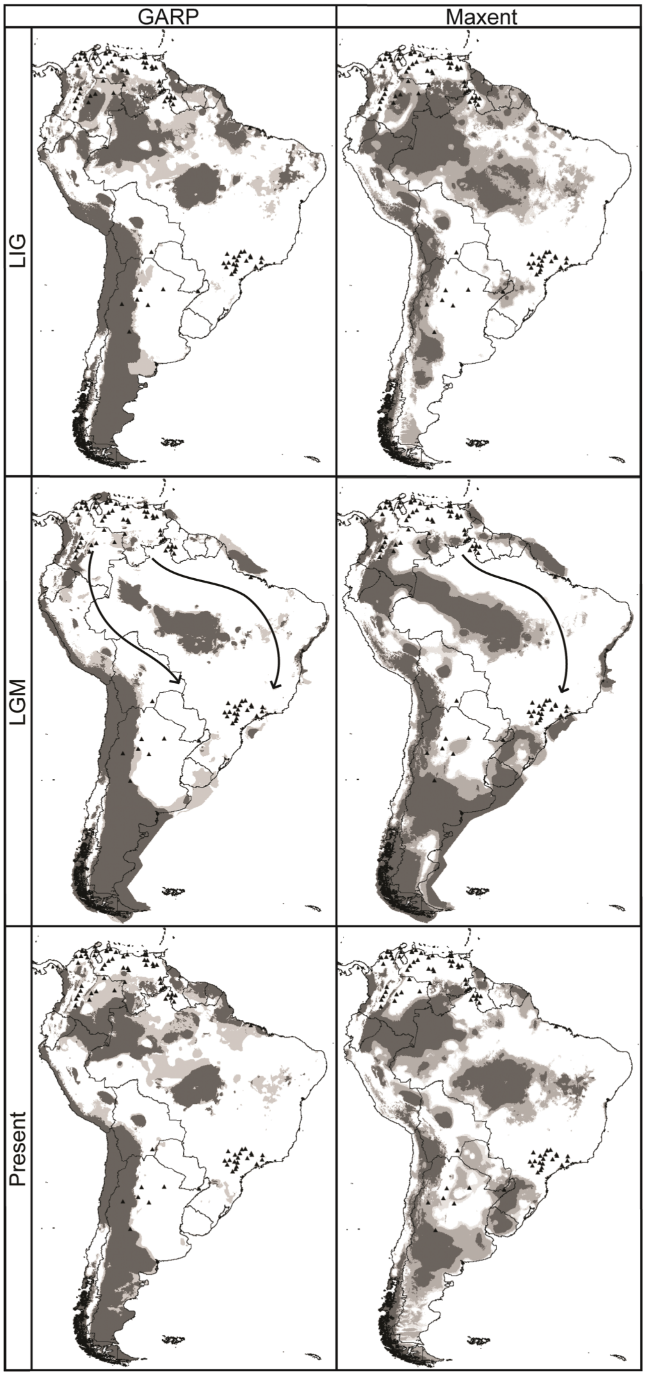

Figure 4. Projections of modeled potential distributional areas for *Crotalus durissus* during the Last Interglacial, Last Glacial Maximum (LGM), and the present day. Black lines indicate climatically suitable dispersal corridors reconstructed at LGM. Suitability is indicated via shading, with white denoting areas of high climatic suitability, light gray moderate suitability, and dark gray low suitability. Black triangles indicate present-day occurrence points.

Though still not completely clear, overall understanding of late Pleistocene climatic events and biotic responses in the Amazon Basin has improved significantly in recent years. The vast majority of data feeding this understanding of South America's climate during the Pleistocene derive from sites along the Atlantic seaboard and in the central Andes (Wang et al. 2004, Whitney et al. 2011); however, limited data also now exist for South America's continental interior (Whitney et al. 2011). While paleoclimatic reconstructions from the coastal and Central Andean regions suggest an overall increase in summer monsoon activity during the LGM, Whitney et al. (2011) concluded that South America's continental interior and lowlands regions experienced significantly drier conditions. Generally, the Last Glacial period (10-110 Ky BP) was characterized by abrupt, millennial-scale climatic fluctuations correlating with northern glacial-interglacial cycles (Wang et al. 2004, 2006, Kanner et al. 2012, Mosblech et al. 2012). Varying in duration from a few hundred years to several thousand, episodes of high precipitation during active summer monsoons appear to have been associated with northern stadials (LGM, 20-25 Ky BP; Heinrich event 1, 15-17 Ky BP; and Younger Dryas, 11-13 Ky BP), while drier periods were associated with reduced monsoonal activity and interglacial events in the Northern Hemisphere (Wang et al. 2004, 2006, Zech et al. 2008, Kanner at al. 2012).

The frequency and variable durations of these events may have presented opportunities for periodic dispersal events by *C. durissus* southward across the Amazon Basin as variable climatic conditions expanded and contracted suitable habitat patches (Vegas-Vilarrúbia et al. 2012). Indeed, paleovegetation projections indicated expansion of *cerrado* and other grassland habitats across the eastern edge of the Amazon Basin (Anhuf et al. 2006), as well as seasonally dry tropical forest (Whitney et al. 2011). Of course, caution must be exercised in stating explicitly where particular vegetation types expanded or contracted, particularly for c*errado* versus seasonally dry forest (Pennington et al. 2000, Mayle et al. 2004, Pennington 2004), as modern distributions of seasonally dry tropical forest tend to be discontinuous and adjacent to c*errado* (Mayle et al. 2004). However, given the broad climatic overlap of these two biomes at present, the general pattern of expansion and contraction in response to glacial cycles likely occurred in concert (Prado and Gibbs 1993, Pennington et al. 2000).

Our modeling exercise indicated two possible routes of dispersal for *C. durissus* during the LGM: an Atlantic corridor and a western corridor along the foothills of the Andes. The Atlantic corridor, as reconstructed by both Maxent and GARP, falls in line with current understanding of overall dynamics of the coastal region of northeastern South America during the late Pleistocene. Determining the exact proportions of savannah versus seasonally dry forest will require more palynological and geomorphological data than are presently available (Prado and Gibbs 1993, Colinvaux and de Oliveira 2001, Anhuf et al. 2006, Quijada-Mascareñas et al. 2007, Cowling 2011, Hannah et al. 2011). However, the overarching pattern of change is consistent with periodic establishment of suitable habitat in lieu of favorable climatic conditions as suggested by our models.

The interior (western) corridor along the eastern base of the Andes identified in some of our models was not as well supported as the Atlantic corridor. The extent to which millennial-scale climate events of the Last Glacial cycle were manifested in interior South America remains unclear (Fritz et al. 2010); however, a recent study by Mosblech et al. (2012) found no evidence of significant drying of the western Amazon Basin in the last 94,000 years. While this result does not instill much confidence, lack of evidence of drying does not necessarily mean that vegetative communities in the region were not impacted by overall drier LGM conditions. In fact, the notion of an Andean dispersal corridor for savannah species during the LIG is not new (da Silva and Bates 2002), so until a better picture of paleoclimates of the South American interior emerges, the potential of an Andean route should not be discarded entirely.

Finally, phylogeographic investigations by Wüster et al. (2005a,b) and Quijada-Mascareñas et al. (2007) found low sequence divergence between *C. durissus* populations north and south of the Amazon Basin, indicating a fairly recent (~1.08 My BP, if molecular clock estimates are to be believed) vicariant event most probably via interruption of a corridor of suitable habitat. Assuming accuracy of this estimation, vicariance of *C. durissus* perhaps coincided with the Mid-Pleistocene Transition (MPT; 1.5 My – 650 Ky BP), a period exhibiting pseudo-periodic moderate climate shifts approximately every 100 Ky (Sepulcre et al. 2011). Despite on-going debate regarding the pattern and extent of vegetation shifts during the Pleistocene, at present no adequate climate data resources exist from which niche models can anticipate mid-Pleistocene distributional responses with any confidence. However, extrapolating from evidence for the more chaotic and extreme Late Pleistocene, MPT climate shifts could have provided windows of optimal conditions stable for long enough to facilitate dispersal from north to south across the Amazon Basin.

The issue of model transferability more generally in ENM studies is an ongoing challenge (Peterson et al. 2007, Owens et al. 2013), and some degree of uncertainty should be expected when projecting spatial and temporal responses of vegetation across time owing to the coarse spatio-temporal resolution (~5 km resolution after downscaling) of paleoclimate reconstructions. A single grid cell at this resolution may often encompass diverse situations (Marchant and Lovett 2011), leading to generalization of conditions. This generalization reduces ability to identify climatically suitable patches at finer extents, thus preventing detection of narrow barriers (Peterson and Nyári 2008). Further, because data available for the LGM and LIG encompass only climatic variables, our models are indicators of climatic suitability only, and do not distinguish directly among vegetation types or other landscape attributes (Nogués-Bravo 2009).

Climate change is a significant factor in the future shifting of plant community structure subsequently impacting the distribution and survivability of most organisms on Earth. Knowledge of the spatiotemporal distribution of species is a major underpinning in understanding the evolution of biodiversity (Svenning et al. 2011). Paleoreconstruction exercises such as the one we present here strengthen understanding of the biogeographic patterns of a given region, enhancing ability to assess "critical" areas more adequately and ultimately playing a significant role in management and preservation of regions such as the c*errado* and other centers of endemism (da Silva and Bates 2002, Varela et al. 2011). Exploration of model-based scenarios for many taxa in relation to critically, non-model-based studies (genetic, paleo-environmental studies, etc.), provide a form of "ground-truthing" for the model-based results. By identifying most parsimonious scenario(s) of species' and community responses to past climate changes, we improve ability to develop and implement more effective, long-term management strategies in the face of projected future climate scenarios.

