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Nonvolant Mammal Megadiversity and Conservation Issues in a Threatened Central Amazonian Hotspot in Brazil

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Abstract

Amazonia National Park is located in southwestern Pará State in central Amazonia. The 10,707 km^2 park is one of the largest protected areas in Brazil and is covered with pristine forests, but the region is threatened by dam construction projects. An incomplete mammal biodiversity inventory was conducted in the area during the late 1970s. Here, we present results of sampling from 7,295 live-trap nights, 6,000 pitfall-trap nights, more than 1,200 km of walking transect censuses, and approximately 3,500 camera-trap days, all conducted between 2012 and 2014. These sampling efforts generated a list of 86 known species of nonvolant mammals, making the park the single most species-rich area for nonvolant mammals both in the Amazon Basin and in the Neotropics as a whole. Amazonia National Park is a megadiverse site, as is indicated by its mammalian richness, which includes 15 threatened mammal species and 5 to 12 new species of small mammals. As such, it merits being a high-conservation priority and should be an important focus of Brazilian authorities' and the international scientific community's conservation efforts. A comprehensive conservation plan is urgently needed, especially given the ecological threats posed by dam construction.

Keywords

Amazon, Amazonia National Park, megadiverse mammalian assemblage, new species, threats

Introduction

The Amazon is the largest tract of rainforest in the world and harbors the greatest level of biodiversity on Earth (Sayre, Bow, Josse, Sotomayor, & Touval, 2008). However, a significant proportion of the rainforest has suffered direct negative effects from human activities. In addition, despite including some of the largest protected areas in the world, the Amazon remains very poorly known biologically (Instituto Nacional de Pesquisas Espaciais [INPE], 2015), even for relatively well-studied groups such as mammals.

Within Brazilian Amazonia, there are severe and ever-increasing human disturbances including large-scale agriculture, cattle ranching, mining, and dam construction (Fearnside, 2005; Nogueira, Yanai, Fonseca, & Fearnside, 2015; Silva, Pereira, & da Rocha, 2015). Approximately 18.8% of the original vegetation cover in the Brazilian Amazon basin has already been lost

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(INPE, 2015). Construction of new hydroelectric dams in the near future could result in the flooding of over 10 million hectare of Amazonian forest (Fearnside, 2006), with widespread species extinctions predicted, as well as large-scale faunal displacements and unpredictable barrier effects (Benchimol & Peres, 2015). Consequently, protected area enforcement is becoming increasingly important for safeguarding the region's overall biological richness. However, in most protected areas, there is still limited data regarding biodiversity, particularly species composition and diversity.

Brazil currently has 705 recognized species of mammals (Dalponte, Silva, & Júnior, 2014; Gregorin & De Vivo, 2013; Gualda-Barros, Nascimento, & Amaral, 2012; Paglia et al., 2012; Sampaio et al., 2015). Of these, 403 occur in the Amazon and 235 are endemic to the biome (Dalponte, Silva, & Júnior, 2014; Gregorin & De Vivo, 2013; Gualda-Barros, Nascimento, & Amaral, 2012; Paglia et al., 2012; Sampaio et al., 2015). However, given its extensive tracts of unexplored areas, many new mammalian species, especially rodents, marsupials, and bats, could still be discovered in Amazonia (Costa, Leite, Mendes, & Ditchfield, 2005; Vivo, 1996).

There are reliable and complete inventories of Amazonian mammals from only a few study sites, and these often do not include species counts. In 1996, for example, Voss and Emmons listed 12 Neotropical sites at which the checklist of nonvolant mammal species was nearly complete. Only two were in Brazilian Amazonia: Cachoeira do Espelho, mid-Xingu River (the site of the Belo Monte hydroelectric development), Pará, and the Ducke Reserve.

Since Voss and Emmons (1996) summarized the checklists, several additional and high-quality studies have been published including one by Peres (1999) on Urucu, central Amazonia (Amazonas state); Bergallo, Carvalho, and Martins-Hatano (2012) for Carajás (Pará state); Vieira (2012) for Bico do Papagaio (Pará-Tocantins-Maranhão tristate border); and a multisite species list for Amapá state (da Silva et al., 2013). Additional publications have focused on particular groups, such as small, nonvolant mammals (Barnett & da Cunha, 1994; da Silva et al., 2013; Da Silva et al., 2007; Gettinger, Ardente, & Martins-Hatano, 2012; Lambert, Malcolm, & Zimmerman, 2006; Malcolm, Patton, & da Silva, 2005; Patton, Da Silva, & Malcolm, 2000; Ribeiro-Júnior, Rossi, Miranda, & Ávila-Pires, 2011; Santos-Filho, Peres, da Silva, & Sanaiotti, 2012; Santos-Filho, Silva, & Sanaiotti, 2006) and medium and large mammals (Benchimol & Peres, 2015; Borges, Calouro, & Sousa, 2015; Carvalho et al., 2014; Martins, Sanderson, & Silva-Júnior, 2007; Pimenta, 2012).

This study contributes to the literature with data on the nonvolant mammalian assemblage of Amazonia National Park (ANP). George et al. (1988) assembled a species checklist for the park in the late 1970s, but it was incomplete and mostly based on interviews. Another study by Ayres and Milton (1981) focused specifically on primates in the park. The integrity of the park is currently threatened by the Program for the Acceleration of Growth, a Brazilian government initiative for social infrastructure development that includes plans for a series of very large dams in the Tapajós River valley, which has reduced the size of the park by 437.6 km^2 (Bernard, Penna, & Araújo, 2014; de Marques & Peres, 2015). Brazilian legislation prohibits such development or economic activities in fully protected areas like national parks, where only activities related to visitation or tourism and research are allowed. For this reason, the ANP has been reduced to make areas "legally" accessible to development.

The Brazilian Biological Diversity Project (PROBIO) considers ANP a high-priority area for conservation (Maury, 2002), and a taxon-based analysis of mammals is a specific priority (Maury, 2002). A definitive species list is a key to informing an effective conservation strategy.

