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Filling data gaps on the diversity and distribution of Amazonian bats (Chiroptera): The case of Amapá, easternmost Brazil

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ABSTRACT. Brazil is the second most bat species-rich country in the world, but the information on its species diversity, occurrence and distribution is still heterogeneous and fragmented. None of the Brazilian biomes are well surveyed for bats, but this situation is more critical in Amazonia, an area covering nearly 2/3 of the country. Here we provide updated information on the bats of Amapá, once a data gap in the diversity and distribution of bats in the easternmost Amazonia, and the Guiana Shield as well. Rapid biological assessments (5,551 mistnet.hours) were conducted in conservation units and areas of concern, resulting in 1,695 captures, 59 species, 36 genera and six families for the State. New records for the state and for the Guiana Shield area are reported. With our records, 82 species of bats are currently known in Amapá, filling a gap in the knowledge of bat fauna in the Amazon River's delta region.

KEY WORDS. Biogeographic patterns; Eastern Amazonia; Guiana Shield; Rapid Assessment Program (RAP); species distribution.

Brazil holds the second richest bat fauna in the world (167 species in nine families), after Colombia (178 species) (Alberico *et al*. 2000, Reis *et al*. 2007, A. Paglia pers. comm.). Is spite of such richness, information on the diversity, occurrence and distribution of Brazilian bat species is still heterogeneous and fragmented. None of the Brazilian biomes are well surveyed for bats, but this situation is more critical in Amazonia, an area covering nearly 2/3 of the country. Official bat records are missing for nearly 75% of this extraordinairily species rich biome (Bernard *et al*. 2011). In spite of that, the top species-rich sites in Brazil are located in that region: Alter do Chão, state of Pará (Bernard & Fenton 2002), and the BDFFP reserves in Manaus, state of Amazonas (Sampaio *et al*. 2003), each holding 72 species.

The poor sampling of the Brazilian Amazonia results in large distributional data gaps, and as a consequence, refined biogeographic patterns of the bats in the Amazon Basin are still missing (Lim & Engstrom 2001b). The gaps in the knowledge for this important and diverse order of mammals result mainly from the complexities of performing inventories in Amazonia, and consequently, from the small number of well-sampled sites in the region (Lim & Engstrom 2001b, Bernard & Fenton 2002). Until the beginning of 2000s, little was know regarding the regional distribution of bat species in the state of Amapá (easternmost corner of the Brazilian Amazon) (Martins *et al*. 2006). Bat records for this region were only sparse and sporadic (Carvalho 1962, Piccinini 1974, Mok *et al*. 1982, Peracchi *et al*. 1984, Bernard & Sampaio 2008).

Covering 142,814 km^2, Amapá is well preserved, with more than 90% of its area in pristine condition (INPE 2006). A large proportion of the state's territory (circa 70%) is protected by state and federal conservation units and indigenous lands, providing good conditions for sampling plant and animal communities that have not been affected by deforestation or other anthropogenic impacts. Moreover, due to the geographic location of Amapá – on the delta of the Amazon River and marking the transition to the highlands of the Guiana Shield – data on the distribution of bat species in the state are required to refine analyses of possible differences between the faunal components of eastern, western and central Amazonia (Bernard *et al*. 2001). In order to contribute with the filling of data gaps on the bat distribution in Amazonia here we a) present an updated analysis on the bat diversity in Amapá, b) provide comments on new records for the state and for the Guiana Shield, c) compare the bat fauna in Amapá in the context of the Guiana Shield, and d) analyze the contribution of the conservation units for the maintenance of Amapá's bat diversity.

MATERIAL AND METHODS

Ten rapid biological assessments were conducted at the following conservation units: Parque Nacional Montanhas do Tumucumaque (PNMT), Floresta Nacional do Amapá (FNA), and the Reserva de Desenvolvimento Sustentável Rio Iratapuru (RDSI, Fig. 1, Tab. I). A complete description of the three conservation units sampled, the methodology used for site selection, and for the capture and identification of bats can be found in Martins *et al.* (2006). The sampled areas consist of a mosaic of non-flooded terra-firme forests and wetland forests. Each site was sampled for a maximum period of 10 consecutive nights, with mist-nets set up to three meters high in the understory and along trails in the forest. During most nights, 10 mist-nets were opened from 18:00 to 24:00 h. The sampling effort was calculated in net-hours (mnh), i.e., one 12 x 2.5 m mist-net open for one hour equals 1 mnh. The species accumulation curve was calculated based on the capture effort of each sampled night and the species accumulation.