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Effects of reduced-impact logging on medium and large-bodied forest vertebrates in eastern Amazonia

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Abstract: Standard line-transect census techniques were deployed to generate a checklist and quantify the abundance of medium and large-bodied vertebrate species in forest areas of eastern Amazonia with and without a history of reduced-impact logging (RIL). Three areas were allocated a total of 1,196.9 km of line-transect census effort. Sampling was conducted from April to June 2012 and from April to August 2013, and detected 29 forest vertebrate species considered in this study belonging to 15 orders, 20 families and 28 genera. Additionally, eight species were recorded outside census walks through direct and indirect observations. Of this total, six species are considered vulnerable according to IUCN (*Ateles paniscus, Myrmecophaga tridactyla, Priodontes maximus, Tapirus terrestris, Tayassu peccary, Chelonoidis denticulata*). Observed species richness ranged from 21 to 24 species in logged and unlogged areas, and encounter rates along transects were highly variable between treatments. However, the relative abundance of species per transect did not differ between transects in logged and unlogged forests. Of the species detected during censuses, only three showed different relative abundance between the two treatments (*Saguinus midas, Tinamus* spp. and *Dasyprocta leporina*). Our results show that the effect of RIL forest management was a relatively unimportant determinant of population abundance for most medium and large vertebrates over the time period of the survey.

Keywords: *fauna, forest management, tropical rainforest, mammals, birds.*

LAUFER, J., MICHALSKI, F., PERES, C.A. **Efeitos da exploração de impacto reduzido em vertebrados de médio e grande porte na Amazônia oriental.** Biota Neotropica. 15(2): e20140131. http://dx.doi.org/10.1590/1676-06032015013114

Resumo: Técnicas padronizadas de censo por transecções lineares foram empregadas para gerar uma lista e quantificar a abundância de espécies de vertebrados de médio e grande porte em áreas de floresta na Amazônia oriental, com e sem uma história de exploração de impacto reduzido (EIR). Três áreas foram amostradas com um esforço total de 1.196,9 km de censo ao longo de transectos lineares. A amostragem foi realizada de abril-junho de 2012 e de abril-agosto de 2013, e detectou 29 espécies florestais de vertebrados consideradas neste estudo pertencentes a 15 ordens, 20 famílias e 28 gêneros. Adicionalmente, oito espécies foram registradas fora dos censos ao longo dos transectos por meio de observações diretas e indiretas. Desse total, seis espécies são consideradas vulneráveis de acordo com a IUCN (*Ateles paniscus*, *Myrmecophaga tridactyla*, *Priodontes maximus*, *Tapirus terrestris*, *Tayassu pecari, Chelonoidis denticulata*). A riqueza das espécies observada variou de 21 a 24 espécies em áreas com e sem corte seletivo, e as taxas de encontro ao longo dos transectos foram bastante variáveis entre os tratamentos. No entanto, a abundância relativa das espécies por transecto não diferiu entre florestas não exploradas e exploradas. Das espécies detectadas durante o censo, apenas três apresentaram diferentes abundâncias relativas entre os dois tratamentos (*Saguinus midas*, *Tinamus* spp. e *Dasyprocta leporina*). Nossos resultados mostram que o efeito do manejo florestal EIR não foi relativamente determinante para abundância populacional da maioria dos vertebrados de médio e grande porte.

Palavras-chave: *Fauna, manejo florestal, floresta tropical, mamíferos, aves.*

Introduction

Maintaining viable populations of medium and large-bodied vertebrates is essential if tropical forests are to maintain their current structure and composition (Wright et al. 2007, Terborgh et al. 2008, Gutierrez-Granados et al. 2010, Beck et al. 2013). For example, most Amazonian tree species are dispersed by forest vertebrates. In the Guiana Shield and Central Amazonia, frugivorous vertebrates disperse over 94% of all woody plant species (Peres & van Roosmalen 2002). Thus, surveys to assess the impact of any anthropogenic forest disturbance on faunal assemblages are essential to the understanding of biodiversity and ecological processes, as well as planning management and conservation strategies for forests and their constituent faunas (Willis et al. 2007).

However, despite the importance of medium and large vertebrates, extensive knowledge gaps still remain on these species (Paglia & Fonseca 2009). In Amazonia, this lack of knowledge comes partly from the vast area and ensuing difficulties in accessing many areas, both of which hinder studies over much of the basin. Despite the physical remoteness of some areas, between 1988 and 2013 more than 9.5% of primary forests across the Brazilian Amazon was either converted or severely degraded (INPE 2014) by various anthropogenic drivers including deforestation, forest fires, and fragmentation (Fearnside 2005, Michalski et al. 2008, Peres et al. 2010). To help minimize this impact, some 90 million hectares of Amazonian forests have been designated as Sustainable Use Protected Areas (SUPAs) (Peres 2011). Such areas are set aside for the sustainable use of natural resources, in addition to maintaining biodiversity and other ecological functions (Brazil 2000). Timber extraction is therefore a key economic activity in achieving the often intractable goal of reconciling financially viable land-use revenues and forest conservation within SUPAs.

Although controversial, selective logging has been widely promoted as one of the least harmful patterns of land use for tropical forest animal and plant communities (Johns 1991, Grove 2002, Meijaard & Sheil 2008, Gibson et al. 2011, Kudavidanage et al. 2012). However, this activity can alter the composition and structure of the original forest (Peres et al. 2010). Observed changes include modifications in the amount of litter, leaves, flowers and the elimination of fruiting trees important to the trophic viability of frugivore populations (Johns 1988, Uhl & Vieira 1989, Johns 1992, Chapman et al. 2000). In addition, a post-logging forest landscape may become more homogeneous (Kitching et al. 2013), potentially degrading habitats available for the vertebrate fauna. Studies across the humid tropics on the impacts of logging on forest biodiversity are plagued by a myriad of methodological problems (Laufer et al. 2013). Ideally, effectively assessing the impacts of selective logging requires a proper understanding of the structure and composition of forests and their wildlife both before and after logging (Johns 1986, Kohler et al. 2002, Potts 2011, Samejima et al. 2012). This prevents spatially biased, pseudo-replicated, or intrinsically flawed assessments of the effects of selective logging on wildlife, because it retains the original distribution and composition of resident species across treatments (Peres et al. 2010).

The potentially detrimental effects of logging on wildlife can be reduced with the use of management techniques that minimize the effects of disturbances, such as different forms of reduced-impact logging (Putz et al. 2008). This technique consists of planning management actions to minimize the direct and indirect impacts of logging, and to maintain both ecosystem processes and the economic and environmental viability of the activity (Barreto et al. 1998, Putz et al. 2008). RIL typically has a lower cutting intensity than other forms of timber extraction and studies typically report lower levels of collateral damage than those induced by more traditional techniques. RIL is reported to induce lower rates of species loss (Whitman et al. 1998, Azevedo-Ramos et al. 2006, Samejima et al. 2012), minimize the amount of canopy openings, reduce collateral damage (Uhl & Vieira 1989, Bicknell & Peres 2010) and thereby reduce the probability of post-cutting forest fires (Nepstad et al. 1999).

However, our understanding of the effects of forest perturbation associated with RIL on forest fauna, particularly on medium and large-bodied vertebrates, remains very poor. The aim of this study, therefore, was to use standardized wildlife census techniques to inventory the medium and large vertebrate fauna in order to provide both a species checklist and estimate the richness and relative abundance of vertebrate populations at an eastern Amazonian forest landscape providing a RIL-disturbed and undisturbed forest mosaic. For this we collected data within three different areas: one that had never been exposed to selective logging, another 2-3 years after RIL disturbance, and the third including both pre- and post-disturbance one year after a selective cutting operation had occurred. We predict that patterns of species abundance, if not species composition, would remain unchanged. This prediction can be expected due the well conserved landscape, proximity to unlogged forest, and the management forest applied on the forests (RIL). However, we expect to detect the influence of RIL on the abundance of at least some species, particularly on the abundance of those strict forest specialist species, due to their undisturbed old growth ecological requirements.

Methods

1. *Study Area*

The study was conducted in the Rio Jari basin of northeastern Pará, eastern Brazilian Amazonia, within a vast private landholding controlled by Jari Florestal (hereafter, Jari landscape) (00°27'00"– 01°30'00" S; 51°40'00"– 53°20'00" W; Figure 1). This company manages an area of approximately 1,260,000 ha in the transition region between the lowland Amazon and the Guianan Highlands (Souza 2009). Between the 1960s and 1990s, approximately 10% of the landholding area consisting of primary forest was converted to plantations of fast-growing exotic trees (Barlow et al. 2010). The site is currently characterized by a large-scale mosaic of *Eucalyptus* plantations (~ 45,000 ha), secondary forest abandoned for some 20-25 years (> 50,000 ha), and a vast area of primary forest (~ 1 million ha) subjected to extremely low levels of human disturbance (Barlow et al. 2007, Gardner et al. 2007, Parry et al. 2007). The predominant vegetation within the Jari study landscape is dense lowland, submontane and montane rain forest, seasonally-flooded forest (igapó), open evergreen lowland forest, submontane forest with lianas and submontane forest with palms (Souza 2009). The canopy cover (25-50 m tall) is continuous (Souza 2009), and the dominant emergent tree species is the commercially valuable Angelim Vermelho (*Dinizia excelsa* Ducke).