This study is part of a larger effort to evaluate several aspects of the mid-Tapajós River area, its mammalian assemblage, and the likely effects of hydroelectric dam construction. Our study is qualitative and reflects the findings of surveys conducted in and around ANP. Given the importance of the park for biodiversity conservation (Maury, 2002) and the imminent threats it faces from dam construction (Benchimol & Peres, 2015; Bernard et al., 2014; de Marques & Peres, 2015), we felt that ANP merits a special evaluation. A further quantitative analysis for the larger mid-Tapajós area will be published separately. The objective of this study is to provide an extensive field-based checklist for the nonvolant mammal fauna of ANP, and to offer a discussion of the conservation issues facing this key biodiversity hotspot.

Methods

Study Site

ANP is located in central Amazonia, in the State of Pará, where its westernmost limit abuts the Pará and Amazonas state border (04° 02′ 08″ S; 51° 12′ 00″ W; Figure 1). ANP was established in 1974 and is situated on the mid-Tapajós River, 55 km from the town of Itaituba. Its current area (10,707 km^2) makes it one of the 10 largest fully protected reserves in Brazil (Rylands & Pinto, 1998). The park has a humid, tropical equatorial climate, and the hilly terrain is covered with a mosaic of rainforest vegetation types (CNEC Worley Parsons Engenharia, 2014; Ferreira & Prance, 1998). The main forest cover is tall *terra-firme* forest (15–30 m),

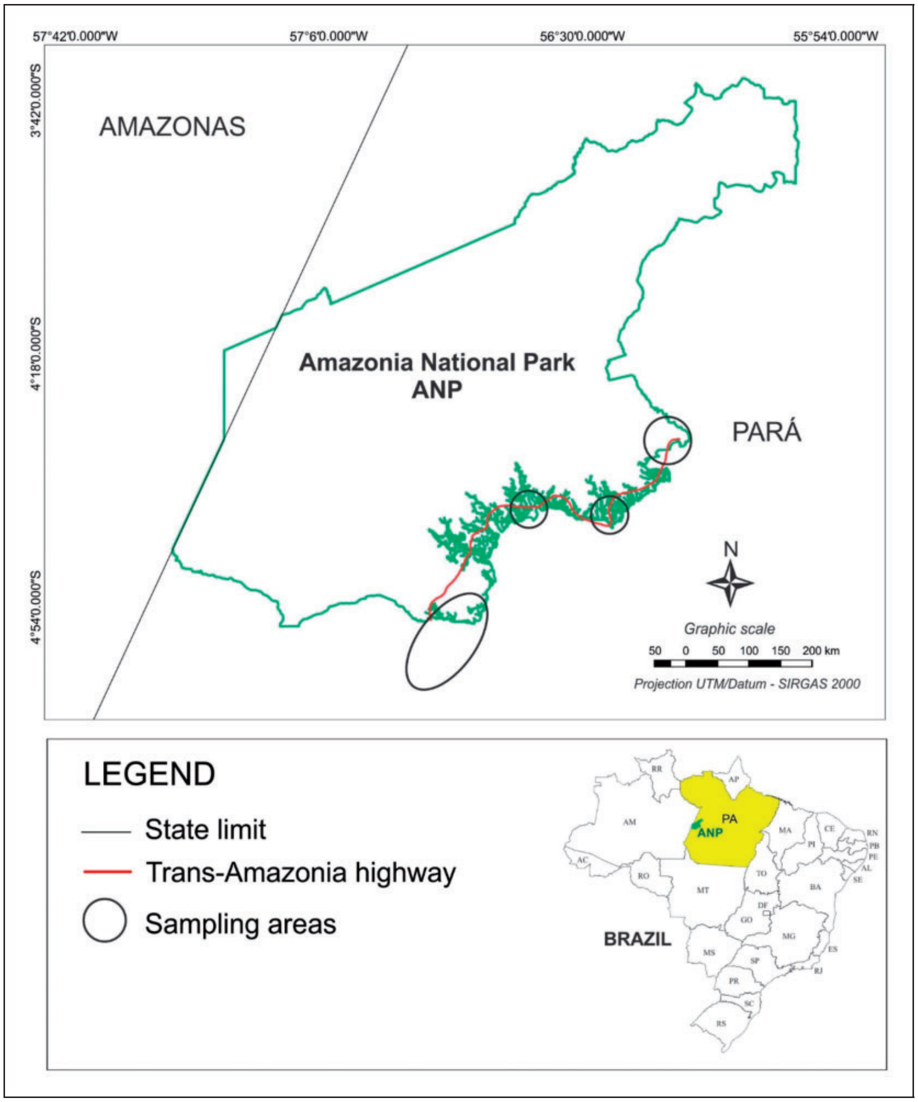

Figure 1. The location of the main study sites in Amazonia National Park, Brazil.

interspersed with areas of lower forest habitat with abundant lianas (10–15 m) which is characteristic of eastern Amazonia (Gerwing & Farias, 2000). Seasonally flooded riverine forest (*igapó*) occupies a narrow strip (rarely more than 10 m wide) along the banks of the Tapajós River and its tributaries (CNEC Worley Parsons Engenharia, 2014). Flooding occurs from January to late April or early May (George et al., 1988). Although data were primarily collected in four areas of ANP, the full east–west length along the Trans-Amazonian highway was also sampled in order to generate as complete a picture as possible of nonvolant mammal fauna in ANP data (Figure 1). We assumed a constant detection rate among the sample areas.