Data from two previous, unpublished studies were used to complement our species list and analysis: an eight-month assessment of the Área de Proteção Ambiental do Rio Curiaú (Curiaú Environmentally Protected Area – APA Curiaú); plus data from a 18-day survey at the Reserva Biológica do Lago Piratuba (Lake Piratuba Biological Reserve – REBIO Piratuba) (Fig. 1). APA Curiaú (21,676 ha), located on the southeastern portion of Amapá, on the banks of the Amazonas River, has three distinct ecosystems: cerrado (savannas), wet plains, and

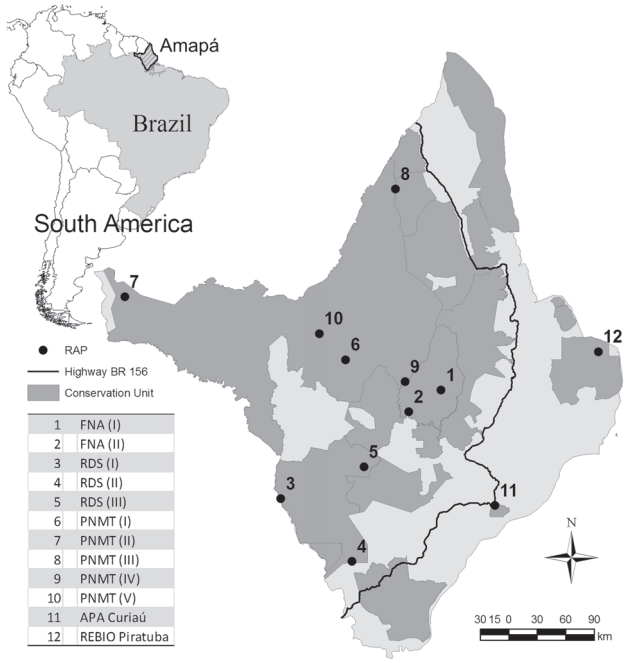

Figure. 1. Location of the rapid biological inventories for bat species conducted in Floresta Nacional do Amapá (FNA), Reserva de Desenvolvimento Sustentável do Rio Iratapuru (RDSI), Parque Nacional Montanhas do Tumucumaque (PNMT), Área de Proteção Ambiental do Rio Curiaú, and Reserva Biológica do Lago Piratuba, Conservation Units in the State of Amapá, Brazil, 2004-2006.

Table I. Location, sample effort and capture index of bats obtained in two rapid biological inventories in Floresta Nacional do Amapá (FNA), three in Reserva de Desenvolvimento Sustentável do Rio Iratapuru (RDSI), five expeditions to Parque Nacional Montanhas do Tumucumaque (PNMT), one to APA do Rio Curiaú (APA Curiaú), and one to Reserva Biológica do Lago Piratuba (REBIO Piratuba), all Conservation Units in the state of Amapá, Brazil. 2004-2006.

Site	Nights	Effort (nets-hour)	Species	Captures	Species/capture	Species/effort	Captures/effort
PNMT I (52°29'32"W; 01°35'45"N)	8	326.0	29	304	0.09	0.09	0.93
PNMT II (54°35'15"W; 02°11'36"N)	8	424.0	27	166	0.16	0.06	0.39
PNMT III (52°01'10"W; 03°12'59"N)	10	703.0	19	33	0.58	0.03	0.05
PNMT IV (51°55'39"W; 01°23'13"N)	9	664.0	28	195	0.14	0.04	0.29
PNMT V (52°44'28"W; 01°50'41"N)	10	760.0	28	167	0.17	0.04	0.22
Total (PNMT)	45	2877.0	48	865	0.06	0.02	0.30
RDSI I (53°06'24"W; 00°16'35"N)	9	438.5	19	121	0.15	0.04	0.27
RDSI II (52°26'24"W; 00°18'36"S)	8	625.5	23	168	0.14	0.04	0.27
RDSI III (52°19'08.3"W; 0°34'45"N)	10	565.0	29	142	0.20	0.05	0.25
Total (RDSI)	27	1629.0	40	431	0.09	0.02	0.26
FNA I (51°35'17"W; 01°18'07"N)	8	542.0	35	268	0.13	0.06	0.49
FNA II (51°53'37"W; 01°06'37"N)	9	504.0	21	131	0.17	0.04	0.23
Total (FNA)	17	1045.0	38	399	0.09	0.04	0.36
APA do Curiaú (00° 00'-00°15'N; 51°00'W)	14	1070.0	37	342	0.11	0.03	0.32
REBIO Piratuba (01°10'-01°50'N; 49°34'-50°34'W)	17	917.0	29	176	0.16	0.03	0.19
Total	120	7539.0	69	2213	0.03	0.01	0.29