The average annual rainfall is 2,115 mm, with an average annual temperature of 26°C (22°-34°C) (Ribeiro et al. 2008, Souza 2009). The three driest months of the year experience 60 mm lower precipitation (RADAM 1974). Soils consist mostly of yellow oxisols, inceptisols and podzolics. Other soil types, such as the ultisol and plinthosols, occur in smaller patches. The soils of upland forests vary in their proportions of sand, clay and silt, and include gravel to a greater or lesser extent (Souza 2009).

2. *Survey Areas*

Our field sampling took place in three Annual Operating Plots (POAs – from the Portuguese acronym, *Planos Operacionais Anuais*) (Figure 1). These contiguous areas span over 450 km^2. We sampled two areas before the intervention of selective logging: control area (POA-08) and POA-07$_{\mathrm{PRE}}$. These areas had been exposed to low levels of human impact (e.g.: subsistence hunting and a low density of narrow unpaved roads). In POA-07, two long-established roads (> 20 years) were supplemented by 8 km of recent logging roads (> 2 years) to support forest management activities. The control area had some 20 km of much older roads (> 25 years) built by the company for forest inventories of the area. Two other areas were sampled after they had been exposed to RIL, POA-07$_{\mathrm{POST}}$ (logged in 2012) and POA-06 (logged in 2010-2011). POAs-07 and 08 were surrounded to the north by > 20 year-old secondary forests and tree plantations (*Eucalyptus* plantations). To the south of POA-06 (> 2 km) lay a region where RIL disturbance had taken place between 2006 and 2008. The other sampling areas were embedded within a vast matrix of undisturbed primary forest. All areas had been exposed to little or no hunting pressure. Throughout the entire time period of eight months of fieldwork, we detected fewer than ten signs of any present or past hunting activity (including vehicle tracks, hunting traps, direct encounters with hunters, spent shells, and gunfire shots).

POA-07 and POA-06 were cut according to reduced-impact logging techniques. These aim to minimize logging impacts through careful planning of access roads and transportation, a 100% forest inventory of the area to be managed, selection of individual trees for cutting (DBH > 50 cm), and control of tree felling direction, among other mitigating measures to minimize collateral damage. The maximum cutting intensity allowed for these areas was 3-4 individual trees • ha^{-1} (or 30 m^3 of sawable timber per ha), which is similar to other Amazonian sites (Uhl & Vieira 1989). The minimum cut-off of logging intensity applied to the surveyed areas varied according to the spatial distribution of species of high commercial value and abiotic characteristics of the region (e.g. topography and drainages). The logged areas (POA-07$_{\mathrm{POST}}$ and POA-06) were harvested at low intensity (22.8 m^3 • ha^{-1}). This logging intensity and the resulting collateral damage amounted to a 16.9% reduction in

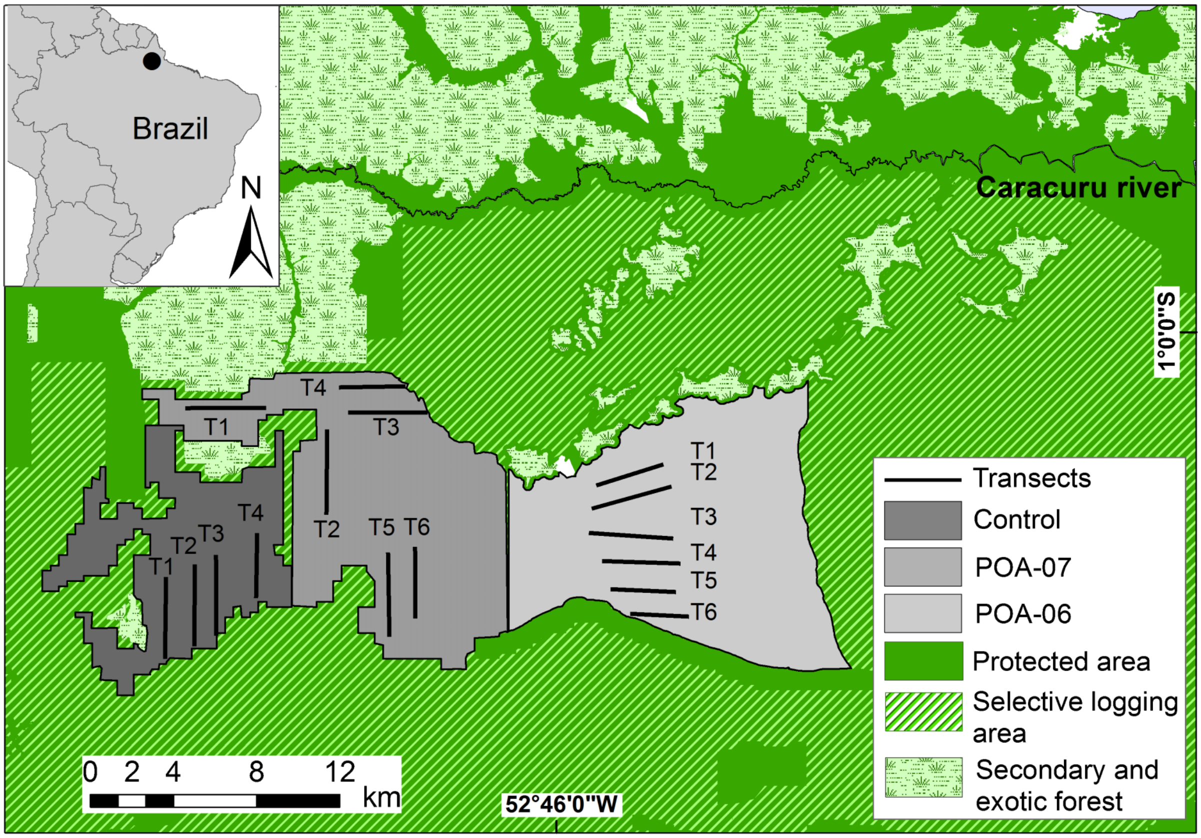

Figure 1. Location of the three study sites where medium and large-bodied vertebrates where surveyed in the municipal county of Almeirim, Pará, Brazil. Gray areas indicate those selected for the study, control, POA-07 (pre- and post-logging) and POA-06 areas. The green area indicates a legal forest reserve (LR) within the Jari study landscape and the hatched area, superimposed onto the LR, is the total area allocated to low-impact selective logging. Therefore, only the area south of POA-06 had been previously logged prior to this study (< 6 years).

forest basal area, compared to the basal area of the unlogged forest used as a control (J. Laufer, unpublished data).

3. *Vertebrate censuses*

We conducted two sessions of line-transect censuses of vertebrates over a 2-year period. The first sampling session occurred between April and June 2012, when we sampled POA-07 before selective logging intervention (POA-07$_{\text{PRE}}$). The second, between April and August 2013, sampled an area without intervention of selective logging, and another two with one and 2-3 years post-harvesting, respectively (POA$_{\text{Control}}$, POA-07$_{\text{POST}}$ and POA-06). We avoided sampling any site during the months of July-December, when selective cutting normally takes place. To sample medium and large (> 250 g) vertebrates, we used a standardized line-transects census technique adjusted to local conditions (Peres & Cunha 2011). The census was conducted by observers with at least three years of experience of monitoring neotropical forest fauna. In total, a census effort of 1,196.9 km of line transect walks was accumulated in both unlogged treatments, POA-07$_{\text{PRE}}$ and POA$_{\text{Control}}$ (henceforth, UL), and logged forest (LF) treatments, POA-07$_{\text{POST}}$ and POA-06. In each area between four and six linear transects of 3.2 to 4.5 km in length were cut, marked every 50 m, and mapped using a handheld GPS (Table 1). To maintain spatial independence, we spaced all transects by a minimum distance of 1 km (1-1.9 km, mean = 1.2 km, SD = ± 0.2). Each transect was walked at least 7 times in the morning and 3 to 7 times in the afternoon. To minimize possible sampling bias and randomly reshuffle observer effects, observers in each treatment were systematically rotated.

We followed the sampling protocol proposed by Peres & Cunha (2011) to census all diurnal forest vertebrate species larger than 250 g. Transects were walked at an average velocity of 1.25 km • h^{-1} (Buckland et al. 2010a, b), which allows the use of both auditory and visual detections across all strata of the forest (Peres & Cunha 2011). We systematically stopped for up to 1 min approximately every 100 m along transects to increase the likelihood of acoustic detections. Census work took place in the morning between 06:00 h and 11:00 h and in the afternoon from 13:30 h to 16:30 h. The sampling period varied with the logistics of each area and the vagaries of weather conditions. Censuses were discontinued during periods of mild to heavy rainfall, because under such conditions auditory detection is impaired and animals become less active (Peres 1999).

For each detection we recorded time, species and distance along the transect. For all small and large tinamous species (*Crypturellus* spp. and *Tinamus* spp., respectively), we grouped detection data by genus, due to inherent difficulties in identifying these birds to species during censuses (Bicknell & Peres 2010). To boost the detection power of vertebrate species occupancy (presence/absence) data we used both direct and indirect observations (presence of tracks, feces, hair and burrows) obtained along transects, as well as along the survey areas. Those ancillary data were also obtained when survey transects were being initially opened and during movements on foot between transects.