Data Collection

We conducted five different fieldwork survey expeditions between June 2012 and June 2014. These generated a total of approximately 80 days (15 days per expedition) of intensive sampling by four teams working simultaneously, each comprises several biologists and field assistants. Two teams collected data for small mammals, and two for medium–large mammals. Concurrently, we conducted a camera-trapping survey over several consecutive months (IBAMA collecting license 66/2012 and ICMBio collecting license 004/2012-CR3/Santarém). We conducted the surveys in both wet and dry seasons and during all water-level regimes and included all vegetation formations. Although we did not assess seasonal differences, a preliminary analysis for a larger area of the mid-Tapajós did not find any differences between seasons (T.G. de Oliveira, unpublished data). The taxonomy we used follows that of Paglia et al. (2012).

We assessed sample efficacy on graphs, plotting daily sample sizes of small and medium–large mammals against the randomized ($n = 1{,}000$) number of observed species (Sobs Mao Tau). The expected species richness for each group was estimated using Jackknife 1, Ice, and Chao 2, generated with the program EstimateS *7.5.1* Colwell 2005. We considered species richness using the classic mastozoological approach (Voss & Emmons, 1996) which, according to Eisenberg (1999, p. 528), is "the number of species tabulated for a defined geographical area," that is, the known species composition, not the expected species richness derived from estimators. The intention of this study was to estimate species richness only, and it did not account for variations in detection probabilities among methods, types of traps, or species. We compared our findings with other studies of nonvolant mammal species which, between them, provided a nearly complete checklist. These studies were based on direct measures of sampling efforts, and some spanned several decades.

Small, Nonvolant Mammals

Small, nonvolant mammals included marsupials and small rodents (<1 kg). Sherman and Tomahawk live traps were deployed in four sampling areas, distributed along five 300-m trap lines. Trap lines were positioned every 1 km along a 5-km transect trail and ran perpendicular to the trail. Sherman traps were deployed 15 m apart (20 units per trap line) on every site, and Tomahawk traps were deployed on alternate sites, 30 m apart on the ground (10 units per trap line), following standard protocols (Lambert, Malcolm, & Zimmerman, 2006; Vieira, 2012). Sherman traps were also placed in the subcanopy at heights of 1 to 2 m every 30 m. Traps were checked and baited every morning (with a banana, peanut butter, corn flour, baked *babassu* palm nut, and vanilla essence mix), and left open for three consecutive nights. Small mammals were also sampled using pitfall traps (Hice & Schmidly, 2002; Voss & Emmons, 1996) comprising fifteen 60-L buckets placed in five parallel lines, 10 m apart from each other, in all four sampling areas. Following Hice and Schmidly (2002), we set up a staked plastic fence running through the midlines which linked the buckets. Pitfall trap lines remained open for five consecutive nights. When used together, studies have found that these two methods effectively sample the full range of terrestrial and scansorial small mammals (Santos-filho, Lázari, Pedro, Sousa, & Canale, 2015; Vieira, 2012; Voss & Emmons, 1996).

Voucher specimens were collected to confirm species' identification and were deposited in the Museu Paraense Emilio Goeldi collections, Belém. Marsupials and small rodents were identified using Wilson and Reeder (2005), Gardner (2008), Mendes-Oliveira and Miranda (2015), and Patton, Pardiñas, and D'Elia (2015). Additional molecular analyses were conducted on some *Marmosops*, *Hyleamys*, *Neacomys*, and *Proechimys* spp. specimens in order to clarify taxonomic designations. The analyses of the first three genera were undertaken at the Molecular Genetics Laboratories, Universidade Federal de Mato Grosso (R. Rossi, personal communication, August 10, 2015), and the fourth at the Universidade Estadual do Maranhão (*Proechimys*, L. Tchaika, unpublished data).

Medium and Large Mammals

Medium and large mammals included all primates, edentates, carnivores, ungulates, aquatic mammals, large rodents (>1 kg), and rabbits. A variety of sampling methods was used to maximize species detection (Oliveira, 2007; Oliveira & Cassaro, 2005; Oliveira, de Paula, & Figueira, 1998; Wilson & Delahay, 2001), including line transects, camera trapping, tracks, signs (e.g., burrows and claw marks), and opportunistic observations (e.g., live animal sightings, vocalizations, skeletal remains, and roadkill). When needed, species' identification were confirmed using field guides (Bonvicino, Oliveira, & D'Andrea, 2008; Emmons & Feer, 1997).

Censuses were conducted along five different 5-km transect lines in the established four sampling areas. Transects were perpendicular to the Tapajós River and generally originated in the *igapó* forest. Each transect was sampled five times over five different field survey expeditions to include the full range of seasonal and water regime variations. Additional censuses were conducted on foot along existing visitor access trails and along the Trans-Amazonia highway. These supplementary transects varied in length. All transects were walked both diurnally (morning or afternoon) and nocturnally.

Camera traps (Tigrinus and Bushnell) were located at 50 sites and positioned approximately 20 cm above the ground in strategic places favored by animals (Oliveira & Cassaro, 2005). Intervals varied from 500 m to 1 km in each sampling area. Units operated continually for 20 to 60 days before being checked to verify battery function or to be relocated. Camera trapping was conducted along transect lines and in additional sites within the established sampling areas. We used 5 to 10 cameras in each sampling area and rotated them to maximize detection opportunities.

Park Conservation Issues

To determine the conservation issues facing ANP, we visited all accessible areas and interviewed park personnel. We made a rough estimate of the portion of ANP under threat based on our ground checks and the interviews and also on a satellite imagery evaluation conducted by INPE (2015). We compared the threats identified with those reported by Rylands in 1991. We considered issues of land tenure, government decrees threatening the integrity of ANP, the conservation management plan and its implementation, and the availability of human resources support (administrators, technicians, and park rangers). Rylands (1991) and Rylands and Pinto (1998) included 13 previously listed threats: (a) inadequate management, (b) hunting, (c) human invasion, (d) deforestation and timber exploitation, (e) agriculture or cattle ranching, (f) pollution, (g) adjacent development (i.e., human activities in adjacent areas), (h) changes in water regime or hydroelectric dams, (i) gold mining, (j) other mining, (k) burning (for pasture renovation only), (l) roads, and (m) erosion. Although our intent was to present qualitative data on current and future threats facing ANP, an assessment of threat intensity was beyond the scope of the study.