várzeas (white water flooded forests). The sampling methodology used in these two sites was similar to that described by Martins *et al*. (2006). APA Curiaú was sampled for 14 nights, with monthly captures conducted between November, 2005 and June, 2006. REBIO Piratuba (395,000 ha) is located in the Atlantic sector of the coastal plains of Amapá, near the delta of the Amazonas River, an area where the coastal plain reaches its wider longitudinal extension and forms a large complex of lakes. The main ecosystems are wetlands, mangroves, flooded plains and small patches of rainforest. REBIO was sampled for 17 nights, between 9 and 28 of November 2006, along its coastal area, including mangroves and meadows.

A similarity analysis was performed focusing only on areas of the Guiana Shield (see Lim *et al*. 2005), based on a species by area matrix (see Simmons & Voss 1998, Lim & Engstrom 2001b, Bernard & Fenton 2002). When using that matrix, the list from Iwokrama was updated based on new data from Lim & Engstrom (2005); corrections and updates were made on the list of species that occur in French Guiana based on more recent data for the localities of Saül and Arataye (Simmons *et al*. 2000), and taxonomic adjustments, as for example the non validity of *Molossus barnesi* Thomas, 1905 (Molossidae) (Eger 2007). We used Jaccard's coefficient (Jij = Cij/Tij, where Cij is the number of species common to both faunas and Tij is the total number of species in the two faunas combined (Tij = Ni + Nj – Cij)) to calculate faunal similarity between areas. Areas were clustered by the unweighted pair group method with arithmetic average (UPGMA), using the software MVSP 3.1 (Kovach 1993).

For the species captured in Amapá, we followed the nomenclatures proposed by Koopman (1993), Lim (1997) – which considered *Artibeus planirostris* (Leach, 1821) (Phyllostomidae) as a valid species for the sampled area –, Simmons & Voss (1998) and Simmons (2005) . Unlike the latter author, however, we did not consider *Micronycteris homezi* Pirlot, 1967 (Phyllostomidae) as a valid species (Ochoa & Sanchez 2005). We excluded the record for *Eptesicus fuscus* Beauvois, 1796 (Vespertilionidae) made by Piccinini (1974), because later identifications of the specimen in question have revealed that it is in fact *Eptesicus furinalis* d'Orbigny, 1847 (Mok *et al*. 1982). Vouchers of the specimens collected are deposited at the Coleção de Fauna do Amapá, at Instituto de Pesquisas Científicas e Tecnológicas do Amapá (IEPA), in Macapá, Brazil. Captures and collections were conducted with permits 002/2004 (FNA), 143/2004 (RDSI), and 075/2004 (PNMT), issued by IBAMA.

RESULTS

Although we tried to standardize our capture efforts, unexpected events such as intense rain and logistical problems to access the sites created some difficulties. Therefore, sampling nights per site varied between 8 and 10, and capture effort between 326 and 760 mnh per inventory (Tab. I).

Two inventories were conducted (total sampling effort of 1,045 mnh) at FNA, resulting in 399 captures, 38 species, 29 genera, and five families (Tabs I and II). The three most frequent species were *Artibeus planirostris*, *Artibeus obscurus* Schinz, 1821, and *Carollia perspicillata* Linnaeus, 1758. Eighteen species were recorded in both sampled sites. Of these, 17 were collected only during the first expedition, and three exclusively during the second. Twelve species were captured only once. The number of recorded species per night varied between zero and 23. Average capture indexes were 0.36 bat/mnh (varying between zero and 0.77 bat/mnh), 0.09 species/capture and 0.04 species/mnh.

Five inventories were conducted at PNMT (2,877 mnh), totaling 865 captures, 48 species, 32 genera and five families. The three most frequent species were *A. planirostris* (367 captures), *A. obscurus* (71), and *Rhinophylla pumilio* Peters, 1865 (57). Seven species were recorded in all five inventories and 14 were recorded only once. The number of recorded species per night varied between one and 16. Capture indexes were 0.30 bat/mnh (from 0.05 to 0.93 bat/mnh), 0.06 species/capture and 0.02 species/mnh.