4. *Data Analysis*

To analyse whether the cumulative sampling effort in different areas was representative of the medium and large vertebrate assemblage we constructed per-transect species richness rarefaction curves, in which all visual and acoustic observations were combined. We analyzed data using the *vegan* (Oksanen et al. 2013) and *indicspecies* packages (De Cáceres & Jansen, 2014) with the R program function *specaccum* and *multipatt,* respectively (R Development Core Team 2013). ANOVAs were applied to perpendicular detection distances from transects (for both visual and acoustic records) to examine the variation in lateral detectability between the two treatments

Table 1. Sampling effort along different line transects in both logged and unlogged forest, length of transects (km), total distance censused (km), and encounter rates for all vertebrate species (visual and acoustic detections per 10 km walked) for each transect/treatment.

Unlogged Forest							
POA-07 (PRE)				**Control**			
Transect	**Length (km)**	**Total (km)**	**Encounter rate**	**Transect**	**Length (km)**	**Total (km)**	**Encounter rate**
T1	4.1	51.4	11.7	T1	3.9	75.0	14.1
T2	4.2	49.8	13.1	T2	3.9	65.9	13.5
T3	4.0	40.0	14.3	T3	4.0	69.1	23.7
T4	3.2	37.8	15.1	T4	3.2	66.6	15.9
T5	4.1	53.0	11.9				
T6	3.4	44.2	9.5				
TOTAL	**22.9**	**276.2**	**12.4**	**TOTAL**	**15.0**	**276.5**	**16.8**

Logged Forest							
POA-07 (POST)				**POA-06 (POST)**			
Transect	**Length (km)**	**Total (km)**	**Encounter rate**	**Transect**	**Length (km)**	**Total (km)**	**Encounter rate**
T1	4.1	55.9	13.8	T1	3.8	52.5	10.5
T2	4.2	58.1	7.7	T2	4.5	63.0	11.0
T3	4.0	54.5	9.9	T3	3.8	62.3	9.5
T4	3.2	43.6	15.3	T4	4.5	57.4	8.9
T5	4.1	57.1	12.1	T5	3.8	49.0	11.4
T6	3.4	47.6	13.9	T6	4.5	43.4	14.1
TOTAL	**22.9**	**316.6**	**11.9**	**TOTAL**	**24.8**	**327.6**	**10.7**

Table 2. Form of detection for medium and large vertebrate species recorded along different logging treatments in this study. D = direct visual and acoustic observations; I = indirect observations (tracks, feces, hair and burrows). Unlogged Forest (UL) and Logged Forest (LF) correspond to relative abundance (detections per 10 km walked) of species in the two forest treatments. * Observations recorded outside censuses.

Group	Species	POA-07$_{PRE}$	Control	POA-07$_{POST}$	POA-06	Detection type	UL	LF
Birds	*Ara* spp.	x	x	x	x	D	0.29	0.31
	Harpia harpyja (Linnaeus, 1758)	x		x*		D	0.02	
	Psophia crepitans (Linnaeus, 1758)	x	x	x	x	D	0.22	0.12
	Penelope marail (Müller, 1776)	x	x	x	x	D	1.70	1.43
	Crax alector (Linnaeus, 1766)	x	x	x	x	D	0.58	0.42
	Tinamus spp.	x	x	x	x	D	2.88	1.82
	Ramphastos tucanus (Linnaeus, 1758)	x	x	x	x	D	1.94	1.46
	Amazona ochrocephala (Gmelin, 1788)	x	x	x	x	D	1.32	0.95
	Ibycter americanus (Boddaert, 1783)	x	x	x	x	D	0.20	0.06
Primate	*Alouatta macconnelli* (Linnaeus, 1766)	x	x	x	x	D	0.58	0.50
	Ateles paniscus (Linnaeus, 1758) [V]	x	x	x	x	D	0.69	0.73
	Pithecia pithecia (Linnaeus, 1766)	x		x	x	D	0.07	0.06
	Saguinus midas (Linnaeus, 1758)	x	x	x	x	D	2.50	1.06
	Saimiri sciureus (Linnaeus, 1758)		x			D	0.02	
	Sapajus apella (Linnaeus, 1758)	x	x	x	x	D	0.45	0.68
Ungulata	*Tapirus terrestris* (Linnaeus, 1758) [V]	x	x	x	x	D, I	0.16	0.06
	Pecari tajacu (Linnaeus, 1758)	x	x	x	x	D, I	0.13	0.30
	Tayassu pecari (Link, 1795) [V]	x				I		
	Mazama americana (Erxleben, 1777)	x	x	x	x	D, I	0.11	0.23
	Mazama gouazoubira (G. Fischer [von Waldheim], 1814)	x	x	x	x	D, I	0.18	0.30
Rodentia	*Myoprocta exilis* (Wagler, 1831)		x	x	x	D	0.02	0.06
	Sciurus aestuans (Linnaeus, 1766)	x	x	x	x	D	0.22	0.19
	Dasyprocta leporina (Linnaeus, 1758)	x	x	x	x	D, I	0.20	0.39
	Cuniculus paca (Linnaeus, 1766)	x		x	x	I		
Pilosa	*Myrmecophaga tridactyla* (Linnaeus, 1758) [V]		x		x	D	0,04	0.02
	Tamandua tetradactyla (Linnaeus, 1758)	x	x		x	D	0.07	0.02
Cingulata	*Cabassous unicinctus* (Linnaeus, 1758)		x	x		D, I	0.04	0.02
	Euphractus sexcinctus (Linnaeus, 1758)				x	D		0.02
	*Dasypus kappleri (*Krauss, 1862*)*	x	x			I		
	Priodontes maximus (Kerr, 1792) [V]	x		x	x	I		
Carnivore	*Eira barbara* (Linnaeus, 1758)	x*	x	x	x	D	0.04	0.14
	Puma yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	x*				D		
	Leopardus spp.	x*	x	x*	x*	I		
	Panthera onca (Linnaeus, 1758)	x*	x*	x*	x*	D, I		0.02
	Puma concolor (Linnaeus, 1771)	x*	x*	x*	x*	I		
Chelonia	*Chelonoidis denticulata* (Linnaeus, 1766)[V]		x	x*		D, I	0.02	
	Platemys platycephala (Schneider, 1792)		x*	x*		D		

[V] Species considered to be vulnerable according to IUCN.

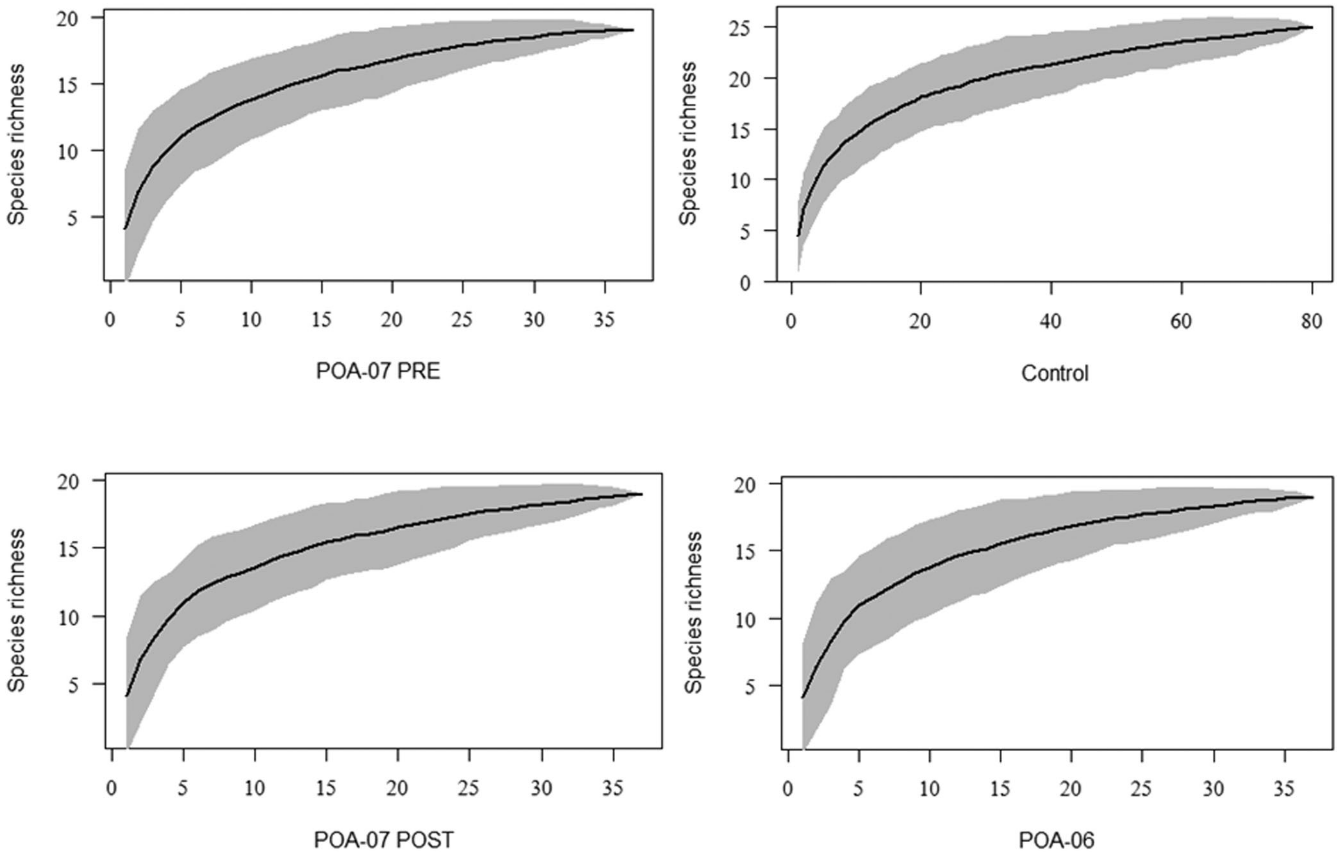

Figure 2. Cumulative species richness curve for medium and large vertebrates across the four study sites showing the 95% confidence intervals (gray areas). All four sampling areas reached asymptotes.