Results

Mammalian Assemblages

A total sampling effort of 7,295 live-trap nights, 6,000 pitfall nights, more than 1,200 km of transects walked on foot (census only), and 3,500 camera-trap days yielded a checklist of 86 species of nonvolant mammals for ANP (Appendix 1). Three additional species were added to this list based on museum specimens collected in the area prior to our study. The current checklist includes 11 orders and 29 families. The most species-rich groups were rodents ($n = 30$), followed by carnivores ($n = 15$), marsupials ($n = 13$), and primates ($n = 10$; Figure 2, Table 1). We can thus confirm that ANP comprises about 21% of Brazilian Amazonian mammals and 12% of all mammal species found in Brazil.

A total of 15 species on the list are considered threatened (classified as Vulnerable or Endangered by either Brazilian or IUCN Red Lists, or both). Three are classified as Near Threatened, and eight are considered Data Deficient (IUCN, 2015; MMA, 2014). Thus, about 17% of the mammal species on the ANP checklist are threatened (Appendix 1), and 30% are of conservation concern. Carnivores, especially felids, are the most threatened group, with seven Vulnerable species. Three species (two primates and the pink river dolphin) are considered Endangered.

Based on molecular and morphological data, five small nonvolant mammals found during the study were undescribed species. Two were marsupials: a short-tailed opossum, *Monodelphis* sp. nov. (*adusta* group; Pavan, Jansa, & Voss, 2014), and a four-eyed opossum, *Metachirus* sp. nov. (current study, Figure 2(d)). Three were new species of small rodents, two were *Neacomys* (labeled as *Neacomys spinosus* on maps generated by

Figure 2. Examples of the most speciose groups of nonvolant mammals found in Amazonia National Park, Brazil, and their conservation designations. A. Margay (*Leopardus wiedii*), carnivore, Vulnerable; B. Black-and-white tassel-ear marmoset (*Mico humeralifer*), primate, Data Deficient; C. The rare and recently described fish-eating rat (*Neusticomys ferreirai*), rodent, Data Deficient; D. A new species of four-eyed opossum (*Metachirus* sp. nov.), marsupial, unknown status.

Table 1. Confirmed Numbers of Species of Nonvolant Mammal Groups Recorded at Six Well-Studied Areas in the Amazon.

Taxon	Cocha Cashu or Paktiza, Peru[a,g]	Urucú, Brazil[b]	Manaus, Brazil[c,g]	ANP, Brazil[d]	Belo Monte, Brazil[e]	Carajás, Brazil[f,g]
Didelphimorphia	12	9	9	13	11	12
Edentates	7	7	8	9	11	11
Ungulates	5	5	5	5	5	5
Sirenia	0	0	0	1	0	0
Cetacea	0	0	0	2	0	2
Primates	13	13	6	10	10	8
Carnivora	13	13	8	15	13	16
Lagomorpha	1	1	0	1	1	1
Rodentia	27	26	16	30	25	25
Total	78	74	52	86	76	80

[a]Janson and Emmons (1990), Pacheco and Vivar (1996).
[b]da Silva and Mendes-Oliveira (2012).
[c]Peres (1999).
[d]This work.
[e]Eletrobrás (2009).
[f]Bergallo et al. (2012).
[g]Areas of long-term studies.

Emmons & Feer, 1997; Eisenberg & Redford, 1999; Bonvicino et al., 2008) and one was a species of spiny rat, *Proechimys* sp. nov. (present study). Additionally, seven other taxa may represent either new species or cryptic taxa that are in need of revision or revalidation (Gardner, 2008; Voss & Jansa, 2009; Woods & Kilpatrick, 2005; Appendix 1).

We now consider our checklist to be complete for medium and large mammals but incomplete for small mammals, particularly the most species-rich group (see discussion for further details). Rarefaction curves for small mammals showed that species-encounter rates were still rising, whereas an asymptote was reached for medium and large mammals (Figure 3). Consequently, true nonvolant mammal species richness in ANP is likely to be higher than reported here. All estimators used predicted the 53 species we observed for medium–large mammals and 35 to 37 species for small mammals which, if confirmed, would increase the species count to 90 nonvolant mammals.

Park Conservation Issues

When ANP was created in 1974, it covered 11,145 km^2. However, national statutes do not permit the construction of dams in protected areas, and for this reason, parts of the park were degazetted in June 2012 by official decree in order to allow legal rights of access for the construction of the São Luiz do Tapajós Hydroelectric Dam (Figure 4). The area lost totals 437.6 km^2 and will be flooded when the dam is completed. The current area of the park is thus 10,707 km^2, 118.21 km^2, or 1.1% of which is deforested. Some 24.9 km^2 was lost before 1997 and a further 93.31 km^2 between 1997 and 2014 (INPE, 2015).

ANP has only seven park personnel (three responsible for research and public issues, two rangers, one overseeing land tenure issues, and the park manager). ANP overlaps with the Andirá-Maraú Indigenous Area and land tenure issues remain unresolved. Official reports from 1989 to 1990 indicate that the legal status of only 85% of the park had been formalized (MINTER-IBAMA, 1990) and, according to park personnel (L. Coelho and J. Vasconcelos, personal Communication, December 16, 2015), this remains unchanged. ANP has had a management plan since 1978 (IBDF/FBCN, 1979), but it is very outdated and has not been properly implemented. It also has an advisory council, which was set up in 2004. Approximately four surveillance operations are conducted annually (L. Coelho and J. Vasconcelos, personal communication, December 16, 2015).