Three inventories were conducted at RDSI (1,629 mnh), totaling 431 captures, 40 species, 27 genera and five families. The three most frequent species were *A. planirostris* (87 captures), *Pteronotus parnellii* Gray, 1843 (46) e *R. pumilio* (44). Ten species were common to all three inventories and 11 were captured once. The number of recorded species per night varied between one and 14. Capture indexes were 0.26 bat/mnh, 0.09 species/capture and 0.02 species/mnh.

When computed together, the 10 inventories resulted in 89 sampling nights and 5,552 mnh of capture effort. A total of 1,695 specimens were recorded, belonging to 55 species, 36 genera and six families: Emballonuridae, Mormoopidae, Phyllostomidae, Noctilionidae, Vespertilionidae and Molossidae (Tab. II). The five most abundant species were *A. planirostris* (545 captures), *A. obscurus* (123), *C. perspicillata* (117), *R. pumilio* (115), and *Lonchophylla thomasi* J.A. Allen, 1904 (109). Altogether, these species represented 59.5% of all captures and the most frequent species, the frugivorous *A. planirostris*, was responsible for 32% of all captures. Eight species were captured once in all areas and another five (*A. obscurus*, *A. planirostris*, *Carollia brevicauda* Schinz, 1821, *L. thomasi* and *Phyllostomus elongatus* E. Geoffroy, 1810) were recorded in all inventories. The average capture indexes for the 10 inventories were 0.31 bat/mnh, 0.03 species/capture and 0.01 species/mnh. With exception of FNA II, the species accumulation curve did not indicate evident stabilization (Fig. 2).

Only one inventory was conducted at REBIO Piratuba (17 nights, 917 mnh), with 176 captures, 29 species, 20 genera and six families. The three most frequent species were *C. perspicillata* (33 captures), *P. elongatus* (20) e *A. planirostris* (18). Eight species were captured once. The number of recorded species per night varied between zero and 11. The average capture indexes were 0.19 bat/mnh, 0.16 species/capture and 0.03 species/mnh.

Table II. Updated list of bat species for the State of Amapá, Brazil. Sources: (A) Carvalho (1962), (B) Piccinini (1974), (C) Taddei *et al.* (1978), (D) Mok *et al.* (1982), (E) Peracchi *et al.* (1984), (F) This study, (G) Curiaú (unpubl. data), (H) REBIO Piratuba (unpub. data), (*) new records for the state, obtained in this study.

Species/Family	PNMT						FNA			RDSI				Total	Other sources
	I	II	III	IV	V	Total	I	II	Total	I	II	IIII	Total		
Emballonuridae															
Centronycteris maximilliani							1		1					1	F
Diclidurus albus															E
Diclidurus scutatus															B
Peropteryx kappleri											1*		1	1	*
Peropteryx macrotis										7			7	7	B, F
Rhinchonycteris naso	1		6	1	1	9	1		1					10	A, B, E, F
Saccopteryx bilineata	1				1	2						1	1	3	A, B, D, F
Saccopteryx canescens															B
Saccopteryx leptura															B, E
Molossidae															
Cynomops cf. planirostris															G
Eumops trumbulli															E
Molossus rufus															A, B, E
Molossus molossus							25		25			21	21	46	A, B, E, F
Nyctinomops laticaudatus										7		6	13	13	F
Promops nasutus															E
Mormoopidae															
Pteronotus parnellii	1	2	3	6		12	22	14	36		36	10	46	94	F
Pteronotus personatus															E
Noctilionidae															
Noctilio albiventris															A, B, E
Noctilio leporinus		1				1								1	A, B, F
Phyllostomidae															
Ametrida centurio			1	1		2								2	E
Anoura caudifera	2			1		3								3	C,E, F
Anoura geoffroyi				1		1		2*	2					3	*
Artibeus cinereus	2	3	1		6	12	3	1	4	4	2	2	8	24	B,D,E, F
Artibeus concolor	2			1	2	5				1		2	3	8	F
Artibeus gnomus	1		1	1		3				2		3	5	8	F
Artibeus lituratus	5	2		7	2	16	4	2	6	15	10	2	27	49	B,D,E, F
Artibeus obscurus	20	4	1	17	29	71	22	6	28	3	10	11	24	123	E, F
Artibeus planirostris	157	77	3	92	38	367	73	18	91	37	44	6	87	545	B,D,E, F
Carollia cf. castanea															H
Carollia brevicauda	6	7	1	1	11	26	10	2	12	7	10	4	21	59	Ft02
Carollia perspicillata	29	10	1	2	8	50	37	9	46		15	6	21	117	A, B, D, E, F
Chiroderma trinitatum				1		1	1	0	1					2	F
Chiroderma villosum		1	1			2								2	F
Choeroniscus minor	1					1								1	F
Chrotopterus auritus		1	2	1	1	5	2	2	4	1	1	1	3	12	F
Desmodus rotundus	1		1	1	1	4	1	1	2					6	A, B, E, F
Diaemus youngi															E
Diphylla ecaudata															E
Glyphonycteris sylvestris					1	1		1*	1			1	1	3	*