(Endo et al. 2010). We use the canonical significance threshold of $P > 0.05$ to accept the null hypothesis that there were no significant differences between treatments.

We combined data from visual and acoustic records to calculate the relative abundance of different species (detections every 10 km traveled on linear transects). We excluded from estimates of relative abundance all perpendicular distances farther than 50 m from transects to minimize the influence of detectability bias (Michalski & Peres 2007). Due to the low number of detections ($N < 30$) for most species, we did not attempt to derive a population density index (Buckland et al. 2010b). We used a non-parametric, Mann-Whitney test to examine differences between treatments (logged and unlogged areas). We considered transects in each POA as independent samples due to the minimum distance of 1.0 km between them. We also used an indicator analysis to understand which species differ in abundance between logged and unlogged areas (De Cáceres & Legendre 2009). For this analysis we used the relative frequency of each species in the indicator value index between unlogged and logged forests.

Results

Considering all line-transect censuses, we recorded a total of 29 species of medium and large vertebrates from 20 families, 15 orders and 28 genera. We also recorded eight additional species through direct and indirect observations outside systematic census routines (Table 2). Of the species total, six are considered Vulnerable by the International Union for Conservation of Nature (IUCN) (Table 2). Of all 1,537 detection events (visual and acoustic) obtained in 2012 ($\text{POA-07}_{\text{PRE}}$) and 2013 (other POAs), 809 took place in unlogged areas and 728 in logged areas. Overall encounter rates along transects in unlogged areas was significantly higher than in logged areas ($U_{10,12} = 90$, $P = 0.05$). The average encounter rate per 10 km walked in unlogged and logged areas was 14.27 (SD = ± 3.80) and 11.48 (SD = ± 2.33), respectively (Table 1). The ANOVAs of overall lateral detectability of all species detected among the four sampling areas was not significantly different (P = 0.056-0.881, mean ± SD = 0.499 ± 0.270). Species accumulation curves for the four areas suggest that the overall sampling effort deployed adequately sampled the medium and large vertebrate fauna of the Jari landscape (Figure 2).

The overall species richness detected in UL and LF areas was similar, ranging from 21 to 24 species. This variation was greater (10 - 19 species) if we consider individual transects within unlogged and logged forest treatments. Species richness was lower in transects at unlogged areas than in transects at logged areas, although the difference was not significant ($U_{10,12} = 40.5$, $P = 0.20$). The unlogged area had an average of 14.4 species (SD = ± 2.6) detected every 10 km walked, while logged areas had an average of 15.8 species (SD = ± 1.48). Only one species occurred exclusively in UL areas, the squirrel monkey (*Saimiri sciureus*), while the six-banded armadillo (*Euphractus sexcinctus*) was only detected in LF areas, but none of these species can be considered specialists of either logged or unlogged forests. The indicator analysis revealed the association of distribution pattern of four species (*Ara* spp. (P = 0.001), *Dasyprocta leporina* (P = 0.006), *Pecari tajacu* (P = 0.022) and *Eira barbara* (P = 0.028)) with

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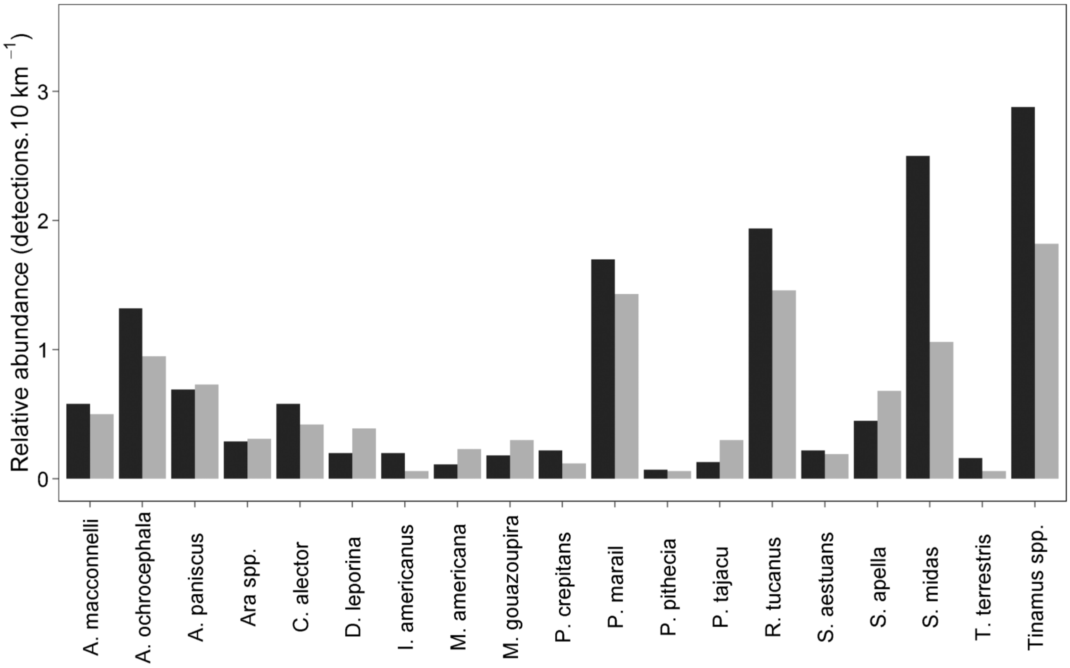

Figure 3. Change in relative abundance (detections • 10km^{-1} walked) of the main species detected in the two forest treatments (black: Unlogged Forest; gray: Logged Forest).

LF areas. On the other hand, we did not find any species that were significantly associated with UL areas.

Relative species abundance per transect did not differ between UL and LF areas ($U_{144,\ 190}$ = 14744.5, P = 0.19) (Figure 3). The mean abundance was 0.99 (± 1.02) and 0.73 (± 0.65) detections • 10 km^{-1}, respectively. The five most abundant species in UL and LF areas were the same (except for POA-06). These included a small-bodied callitrichid primate, the golden-handed tamarin (*Saguinus midas*) and four birds: white-throated toucan (*Ramphastos tucanus*), large tinamous (*Tinamus* spp.), yellow-crowned amazon (*Amazona ochrocephala*) and marail guan (*Penelope marail*). The difference in POA-06 is attributed to the presence of spider monkey (*Ateles paniscus*), the fourth most abundant species (1.0 detection • 10 km^{-1}) at this site.

Three species showed significantly different relative abundances between the two treatments. *S. midas* showed increased abundance in unlogged forest compared to logged forest ($U_{10,12}$ = 100, $P < 0.001$), with means of 2.3 (± 1.1) and 1.0 (± 0.7) detections • 10 km^{-1}, respectively. The same pattern was observed for large tinamous, in that their relative abundance was 62% lower in logged compared to unlogged areas ($U_{10,12}$ = 108, $P < 0.001$). Agouti (*D. leporina*) was the only species with the highest relative abundance in logged areas ($U_{10,12}$ = 26.5, P = 0.03), with mean encounter rates of 0.14 (± 0.25) and 0.41 (± 0.31) for unlogged and logged forest areas, respectively. Moreover, this species was detected in 11 of 12 transects censused in logged areas, but in only three of the 10 transects censused in unlogged areas.

Discussion

Timber extraction in Amazonian forests holds a huge potential for growth in terms of both spatial extent and revenue (FAO 2010, Shearman et al. 2012), and this is often considered a relatively benign land-use in terms of biodiversity responses to selective logging (Gibson et al. 2011). Despite its importance in the neotropics, there are still insufficient studies attempting to understand the effects of tropical forest timber extraction on medium and large vertebrates (Laufer et al. 2013). In addition, whether logging induces either positive or negative impacts on forest fauna remains unclear, as studies have found different results. For example, studies conducted in similar forests on the French Guiana showed opposite results for the trends on abundance of two species groups (*Psophia crepitans* and Tinamous) (Thiollay 1997, Bicknell & Peres, 2010). As we predicted, this study suggests that reduced-impact selective logging in itself did not strongly affect the species composition and relative abundance of the medium and large vertebrate populations, except for a few species. These results are consistent with other assessments of the degree to which RIL disturbance in tropical forests affects forest biotas (Azevedo-Ramos et al. 2006, Bicknell et al. 2014). The largely unaltered population abundances may result from the interaction of several factors, such as low levels of basal area removal and collateral damage, conserved landscape context and proximity to unlogged forest, and resilient life histories of several species.

A total of 28 of the 37 medium and large-bodied vertebrate species recorded had already been detected in other studies conducted in the Jari study landscape (e.g. Parry et al. 2007, 2009). However, our study detected nine additional taxa, including harpy eagle (*Harpia harpyja*), jaguarundi (*Puma yagouaroundi*), Brazilian squirrel (*Sciurus aestuans*), southern anteater (*Tamandua tretradactyla*), greater long-nosed armadillo (*Dasypus kappleri*), six-banded armadillo (*E. sexcinctus*), southern naked-tailed armadillo (*Cabassous unicinctus*), yellow-footed tortoise (*Chelonoidis denticulata*) and twist-neck turtle (*Platemys platycephala*) (Table 2). This is largely a function of our greater sampling effort compared to previous studies in the area, which increased the detection probability of these species.