We detected seven primary conservation threats in ANP: inadequate management, hunting, deforestation or timber exploitation, gold mining, roads, adjacent development, change in water regime or hydroelectric dam, and erosion. Although the scope of our research did not allow us to quantify the intensity of these threats, they appeared to be low at the time of our fieldwork. We estimated that, primarily due to its inaccessibility, there has so far been an impact on less than 5% to 10% of the park. However, spurred by the prospect of hydroelectric dam construction, development in areas adjacent to ANP is now a major issue. In addition to development and other human-meditated pressures (such as hunting,

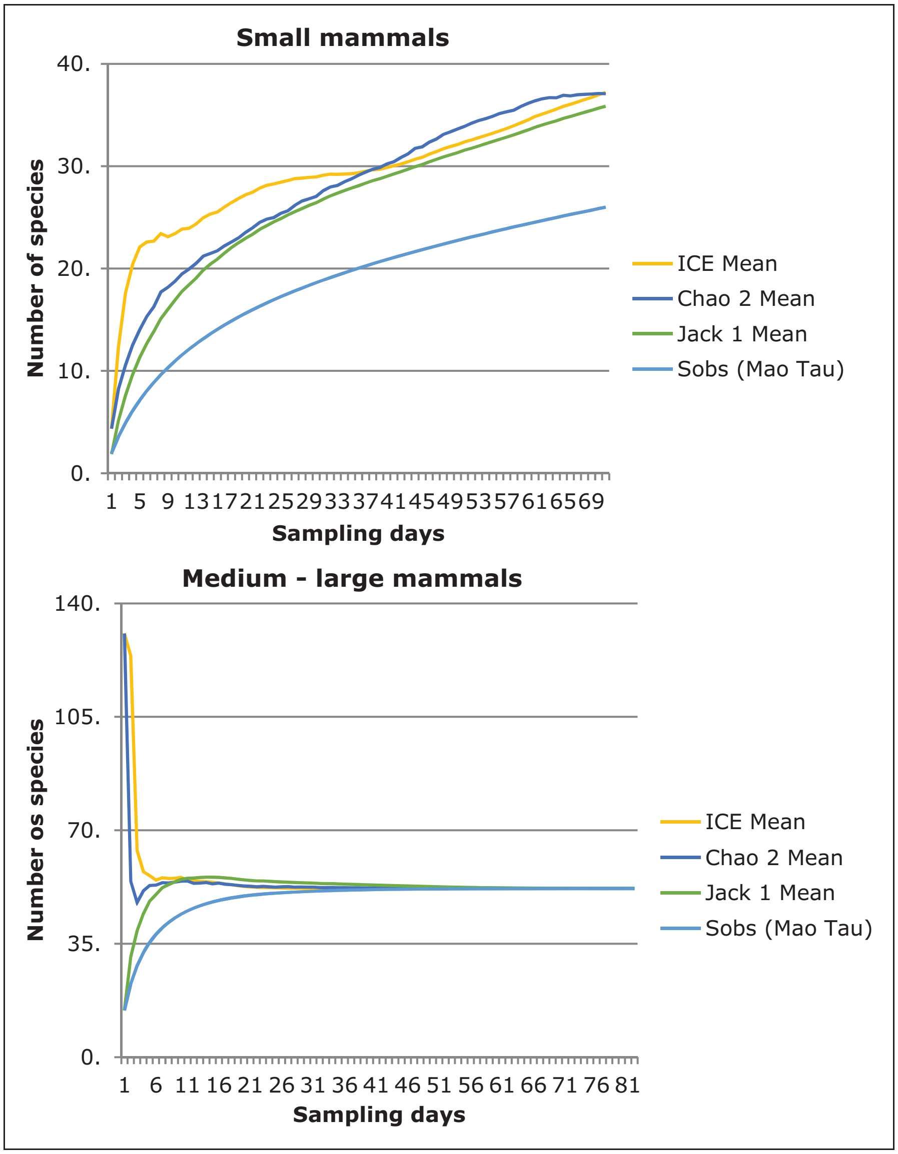

Figure 3. Rarefaction curves for small (top) and medium–large (bottom) nonvolant mammals found in Amazonia National Park, Pará, Brazil.

logging, traffic, and disease spread by domestic animals), which are predicted to increase considerably, dam construction will result in the elimination of *igapó* flooded forest from ANP (CNEC Worley Parsons Engenharia, 2014). Completion of the proposed dam project will add just 6,133 MW to the national electricity grid—a mere 6% of the existing total (see CNEC/ELETROBRÁS, CNEC Worley Parsons Engenharia, 2014; Oliveira et al., 2014 for details).

Discussion

The first faunal assessment of ANP (conducted from 1978 to 1979) listed 101 mammal species (37 bats and 64 nonvolant species; George et al., 1988). The latter included six marsupials, 10 edentates (now 9, due to taxonomic revisions), 12 primates (now 10, due to taxonomic revisions), 13 carnivores, 5 ungulates, 2 cetaceans, 16 rodents, and 1 lagomorph (George et al., 1988). Correcting for taxonomic incongruences, the 1978–1979 survey checklist includes 61 nonvolant species, compared with 86 recorded during this study. A key difference between the two checklists is that the former relied on interviews, while the latter consists solely of direct sightings, photographic records, tracks, and trapping data.

We adequately sampled all vegetation formations but, as only part of ANP was accessible, we expect that there will be further additions to the current species checklist.