Continue

Table II. Continued.

Species/Family	PNMT						FNA			RDSI				Total	Other sources
	I	II	III	IV	V	Total	I	II	Total	I	II	IIII	Total		
Glossophaga cf. longirostris															G
Glossophaga soricina			1	2	1	4	1	5	6		3	1	4	14	A, B, E, F
Lampronycteris brachyotis					1*	1					2		2	3	*
Lionycteris spurelli		1				1	1	2	3		1	4	5	9	C, F
Lonchophylla thomasi	11	10	2	10	5	38	15	35	50	8	9	4	21	109	C, F
Lophostoma brasiliense		2				2				2			2	4	F
Lophostoma schulzi		1			1	2								2	F
Lophostoma silvicolum	6		2	5	4	17	7	3	10	4	2	4	10	37	D, E, F
Macrophyllum macrophyllum										2			2	2	E, F
Mesophylla macconnelli															E
Micronycteris sp.															H
Micronycteris megalotis															A, B
Micronycteris microtis	2					2	3		3					5	F
Micronycteris minuta							1		1					1	B, E, F
Micronycteris schmidtorum		1				1						1	1	2	F
Mimon bennettii							2		2					2	F
Mimon crenulatum	4	1		3	1	9	2	2	4		1	1	2	15	D, E, F
Phylloderma stenops	1					1								1	F
Phyllostomus discolor	10	7	2	1	3	23	1		1			4	4	28	F
Phyllostomus elongatus	11	9	2	5	7	34	3	2	5	2	1	13	16	55	B, D, F
Phyllostomus hastatus	8	3				11	2		2			7	7	20	D, E, F
Plathyrrhinus brachycephalus			1	1		2		1*	1			1	1	4	*
Platyrrhinus helleri	1	3			2	6	3		3		1		1	10	E, F
Platyrrhinus lineatus		1				1					1		1	2	F
Rhinophylla pumilio	8	10		19	20	57	6	8	14	15	13	16	44	115	D, E
Sturnira lilium															E, G
Sturnira tildae	2	2			2	6	3	1	4	2		4	6	16	F
Tonatia saurophila	3	1		1	1	6	6		6		1	2	3	15	F
Trachops cirrhosus	4	3		1	3	11	1	14	15	1			1	27	A, B, F
Trinycteris nicefori	2					2	4		4					6	F
Uroderma bilobatum		2		4	12	18	1		1		1	3	4	23	A, B, E, F
Uroderma magnirostrum											1		1	1	E
Vampyressa bidens											2		2	2	E
Vampyressa thyone							1		1					1	F
Vampyrodes caraccioli				4	2	6	1		1					7	F
Vampyrum spectrum		1			1	2	1		1			1	1	4	E, F
Thyropteridae															
Thyroptera tricolor															A, B
Vespertilionidae															
Eptesicus brasiliensis															E
Eptesicus cf. chiriquinus															B
Eptesicus furinalis															B
Myotis albescens			1	5		6	1		1	1			1	8	F
Myotis nigricans															B,E
Myotis riparius	2					2								2	F
Total of individuals	304	166	33	195	167	865	268	131	399	121	168	142	431	1695	
Total de Species	29	27	19	28	28	48	35	21	38	19	23	29	40	59	82