In addition, earlier studies in the region partly focused on secondary forests after 18-23 years of regeneration. In these species, *E. sexcinctus* and *D. kapleri* were exclusively observed in logged and unlogged forests, respectively (Table 2). *E. sexcinctus* is known to use dry areas of wooded scrub (*cerrados*) and the boundaries between secondary and primary forest (Sousa e Silva Junior & Nunes 2001). The fact that this species was restricted to logged forests therefore supports the disturbance effect induced by RIL. On the other hand, *D. kappleri* is a well known primary forest species (Eisenberg 1989), but is often missing from hunted disturbed forests (e.g. Stone et al. 2009, Sampaio et al. 2010). *P. yagouaroundi* was recorded while moving between different sites within unlogged forest, but this species occurs in a broad range of both open and closed habitats, as well as fragmented and disturbed areas with exotic tree plantations (Michalski et al. 2006). The other six species did not show any clear pattern, being recorded in both unlogged and logged forests.

We uncovered widely variable encounter rates on transects within different forest treatments. This variation was largely due to the higher encounter rates in the control area (Table 1). However, the overall relative abundance did not differ across the two treatments. This indicates that RIL did not induce detectable changes in the relative abundance of medium and large vertebrates between UL and LF areas, at least within 6-18 month recovery time frame documented here. Only three taxa (*S. midas*, *Tinamus* spp. and *D. leporina*) showed significant differences in their relative abundances between treatments. This likely reflects the different ecological requirements of individual species (Bicknell & Peres 2010), variation in their resilience to different disturbance levels, and time required to recovery from RIL disturbance.

Two species that were more significantly abundant in UL areas — golden-handed tamarin and large tinamous — which *Tinamus* spp. is relatively intolerant to selective logging (Thiollay 1992, 1997, Mason 1996). However, the response of golden-handed tamarin was unexpected, given that this specie is a generalist insectivore-frugivore (Pack et al. 1999), and are widely found in secondary forest (Rylands & Keuroghlian 1988). As such, we would expect this species to increase in relative abundance in logged areas. Lower food resource availability in logged areas is a possible explanation, as some key food trees for this species, such as *Manilkara bidentata* (Oliveira & Ferrari 2000), were exploited in the study area. Moreover, other food trees could have been affected by collateral damage from RIL. During the planning and execution phases of RIL cutting activities, several commercially valuable tree species bearing large fruits and seeds may be safeguarded (Putz et al. 2008), whereas forest species with minor or no commercial value are more often damaged during the implementation of roads, skid trails and roundlog storage areas. However, trees earmarked to be logged may have their felling planned so as to not damage seedlings and saplings for a second cutting cycle (Putz et al. 2008, Macpherson et al. 2012). So, until sufficient regeneration occurs in areas exposed to collateral damage, the abundance of golden-handed tamarin in recently-logged areas may decline because they prefer fruits with medium and small seeds (Oliveira & Ferrari 2000), and preferentially inhabit low-and middle strata vegetation (Randarshan et al. 2011).

The only species that apparently benefited from the structural disturbance accompanying RIL was *D. leporina*. This is consistent with studies evaluating this species in other selective logged neotropical forests (Bicknell & Peres 2010). The increase in relative abundance in the area logged is possibly due to behavioral plasticity of this species, which can subsist in even small forest fragments (Jorge 2008, Norris et al. 2010). Moreover, our indicator analysis suggests that *D. leporina* could be defined as an indicator species of logged forests. The same applies to *E. barbara* that was more often recorded in logged forests. Both of these two species are known to prefer or tolerate disturbed forest habitats (Presley 2000, Jorge 2008), so their grouping with logging indicator taxa supports the notion that these species can subsist in large areas of RIL-disturbed forests.

In general, we found that reduced-impact logging did not affect the species composition and relative abundance of most medium and large-bodied vertebrates. The apparent lack of change in species composition and abundance can be explained by the life-history characteristics of the species in this study. Medium and large vertebrates are generally highly mobile, ensuring that they can move around the landscape, migrating to more suitable areas compared to areas affected by RIL (Azevedo-Ramos et al. 2006, Schleuning et al. 2011). In addition to species mobility, two important features of the landscape in the study area must be considered. The first feature is the presence of relatively large areas without any history of RIL disturbance immediately adjacent to areas with RIL activities. One of the guidelines of RIL planning is the choice of areas with gentle topography and high concentrations of tree species with high commercial value (Thiollay 1992, Putz et al. 2001). This fact allows for the persistence of "islands" of unlogged areas surrounded by logged ones. The second is the relatively well preserved matrix of the survey areas. Areas without any RIL disturbance can become a refuge for vertebrate species during reduced-impact logging operations, later acting as a recolonization source for the harvested areas (Johns 1996, Willot et al. 2000). Thus, interstitial areas of unlogged forests in our study landscape are likely to play a critical role in maintaining medium and large vertebrate populations throughout the RIL long-term cutting cycles of the overall forest mosaic.

However, there are other factors that can influence species responses to selective timber extraction. Recovery time, for example, can strongly influence assessments of the effects of selective logging (Putz et al. 2001, Jones et al. 2003, Clark et al. 2009). The response of organisms may have a time lag due to species-specific ecological factors, such as low reproductive rates and high longevity (Chapman et al. 2000, Owiunji 2000). As the recovery time between the end of RIL disturbance associated and field sampling was relatively short in this study (6-18 months), our conclusions should be interpreted with caution. Indeed, longer-term studies should be carried out in selectively logged areas to track how resident populations respond over time (Michalski & Peres 2013). Ecological monitoring in such areas would also help researchers understand the synergistic interactions between RIL and conventional selective logging and other structural or non-structural human-induced forest disturbances (Peres et al 2010). These may occur before or after selective cutting, and may include natural succession following droughts and hurricanes (Whitman et al. 1998, Chapman et al. 2000), overhunting of large-bodied vertebrates (De Thoisy et al. 2005, Poulsen et al. 2009) and forest wildfires (Uhl & Vieira 1989, Cochrane & Laurance 2002, Barlow & Peres 2008, FAO 2010).

This study has helped to understand the short-term responses of medium and large vertebrate populations to large-scale RIL operations in lowland tropical forests. However, there is still a long way to go to fully understand the effects of such RIL impacts in different areas, floristic contexts, landscapes and species assemblages, both within and outside Amazonia. This may yield data to improve our understanding of how to manage the > 45 million hectares of forest available for multiple natural resource use across the Brazilian Amazon alone (Bandeira et al. 2010). Monitoring of species contributing to forest regeneration (Wright et al. 2007, Terborgh et al. 2008) during the recovery process of selectively exploited forests should be undertaken by private companies, government agencies and local communities. With proper management, areas under low-impact selective logging can greatly contribute to the persistence of viable populations of most forest vertebrate species.

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Fishes from Baía da Medalha, southern Pantanal, Brazil: A 20 years review

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Abstract: Located in the Pantanal of Miranda-Abobral, the Baía da Medalha is the largest pond close to the Base de Estudos do Pantanal of the Universidade Federal de Mato Grosso do Sul. The Baía da Medalha has been a study site for several didactic and scientific projects for years. Nevertheless, its fish fauna has never been inventoried. Based on data collected from the beginning of the 1990s up to 2011, we provide a list of fish species from the Baía da Medalha. A total of 97 species were recorded, corresponding to about 40% of the species stated for the Pantanal. Characiformes and Siluriformes were the most species-rich orders, being Characidae and Cichlidae the families with the highest number of species. Regional seasonal flood dynamics and the abundance of aquatic macrophytes may be associated with this high diversity. The representative richness found in this lagoon highlights the importance of such taxonomic surveys to preserve the diversity of aquatic habitats within the Pantanal ecosystem.

Keywords: *lagoon, wetlands, Rio Miranda, ichthyofauna.*

SEVERO-NETO, F., TENCATT, L.F.C., COSTA-PEREIRA, R., TAVARES, L.E.R. **Peixes da Baía da Medalha, Pantanal Sul, Brasil: Uma revisão de 20 anos.** Biota Neotropica. 15(2): e20140116. http://dx.doi.org/10.1590/1676-06032015011614

Resumo: Localizada no Pantanal do Miranda-Abobral, a Baía da Medalha é a maior e mais próxima lagoa da Base de Estudos do Pantanal da Universidade Federal de Mato Grosso do Sul. A Baía da Medalha tem sido área de estudo de diversos projetos didáticos e científicos há anos, entretanto, nenhum inventário sobre sua ictiofauna foi realizado. Aqui é apresentada uma lista de espécies de peixes da Baía da Medalha baseado em dados de coletas do começo da década de 90 até 2011. Um total de 97 espécies foi registrado, correspondendo à cerca de 40% do total de espécies registradas para o Pantanal. Characiformes e Siluriformes foram as ordens mais ricas em espécies, sendo Characidae e Cichlidae as famílias com maior número de espécies. Dinâmicas de inundação sazonal e a abundância de macrófitas aquáticas podem ser associadas a esta alta diversidade. A representativa riqueza encontrada nesta lagoa ressalta a importância de levantamentos taxonômicos a fim de preservar a diversidade dos habitats aquáticos do dentro do ecossistema do Pantanal.