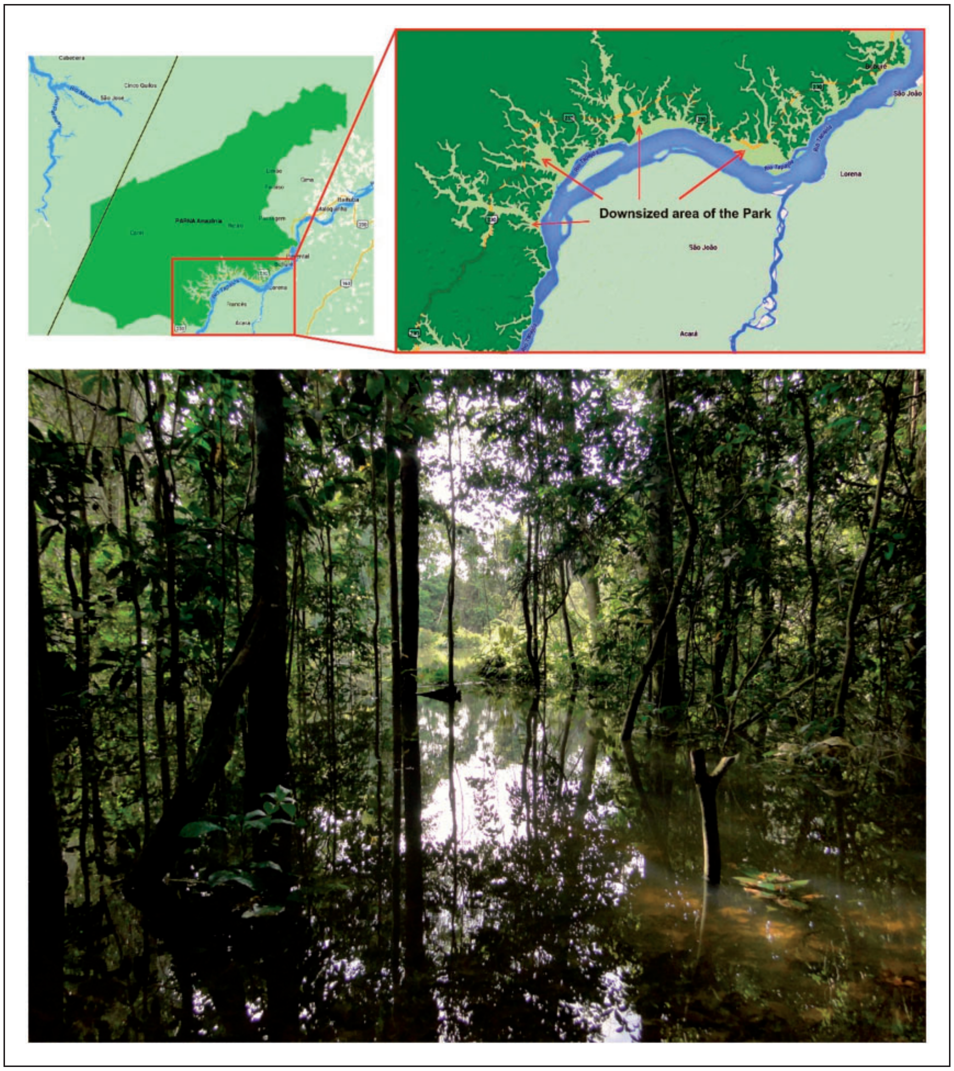

Figure 4. Top left: the part of the Amazonia National Park (dark green) after it has been reduced by 437.6 km^2 by legal decree (light green). Top right: the area expected to be lost includes 100% of the highly productive *igapó* (seasonally flooded riverine forest) habitat (Map Source: ICMBio 2015). Bottom: the *igapó* habitat in this area will be permanently inundated if the São Luiz do Tapajós Hydroelectric Dam goes ahead.

Although we consider the list to be incomplete, a confirmed mammalian richness of 86 nonvolant mammals is still the highest recorded for any area in Amazonia and in the Neotropical region as a whole (Table 1, see Eisenberg, 1999 and Peres, 1999 for further details on mammalian species richness from other areas of the Neotropical region). This is even more notable when compared with reported mammalian richness at other high-ranking sites which have been much more intensively sampled (such as the Cocha Cashu and Paktiza Biological Stations in Manu National Park, Peru, which has 78 species of nonvolant mammals recorded; Janson & Emmons, 1990; Pacheco & Vivar, 1996). Carajás, now the most thoroughly studied area of the Brazilian Amazon, has 80 confirmed nonvolant mammal species (Bergallo et al., 2012), while other well-studied central Amazonian sites all have a lower recorded species richness (Table 1). Even though the studies were heterogeneous, with unstandardized procedures, most were long term, conducted in well-studied areas, and are considered to have been adequately sampled and thus able to offer a confirmed species composition (Bergallo et al., 2012; Janson & Emmons, 1990; Peres, 1999; this study). In this respect, the studies are comparable and emphasize the importance of ANP. Species composition within mammalian groups in ANP was consistent with patterns found in areas throughout the Amazon Basin (Bergallo et al., 2012; Janson & Emmons, 1990; Peres, 1999).

ANP has a confirmed megadiversity of 53 medium and large mammal species, making it by far the most diverse area for these mammals in Amazonia. The observed and expected species richness from three different estimators were equivalent, demonstrating that the species count was consistent and robust. Species richness of medium–large mammals in other areas of the Amazon Basin in Brazil is lower: 45 in Carajás National Forest, 44 in Belo Monte, 42 in Jaú National Park, and 41 in Urucu River Basin (Carvalho et al., 2014; da Silva & Mendes-Oliveira, 2012; Eletrobrás, 2009; Iwanaga, 2004).

Currently, Amazonian marsupials and small rodents (subfamily *Sigmodontinae* and family *Echimyidae*) are difficult to identify, and there are high levels of taxonomic uncertainty (Costa et al., 2005; Voss & Emmons, 1996). There have been few broad, systematic reviews or long-term, integrated studies (Padial, Miralles, De la Riva, & Vences, 2010). Studies focusing on any or all of these issues are essential if the richness of small, nonvolant species of mammals in a region such as the Tapajós is to be clarified.

Overall, apart from a size reduction, very little appears to have changed since the 1990s in terms of infrastructure and the legal status of ANP. Although the number of personnel has increased from five to seven, the active conservation presence in ANP remains modest. Only two of the official on-site ANP staff are park rangers, which is insufficient for the surveillance operations required in such a large, biodiverse area. Furthermore, no park rangers are permanently located within the park, so environmental regulations cannot be consistently enforced. Four surveillance guards based at two outposts are tasked with protecting the park, but they lack any legal authority to detain or arrest violators for criminal behavior. Furthermore, the financial resources available for surveillance and maintenance within ANP are extremely limited.