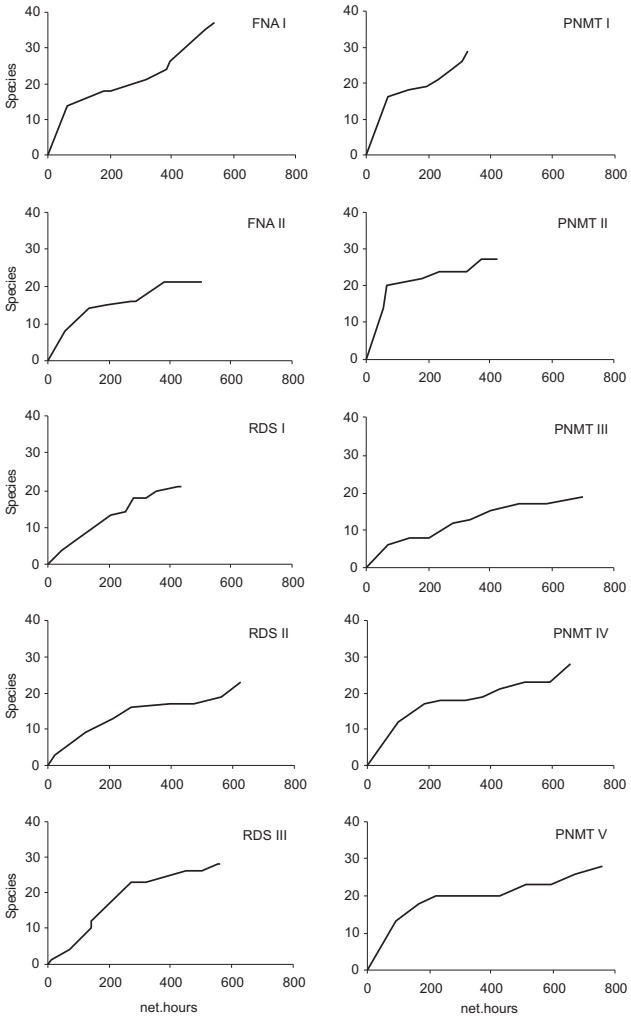

Figure 2. Species accumulation curve based on the number of bats captured in ten expeditions of rapid biological inventories conducted in the State of Amapá, Brazil. (FNA) Floresta Nacional do Amapá, (RDSI) Reserva de Desenvolvimento Sustentável do Rio Iratapuru, (PNMT I) Expedition I, Parque Nacional Montanhas do Tumucumaque, (PNMT II) Expedition II, Parque Nacional Montanha do Tumucumaque, 2004-2006.

The inventory conducted in APA Curiaú (14 nights, 1,070 mnh) resulted in 342 captures, 37 species, 25 genera and five families. The three most frequent species were *A. planirostris* (68 captures), *C. perspicillata* (39) e *Uroderma bilobatum* Peters, 1866 (18). Eleven species were captured once. The number of recorded species per night varied between three and 14. The average capture indexes were 0.32 bat/mnh, 0.11 species/capture and 0.03 species/mnh.

The similarity analysis among the bat faunas in the Guiana Shield areas indicated pairings and groupings (Fig. 3, Tab. III). Closer pairings included the Bolivar and Amazonas areas (Jaccard's coefficient = 0.78), both in Venezuela, but Delta do Amacuro, also in Venezuela, was set apart from the others. French Guiana, Suriname and Guyana formed a sub-group, with the two latter closed together (Jaccard's coefficient = 0.81). Amapá was separated from this sub-group (Fig. 3, Tab. III).

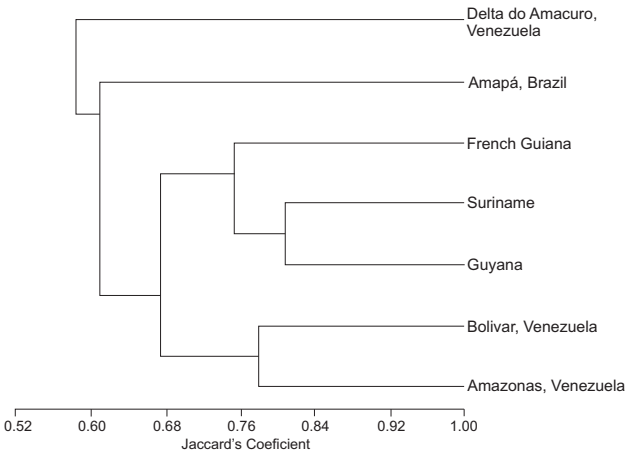

Figure 3. Dendrogram created by the Similarity Analysis UPGMA, using the Jaccard index for the chiropterofaunas in seven sub regions of the Guiana Shield. Species matrix used adapted of Lim *et al.* 2005.

Table III. Percentage of similarity between the bat faunas of seven regions of the Guiana Shield.