Palavras-chave: *Lagoa, áreas úmidas, rio Miranda, Ictiofauna.*

Introduction

The Pantanal is one of the largest continuous wetlands of the world (Junk et al. 2006) and currently possesses an ichthyofauna estimated around 270 species (Britski et al. 2007). The seasonal flooding of the large rivers that cross the Pantanal floodplain sustains a large number of temporary lentic systems, such as lagoons, ponds and meanders (Junk et al. 2006). These aquatic environments associated with large rivers are known as nursery and feeding areas for long-distance migratory species or even permanent habitats for sedentary species. For this reason, such aquatic environments are considered as hotspots of regional fish diversity (Kwak 1988, Bayley 1995).

The Pantanal is divided into 10 subareas according to their geomorphological, hydrological and biogeographical features (Lourival et al. 2000). The Base de Estudos do Pantanal (BEP) of the Universidade Federal de Mato Grosso do Sul (UFMS) is located in the Miranda subregion, which has the following boundaries: to the north, Abobral wetlands; to the south, the

Chaco forests of Porto Murtinho; to the east, the Aquidauna wetlands; and to the west, the Bodoquena Plateau and the Nabileque wetlands (Allem & Valls 1987). With its diversity of aquatic organisms, the BEP is an important site for scholars and researchers at all levels engaged in scientific studies (see Carvalho et al. 2003, Carvalho et al. 2007, Pivari et al. 2008). The Baía da Medalha is the closest lagoon to BEP, and, for logistical reasons, it is the most sampled aquatic habitat in the region. Despite the popularity of this study site and the numerous surveys, no list of fish species has ever been prepared. Therefore, we herein provide a list of fish species for the Baía da Medalha, southern Pantanal, based on a compilation of samplings that have taken place over the last 20 years.

Material and Methods

Study site

The Baía da Medalha (Figure 1) is a tributary lagoon of the Rio Miranda (19°34'34" S, 57°00'46" W), with a total area of approximately 5.4 ha. About 25% of its surface is covered by aquatic macrophytes, such as *Eichhornia azurea* (Pontederiaceae), which corresponds to 45% of the covered area, as well as species of the genera *Rhynchosphora* and *Oxycaryum* (Cyperaceae) (Figure 2). The seasonal flooding of the region follows a unimodal annual cycle whose amplitude varies between two and five meters and lasts from three to six months (Harris et al. 2005), with the high water period generally beginning in late December to April/May, when the river returns to its main channel.

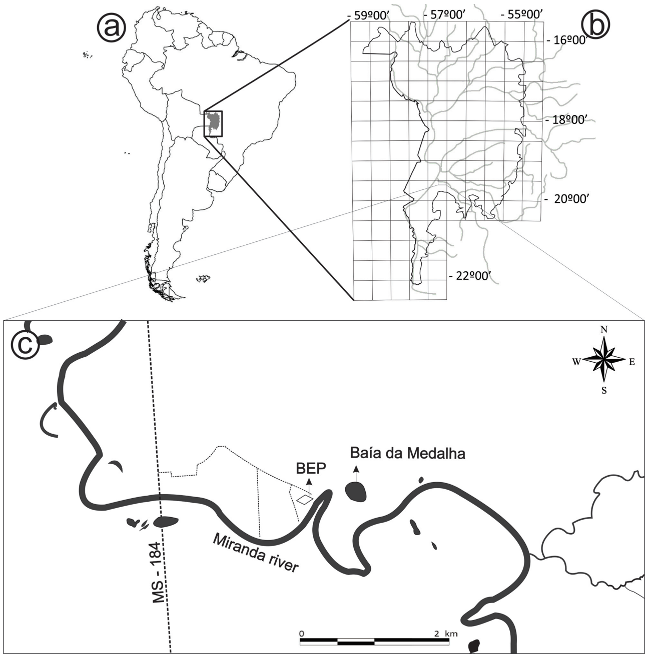

Figure 1. Location of Baía da Medalha, Miranda-abobral Pantanal subregion, mucipality of Corumbá, Mato Grosso do Sul, Brazil.

Samples

The data were compiled from fish samplings performed at the Baía da Medalha from the early 1990s up to 2011. Since these are random samplings for teaching and research purposes, there is no regular periodicity between samples. All samplings were performed during the daytime, generally with throw nets in the open areas and sieves below the macrophyte banks. As a result of the variety and the non- standardized samplings, only the species richness was considered for this study. Alternatively, an accumulation curve was made based in the total number of species collected over the years. Voucher specimens are hosted in the Coleção Ictiológica do Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (NUP) and in the Coleção Zoológica da Universidade Federal de Mato Grosso do Sul (ZUFMS-PIS). The identification of the specimens was made following Britski et al. (2007) and posterior revisionary studies of specific groups. The list of species was arranged according to Reis et al. (2003), with updates provided by www.fishbase.org and http://research.calacademy.org/ichthyology, when necessary.

Results and Discussion

A total of 97 species were recorded (Table 1), representing about 40% of Pantanal fish species (Britski et al. 2007). Resende (2000) recorded 101 fish species belonging to 20 families addressing four floodplain environments in the Miranda River Basin. Catella (1992) recorded a total of 75 species in a pond during the dry season in the Aquidauna subregion, which represents the eastern boundary of the Pantanal. During the same season, Baginski et al. (2007) recorded 95 species in communities of 15 lakes in the floodplain of the Cuiabá River, and Súarez et al. (2001) found a total of 51 fish species in 19 ponds in the Nhecolândia subregion,

Figure 2. View of Baía da Medalha on Miranda-Abobral Pantanal subregion, in September 2011.

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Table 1. Fish species recorded over 20 years in the Baía da Medalha, Pantanal. Species in bold were recorded inside the macrophyte belt.

			01. VII.90	**16. IX.93**	**26. X.96**	**01. IX.97**	**10. IX.99**	**01. VI.00**	**08. IX.09**	**21. IX.10**	**01. XII.10**	**02. XII.10**	**06. X.11**	**22. IV.12**
Characiformes														
	Curimatidae													
		Curimatella dorsalis Eigenmann & Eigenmann, 1889		X										
		Cyphocharax gillii (Eigenmann & Kennedy, 1903)			X		X		X	X				
		Potamorhina squamoralevis (Braga & Azpeculieta, 1983)					X		X	X				
		Psectrogaster curviventris Eigenmann & Kennedy, 1903					X		X	X				
		Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)					X							
		Steindachnerina conspersa (Holmberg, 1891)											X	
		Steindachnerina nigrotaenia (Boulenger, 1902)		X										
	Prochilodontidae													
		Prochilodus lineatus (Valenciennes, 1836)		X					X			X	X	
	Anostomidae													
		***Abramites hypselonotus* (Günther, 1868)**		X										
		Leporinus friderici (Bloch, 1794)							X					
		Leporinus lacustris Campos, 1945		X					X					
		Leporinus obtusidens (Valenciennes, 1836)											X	
	Crenuchidae Characidiinae													
		***Characidium laterale* (Boulenger, 1895)**									X	X		
		***Characidium* aff. *zebra* Eigenmann, 1909**									X	X		
	Characidae Iguanodectinae													
		Piabucus melanostomus (Holmberg, 1891)		X										
	Bryconinae													
		Brycon hilarii (Valenciennes, 1850)							X					
		Triportheus nematurus (Kner, 1858)		X			X							

Continued on next page

Table 1. Continued.

		01. VII.90	16. IX.93	26. X.96	01. IX.97	10. IX.99	01. VI.00	08. IX.09	21. IX.10	01. XII.10	02. XII.10	06. X.11	22. IV.12
	***Triportheus pantanensis* Malabarba, 2004**		X						X	X	X	X	
Serrasalminae													
	Metynnis maculatus (Kner, 1858)											X	
	Metynnis cf. *mola* Eigenmann & Kennedy, 1903		X					X					
	Mylossoma duriventre (Cuvier, 1818)		X										
	Pygocentrus nattereri Kner, 1858	X					X		X			X	
	Serrasalmus maculatus Kner, 1858		X				X					X	
	Serrasalmus marginatus Valenciennes, 1837		X				X					X	
Aphyocharacinae													
	***Aphyocharax anisitsi* Eigenmann & Kennedy, 1903**									X	X		
	***Aphyocharax dentatus* Eigenmann & Kennedy, 1903**									X	X		
	***Aphyocharax nattereri* (Steindachner, 1882)**										X		
	***Prionobrama paraguayensis* (Eigenmann, 1914)**			X									
Incertae sedis													
	***Astyanax asuncionensis* Géry, 1972**		X	X				X	X	X	X	X	
	Ctenobrycon alleni (Eigenmann & Mcatee, 1908)				X			X					
	***Gymnocorymbus ternetzi* (Boulenger, 1895)**		X					X		X			
	***Hemigrammus ulreyi* (Boulenger, 1895)**		X							X	X		
	***Hyphessobrycon eques* (Steindachner, 1882)**		X							X			
	Markiana nigripinnis (Perugia, 1891)											X	
	***Moenkhausia dichroura* (Kner, 1858)**									X			
	***Moenkhausia* aff. *sanctaefilomenae* (Steindachner, 1907)**		X							X	X		
	***Psellogrammus kennedyi* (Eigenmann, 1903)**		X							X	X		
	***Bryconops* sp.**		X										
Characinae													
	Charax leticiae Lucena, 1987	X	X										

Continued on next page

Table 1. Continued.