A qualitative comparison of the historical and current conservation situation in ANP indicates that there have been no positive changes or developments since the park was established over 30 years ago. Park personnel also expressed this view (L. Coelho and J. Vasconcelos, personal Communication, December 16, 2015). In their study, Rylands and Pinto (1998) found the main threats to ANP to be human invasion, impacts from adjacent indigenous reservations, agriculture or cattle ranching, and pollution. Rylands (1991) considered proximity to indigenous reservations as a threat because they are associated with depredation in some other reserves. The findings of our study did not confirm any of these problems. However, we found erosion, human development in adjacent areas, and changes in the water regime to be problems observed in this study that were not present before (Rylands, 1991; Rylands & Pinto, 1998).

Inadequate management and resources for basic infrastructure are listed as the primary problems for all protected areas within the Brazilian Amazon (Rylands & Pinto, 1998), including ANP. It is highly likely that the proposed dam and associated infrastructure, as well as the increase in regional human population pressure (de Oliveira et al., 2014), will add to the suite of current problems facing ANP. Ecologically, further instabilities are expected from the eradication of the *igapó* flooded forest from the park if the dam is completed, including a reduction in carrying capacity and a severe population decline for several species, including threatened primates and carnivores (de Oliveira et al., 2014). Associated infrastructural changes include paving the Trans-Amazonia highway, and this will further increase roadkill (Figure 5) and other negative anthropogenic effects (Bennett, 1991; Trombulak & Frissell, 2000; Wilkie, Shaw, Rotberg, Morelli, & Auzel, 2000). The current low level of staffing needs to be increased considerably to effectively mitigate these changes. ANP, as with

Figure 5. The Trans-Amazonia Highway and a roadkill specimen of the rare and Vulnerable bush dog (*Speothos venaticus*) within Amazonia National Park.

many other protected areas in Brazil, is not far from being a "paper reserve" (Bruner, Gullison, Rice, & da Fonseca, 2001).

Although hunting and timber exploitation are potential problems for ANP, they currently pose less of a threat than the issues described earlier, as they are not practiced at the same levels of intensity observed in other protected areas in the Amazon Basin (Oliveira, 2011; Pezzuti et al., 2004; Rylands & Pinto, 1998). Logging and changes in forest cover were also listed in a worldwide analysis of threats to protected areas dominated by tropical forest habitats (Laurance et al., 2012). Neither is currently highly problematic in ANP, but that could easily change with improved park access. ANP personnel regard human population growth in the park buffer zone, catalyzed by the dam project proposal, as the biggest threat, likely to place tremendous conservation pressure on the area (L. Coelho and J. Vasconcelos, personal communication, December 16, 2015).

Implications for Conservation

This study is important not only for highlighting the biological diversity of ANP and conservation problems it faces but also for providing scientific data to inform the outdated ANP Management Plan (IBDF/FBCN, 1979). The assessment presented here should also serve as a red alert to the international conservation community, particularly regarding the reduction of the ANP's size and the changes to its borders (Bernard et al., 2014; de Marques & Peres, 2015) that the Brazilian authorities allowed in order for hydroelectric dams to be "legally" built. This policy is especially detrimental in protected areas, such as ANP, that have an exceptionally high level of documented biodiversity. It is important to note, too, that Soares-Filho et al. (2005, 2006) predicted that by 2050, the area surrounding ANP will be highly degraded.

The direct effects of dam construction on ANP are still being evaluated (CNEC Worley Parsons Engenharia, 2014). However, it is clear that construction preparations have already increased detrimental human activities, which are of paramount concern for conservation. The likely future of ANP if the dam is constructed can be gauged from another dam site, Belo Monte. There, ecological and socioeconomic environmental impacts were not carefully considered (Barreto et al., 2011; Fearnside, 2015). Any ANP dam-related development activities are likely to isolate the park, potentially reducing the range, carrying capacity, and population sizes of several groups, including threatened primates and carnivores (de Oliveira et al., 2014). The ecological fates of protected areas may be strongly determined by environmental changes immediately outside their boundaries, too (Laurance et al., 2012).

The Protected Areas Downgrading, Downsizing, and Degazettement that affected ANP in 2012 reflects a change in Brazilian government policy that is now primarily concerned with social infrastructure development through electricity generation and transmission in Amazonia (Bernard et al., 2014; de Marques & Peres, 2015). This has also affected several other protected areas, which face the same kind of "legal-political" threat from Brazilian national authorities (de Marques & Peres, 2015).

Our findings of threatened species, high mammalian richness, and 5 to 12 new mammal species at ANP emphasize the importance of the park as a megadiverse and highly important conservation priority area. Therefore, ANP should receive special conservation attention from authorities instead of facing threats from activities that threaten this biodiversity. A well-informed and robust conservation strategy is urgently needed owing to imminent dam construction and associated environmental damage. Brazilian authorities need to act accordingly to meet their stated aims and commitments to biodiversity conservation (Ganem, 2011). We hope that this report will alert both government authorities and nongovernmental organizations to take proper action to stop, mitigate, and avoid the degradation of ANP and its rich megadiversity.

Appendix 1. Nonvolant Mammals Found in Amazonia National Park, Pará State, Brazil.