	VA	BO	DA	GU	SU	FG
AP	0.6	0.56	0.59	0.61	0.65	0.63
FG	0.61	0.61	0.53	0.73	0.78	
SU	0.66	0.7	0.55	0.81		
GU	0.72	0.76	0.59			
DA	0.62	0.64				
BO	0.78					

DISCUSSION

Until 2004, only 48 bat species were known for the state of Amapá (Carvalho 1962, Piccinini 1974, Mok *et al.* 1982, Peracchi *et al.* 1984, Bernard & Sampaio 2008). Most of those records were restricted to the vicinity of the state's capital, Macapá, the nearby Serra do Navio municipality, and a few localities along the main state road, linking Macapá to the city of Oiapoque, at the northernmost corner of the state. Later on, new records were obtained by the first inventories in the PNMT, FNA, and RDSI (Martins *et al.* 2006), adding more 25 species to

the previous state list. With the conclusion of the inventories in those conservation units, and with complementary data from two other areas, we added 10 new records to the bat species list for Amapá, raising the number of bat species that occur in the state to 82. New records for Amapá included *Platyrrhinus brachycephalus* Rouk & Carter, 1972, *Lampronycteris brachyotis* Dobson, 1878, *Glyphonycteris sylvestris* Thomas, 1896, *Peropteryx kappleri* Peters, 1867, and *Anoura geoffroyi* Gray, 1838. Other taxa that could also be new records for Amapá (*Glossophaga* cf. *longirostris* Miller, 1898, *Micronycteris* cf. *homezi*, *Carollia* cf. *castanea* H. Allen, 1890, *Eptesicus* cf. *chiriquinus* Thomas, 1920, and *Cynomops* cf. *planirostris* Peters, 1865) are awaiting final confirmation from specialists.

Even though our inventories were short-termed (8 to 10 days each), and restricted to small areas when compared with the size of the conservation units they belong to, all the sites we sampled presented moderately high bat species diversity. Species composition was diverse, with members of several different feeding guilds. The frequency of captures and abundance patterns of species, with a majority of frugivorous phyllostomidssuch as *A. planirostris*, *A. obscurus*, *R. pumilio*, and *C. perspicillata*, are in agreement with the patterns observed in other inventories conducted in the Neotropics (*e.g.* Moreno & Halffter 2000, Lim & Engstrom 2001a, Bernard & Fenton 2002, Sampaio *et al.* 2003). As in other inventories in the Amazon Basin (e.g. Bernard & Fenton 2002), our sampling in Amapá was strongly influenced by pluviosity and seasonality, negatively affecting the capture indexes and species diversity during the driest months. We suggest that future short-term inventories that aim to maximize the records of bat species in the eastern parts of the Brazilian Amazonia should not be conducted solely during the driest month of the year. Doing so may result in underestimation of the real species diversity in the area.

Biogeographic aspects

The Guiana Shield, delimited in the north by the Orinoco River, in the south by the Amazon River, and in the west by the connected headwaters of Negro and Casaquiare Rivers, is considered an area of high priority for mammal inventories in the Amazon Basin (Silva *et al.* 2001). Encompassing parts or the totality of French Guiana, Suriname, Guyana, the northernmost part of Brazil, and the southern and eastern parts of Venezuela, the Guiana Shield has only a few sites where the mammal fauna can be considered extensively well sampled – e.g. Paracou in French Guiana, Iwokrama Forest in Guyana, Imataca Forest Reserve in Venezuela (Lim & Engstrom 2001a). The Brazilian part of the Guiana Shield can be considered poorly sampled for mammals. Amapá, with most of its territory inserted in the Shield, has areas that were classified as "of possible high importance", "high" or "of very high importance" for performing mammal inventories (Silva *et al.* 2001). Gaps in the knowledge in areas such as Amapá render a complete biogeographical analysis of the mammal fauna in the Amazon Basin very difficult. This situation is particularly problematic when it pertains to bats, which are frequently neglected in inventories conducted in the region.

Few studies to assess the bat diversity in the Brazilian Amazonia have been undertaken (e.g. Bernard & Fenton 2002, Sampaio *et al.* 2003), and the available data are either scarce, incomplete, or irregular. A compilation of a list of mammals of the Guiana Shield indicates the occurrence of 148 species of bats in the region (Lim *et al.* 2005). In the Brazilian Amazonia, the states of Pará (specially the regions of Belém and Alter do Chão, in Tapajós River) and Amazonas (more specifically the area surrounding Manaus) contain most well studied sites for bats, presenting respectively, 116 and 109 species (Bernard & Fenton 2002, Bernard & Sampaio 2008). There is basically no data for the northern and southern state of Amazonas, northeastern and southern Pará, southern Rondônia, northern Amapá, and central to southern Rondônia (Bernard *et al.* 2011). Countries bordering or near Amapá, such as Guyana, Suriname and French Guiana present, respectively, 121, 105 and 100 species of bats (Lim *et al.* 2005).