			01. VII.90	16. IX.93	26. X.96	01. IX.97	10. IX.99	01. VI.00	08. IX.09	21. IX.10	01. XII.10	02. XII.10	06. X.11	22. IV.12
		Cynopotamus kincaidi (Schultz, 1950)		X										
		Galeocharax humeralis (Valenciennes 1834)		X										
		Roeboides microlepis (Reinhardt, 1851)											X	
		Roeboides descalvadensis Fowler, 1932					X							
		Roeboides affinis (Gunther, 1868)					X							
	Stethaprioninae													
		Brachychalcinus retrospina Boulenger, 1892								X				
		Poptella paraguayensis (Eigenmann, 1907)		X			X		X	X	X		X	
	Tetragonopterinae													
		Tetragonopterus argenteus Cuvier, 1816							X				X	
	Cheirodontinae													
		***Odontostilbe paraguayensis* Eigenmann & Kennedy, 1903**		X										
		***Odontostilbe pequira* (Steindachner, 1882)**									X			
		***Serrapinnus notomelas* (Eigenmann, 1915)**									X	X		
	Stevardiinae													
		***Piabarchus analis* (Eigenmann, 1914)**										X		
	Acestrorhynchidae													
		Acestrorhynchus pantaneiro Menezes, 1992		X					X				X	
	Erythrinidae													
		Hoplerythrinus unitaeniatus Spix, 1829		X										
		***Hoplias* aff. *malabaricus* (Bloch, 1794)**									X	X	X	
	Lebiasinidae													
	Pyrrhulininae													
		***Pyrrhulina australis* Eigenmann & Kennedy, 1903**									X	X		
Siluriformes														
	Callichthydae													
	Callychthyinae													
		Hoplosternum littorale (Hancock, 1828)	X											

Continued on next page

Table 1. Continued.

		01. VII.90	16. IX.93	26. X.96	01. IX.97	10. IX.99	01. VI.00	08. IX.09	21. IX.10	01. XII.10	02. XII.10	06. X.11	22. IV.12
Corydoradinae													
	Corydoras britskii (Nijssen & Isbrücker, 1983)					X		X					
	Corydoras hastatus **Eigenmann & Eigenmann, 1888**					X					X		
Loricariidae Hypoptopomatinae													
	Hypoptopoma inexspectatum **(Holmberg, 1893)**									X	X		
Loricariinae													
	Loricariichthys platymetopon Isbrücker & Nijssen, 1979		X					X					
	Rineloricaria parva **Boulenger, 1895**		X										
	Rineloricaria **sp.**									X			
Hypostominae													
	Hypostomus boulengeri **(Eigenmann & Kennedy, 1903)**									X	X		
	Pterygoplichthys ambrosettii **(Holmberg, 1893)**							X	X				
Heptapteridae													
	Pimelodella mucosa Eigenmann & Ward, 1907											X	
	Pimelodella sp.		X										
	Rhamdia quelen (Quoy & Gaimard, 1824)		X										
Pimelodidae													
	Iheringichthys labrosus (Lütken, 1874)		X										
	Pimelodus argenteus Perugia, 1891			X		X			X				
	Pimelodus maculatus Lacépède, 1803			X								X	
Doradidae													
	Anadoras weddellii **(Castelnau, 1855)**										X		
	Ossancora eigenmanni **(Boulenger, 1895)**			X								X	X
Auchenipteridae Auchenipterinae													
	Auchenipterus osteomystax **(Ribeiro, 1918)**	X											
	Trachelyopterus striatulus **(Steindachner, 1877)**										X		

Continued on next page

Table 1. Continued.

			01. VII.90	16. IX.93	26. X.96	01. IX.97	10. IX.99	01. VI.00	08. IX.09	21. IX.10	01. XII.10	02. XII.10	06. X.11	22. IV.12
		***Trachelyopterus coriaceus* Valenciennes, 1840**										X		
Gymnotiformes														
	Gymnotidae													
		***Gymnotus inaequilabiatus* (Valenciennes, 1839)**										X		
	Sternopygidae													
		***Eigenmannia trilineata* López & Castelo, 1966**										X		
	Rhamphichthyidae													
		***Gymnorhamphichthys britskii* Carvalho, Ramos & Albert, 2011**				X								
	Hypopomidae													
		***Brachyhypopomus* sp.**		X										
Cyprinodontiformes														
	Rivulidae													
		Pterolebias longipinnis Garman, 1895												X
		Pterolebias phasianus Costa, 1988												X
Beloniformes														
	Belonidae													
		Potamorhaphis eigenmanni Ribeiro, 1915		X										
Synbranchiformes														
	Synbranchidae													
		***Synbranchus marmoratus* Bloch, 1795**												X
Perciformes														
	Sciaenidae													
		Pachyurus bonariensis Steindachner, 1879		X										
	Cichlidae													
	Astronotinae													
		***Astronotus crassipinnis* (Heckel, 1840)**		X						X				
		Chaetobranchopsis australis Eigenmann & Ward, 1907												
	Cichlasomatinae													
		***Aequidens plagiozonatus* Kullander, 1984**		X							X	X		X
		***Bujurquina vittata* (Heckel, 1840)**		X	X								X	
		***Cichlasoma dimerus* (Heckel, 1840)**		X							X	X		
		***Laetacara dorsigera* (Heckel, 1840)**		X										

Continued on next page

Table 1. Continued.

			01. VII.90	16. IX.93	26. X.96	01. IX.97	10. IX.99	01. VI.00	08. IX.09	21. IX.10	01. XII.10	02. XII.10	06. X.11	22. IV.12
+		***Mesonauta festivus* (Heckel, 1840)**		X										
	Cichlinae													
		***Crenicichla lepidota* Heckel, 1840**		X							X	X		
		***Crenicichla semifasciata* (Heckel, 1840)**									X			
	Geophaginae													
		***Apistogramma inconspicua* Kullander, 1983**									X	X		X
		Gymnogeophagus balzanii (Perugia, 1891)		X		X			X	X				
		Satanoperca pappaterra (Heckel, 1840)							X	X				

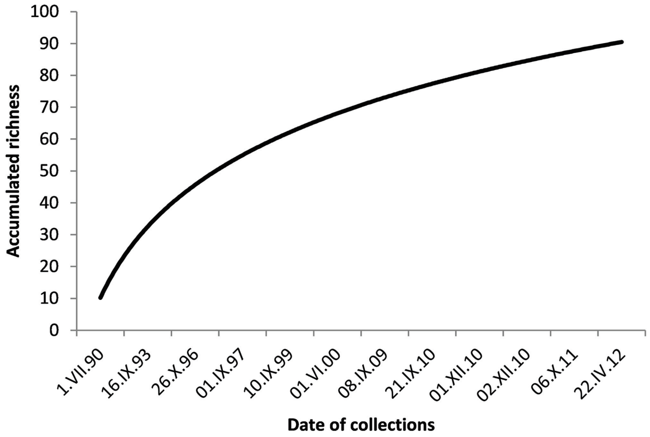

Figure 3. Accumulation curve of fish species over 20 years of sampling in a bay of the Pantanal, Brazil.

varying from seven to 26 species between ponds. As in the aforementioned works, the total number of species and the composition are similar to the ichthyofauna of the Baía da Medalha, which follows the pattern for the Neotropical communities (Lowe-McConnell 1999), with Characiformes as the most representative order (n = 57), being consecutively followed by Siluriformes (n = 21), Perciformes (n = 13), Gymnotiformes (n = 4), Cyprinodontiformes (n = 2), Beloniformes (n = 1) and Synbranchiformes (n = 1). Accumulation curve of species over the years is presented in Figure 3.

Among the 25 families recorded, Characidae and Cichlidae were the richest, with 29 and 12 species, respectively. Characidae is the largest family within Characiformes and accounted for approximately 80% of the abundance in a pond in the Aquidauna subregion during the dry season (Catella 1992). Britski et al. (2007) reported 16 valid species of native cichlids for the Pantanal region, and from that total, 75% were recorded in the Baía da Medalha. This large representation follows the South American pattern, where cichlids are especially successful in lateral lakes of riverine systems (Lowe-McConell 1999).

Macrophytes increase the heterogeneity of microhabitats and therefore may be associated with greater species richness in local communities (Agostinho et al. 2002). Allied to this, macrophytes provide refuge from predators, food source and suitable sites for breeding and larval development for many fish species (Chick & Mclvor 1994, 1997, Grenouillet & Pont 2001). At Baía da Medalha, practically almost half of the richness registered (47 spp., Table 1) was under the macrophyte belt. These are basically small species, such as members of Aphyocharacinae and Cheirodontinae, most likely seeking refuge among the branches from predators, as well as the juvenile forms of *Hoplias malabaricus* and *Triportheus pantanensis*. Among Siluriformes, *Hypoptopoma inexspectatum* was the most frequent in this region, probably feeding on periphyton that grows on the stalks of aquatic macrophytes. Other representatives exclusively found in this meso-habitat are nocturnal and photophobic species, such as Gymnotiformes and Auchenipteridae members, hiding in dens in the transition between the ravine and the macrophytes.

Besides the representative coverage of macrophytes, the hydrodynamics of the Miranda River flooding pulse may also be associated with local species richness. According to Chernoff & Willink (2000), Pantanal environments that are seasonally flooded, such as ponds, harbor the major diversity of the plain, like plants, zoobenthos, fish and decapod crustaceans, compared to habitats that are subject to river current. Moreover, the flood season acts as a homogenizing factor in the floodplain, so the local species composition is maintained by stochastic factors (Thomaz et al. 2007), explaining, in part, the fact that the accumulation curve has not reached the asymptote, despite the large number of species found in these two decades. Thomaz et al. (2007) emphasize that floodplains are formed by a variety of aquatic habitats, such as permanent ponds, canals, backwaters, and main channels of rivers, and that maintaining the diversity and connectivity of these environments is the key to preservation of the entire ecosystem.

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