A comparison between the bat faunas of the aforementioned regions indicates that the species list of Amapá is incomplete and that there is a potential for the inclusion of more than 100 species in this list. French Guiana, for example, has 29 species of bats not yet recorded in Amapá. On the other hand, 12 species that have already been recorded in Amapá are not listed for French Guiana. The bat fauna currently found in Amapá is composed of a set of species widely distributed in the Amazon Basin. However, it seems that there is cohesion between the fauna recorded for Amapá and that recorded for the Guiana Shield (e.g. Bates *et al.* 1998, Simmons & Voss 1998, Patton *et al.* 2000, Voss *et al.* 2001).

Our analysis of the six geographical units of the Guiana Shield proposed by Lim *et al.* (2005) separated Delta do Amacuro from all other areas (Fig. 3, Tab. III). We believe that this separation may have been caused, at least in part, by a sampling bias, since that site was not intensively sampled and the diversity of species there is lower than in other Venezuelan sites (Linares & Rivas 2004). It is also possible that Delta do Amacuro represents a more marginal habitat for bats when compared with the other political units of the Guiana Shield. In fact, pairing patterns in a cluster analysis may be strongly influenced by the effectiveness and completeness of the inventories (Simmons *et al.* 2000, Lim & Engstrom 2001b). The separation of Amapá may be also explained by the incompleteness of its species list (Lim *et al.* 2005), indicating that further, complementary inventories are necessary, especially in other large areas not yet sampled in the state. In fact, Amapá has large spots of Amazonian savannas where the mammal fauna in general has been poorly sampled. The use of mixed techniques to record bat species, including active roost searching, samplings in the canopy, use of harp-traps and bat-detectors will surely increment the list of species found in Amapá.

The current knowledge of bat species richness in the Guiana Shield is heterogeneous: 114 species for the province

of Amazonas, in Venezuela; 126 for Bolívar, Venezuela; 84 for Delta do Amacuro, Venezuela; 121 for Guyana; 105 for Suriname; 101 for French Guiana; and 83 for Amapá, Brazil. Fifty one species (34% of the known total for the Shield) are considered widespread, being found in all seven sites, and four bat species were considered endemic to the area: *Lonchorhina fernandezi* Ochoa & Ibáñez, 1982, *Lasiurus atratus* Handley, 1996, *Molossus barnesi* (presently considered synonym of *M. aztecus* Saussure, 1860 – Eger 2007), and *Platyrrhinus aurarius* Handley & Ferris, 1972 (Lim *et al.* 2005).

Conservation contributions

The inventories described here not only complement the information on the distribution of bat species in Amapá and in the Guiana Shield, but also represent the first study on bats in conservation units in the state of Amapá. These parks and reserves represent a small number of protected areas in the Amazon for which scientific data on bat diversity has been collected on a standardized manner, vouchered, and presented in a reliable and accessible format. Further, the information produced has been made available and incorporated in the conservation unit's management plans (e.g. Martins & Bernard 2008).

No significant threats, requiring immediate intervention, were identified in the sites visited. The relatively high number of species and the diversity of guilds found, even when obtained from short-term inventories, indicate that sampled sites have a good conservation status. Moreover, due to the prissiness of these sites, they have a great potential for research, from the investigation of species' natural histories to the ecological interactions among them. The FNA and RDSI are sustainable use reserves, which means that the use of their natural resources is allowed under certain conditions. Therefore, the data herein presented may be used as the initial parameters for the assessment of the impacts of anthropogenic activities, logging or the extraction of non-timber forest goods, which are foreseen or currently in progress in those units. Bats, due to their ecological diversity, capacity to respond to habitat changes, and high vagility, which allows bats to move through extensive areas in fragmented landscapes, are good candidates for the evaluation of the consequences of deforestation surrounding those protected areas (e.g. Medellín & Gaona 1999, Giannini & Kalko 2004, Thies & Kalko 2004, Alves da Silva *et al.* 2008). Finally, bats are good models for environmental education programs, which could be executed in the several municipalities influenced by the protected areas.

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