Taxon	Common name	Record	Red list status
Didelphimorphia			
Didelphidae			
Caluromys philander (Linnaeus, 1758)	Bare-tailed woolly opossum	C, P	
Chironectes minimus (Zimmermann, 1780)	Water opossum, Yapok	S, T	
Didelphis marsupialis Linnaeus, 1758	Black-eared opossum	C, V, P, T	
Glironia venusta Thomas, 1912	Bushy-tailed opossum	C	DD
Marmosa (*Marmosa*) *macrotarsus* (Thomas, 1899)	Mouse opossum	C	
Marmosa (*Marmosa*) *murina* (Linnaeus, 1758)	Linnaeus' mouse opossum	C	

(continued)

Appendix 1. Continued

Taxon	Common name	Record	Red list status
Marmosops noctivagus (Tschudi, 1845)	White-bellied slender mouse opossum	C, M	
Marmosops sp. 1	Slender mouse opossum	C	
Metachirus sp. nov.	Four-eyed opossum	C	
Marmosa (*Micoureus*) sp. 1	Woolly mouse opossum	C	
Marmosa (*Micoureus*) sp. 2	Woolly mouse opossum	C	
Monodelphis glirina (Wagner, 1842)	Amazonian red-sided opossum	C	
Monodelphis sp. nov. (*adusta* group)	Short-tailed opossum	C	
PILOSA			
Cyclopedidae			
Cyclopes didactylus (Linnaeus, 1758)	Silky anteater	M	
Bradypodidae			
Bradypus variegatus Schinz, 1825	Pale-throated three-toed sloth	S, P, K	
Megalonychidae			
Choloepus didactylus (Linnaeus, 1758)	Linné's two-toed sloth	S, P	
Myrmecophagidae			
Myrmecophaga tridactyla Linnaeus, 1758	Giant anteater	S, P, T	VU
Tamandua tetradactyla (Linnaeus, 1758)	Collared anteater, Tamandua	S, P, T	
CINGULATA			
Dasypodidae			
Cabassous unicinctus (Linnaeus, 1758)	Southern naked-tailed armadillo	S, T, B	
Dasypus kappleri Krauss, 1862	Greater long-nosed armadillo	S, P, T, B	
Dasypus novemcinctus Linnaeus, 1758	Nine-banded armadillo	P, T, B	
Priodontes maximus (Kerr, 1792)	Giant armadillo	P, T, B	VU
PRIMATES			
Aotidae			
Aotus nigriceps Dollman, 1909	Black-headed night monkey	S	
Atelidae			
Alouatta nigerrima Lönnberg, 1941	Black howler monkey	S, Vo	
Ateles chamek (Humboldt, 1812)	Red-faced black spider monkey	S, P	EN
Callitrichidae			
Mico humeralifer (É. Geoffroy, 1812)	Black-and-white tassel-ear marmoset	S, K	DD
Cebidae			
Cebus albifrons (Humboldt, 1812)	Humboldt's white-fronted capuchin	S, P	
Sapajus apella (Linnaeus, 1758)	Tufted capuchin	S, P, Vo	
Saimiri ustus (I. Geoffroy, 1843)	Golden-backed squirrel monkey	S	NT
Pitheciidae			
Callicebus hoffmannsi Thomas, 1908	Hoffmann's titi monkey	S, Vo	
Chiropotes albinasus (I. Geoffroy & Deville, 1848)	Red-nosed cuxiu	S	EN
Pithecia irrorata Gray, 1842	Gray monk saki	S, P	
CARNIVORA			
Canidae			
Atelocynus microtis (Sclater, 1883)	Short-eared dog	S, P, T	VU
Speothos venaticus (Lund, 1842)	Bush dog	S, P, K, T	VU
Procyonidae			
Nasua nasua (Linnaeus, 1766)	South American coati	S, P, T	
Potos flavus (Schreber, 1774)	Kinkajou	S	
Procyon cancrivorus (G. [Baron] Cuvier, 1798)	Crab-eating raccoon	P, T	

(continued)

Appendix 1. Continued

Taxon	Common name	Record	Red list status
Mustelidae			
Eira barbara (Linnaeus, 1758)	Tayra	S, P, T	
Galictis vittata (Schreber, 1776)	Greater grison	T, M	
Mustela africana Desmarest, 1818	Amazon weasel	T	DD
Lontra longicaudis (Olfers, 1818)	Neotropical otter	S, T	NT
Pteronura brasiliensis (Gmelin, 1788)	Giant otter	S, T	VU
Felidae			
Leopardus pardalis (Linnaeus, 1758)	Ocelot	S, P, T	
Leopardus wiedii (Schinz, 1821)	Margay	S, P, T	VU
Puma yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	Jaguarundi	S, P, T, K	VU
Puma concolor (Linnaeus, 1771)	Puma	S, P, T	VU
Panthera onca (Linnaeus, 1758)	Jaguar	S, P, T	VU
Sirenia			
Trichechidae			
Trichechus inunguis (Natterer, 1883)	South American manatee	S	VU
Perissodactyla			
Tapiridae			
Tapirus terrestris (Linnaeus, 1758)	Lowland tapir	S, P, T	VU
ARTIODACTYLA			
Cervidae			
Mazama americana (Erxleben, 1777)	Red brocket deer	S, P, T	DD
Mazama nemorivaga (F. Cuvier, 1817)	Amazonian brown brocket deer	S, P, T	
Tayassuidae			
Pecari tajacu (Linnaeus, 1758)	Collared peccary	S, P, T	
Tayassu pecari (Link, 1795)	White-lipped peccary	S, P, T	VU
CETACEA			
Delphinidae			
Sotalia fluviatilis (Gervais & Deville, 1853)	Tucuxi	S	NT
Iniidae			
Inia geoffrensis (Blainville, 1817)	Pink river dolphin, Boto	S	EN
Lagomorpha			
Leporidae			
Sylvilagus brasiliensis (Linnaeus, 1758)	Tapeti, Forest rabbit	S, T, K	
Rodentia			
Caviidae			
Cavia aperea Erxleben, 1777	Brazilian guinea pig	S	
Hydrochaerus hydrochaeris (Linnaeus, 1766)	Capybara	S, P, T	
Cricetidae			
Euryoryzomys sp. 1	Rice rat	C	
Hylaeamys sp. 1	Rice rat	C	
Neacomys sp. nov. 1	Bristly mouse	C	
Neacomys sp. nov. 2	Bristly mouse	C	
Nectomys rattus (Pelzeln, 1883)	Small-footed bristly mouse	M	
Neusticomys ferreirai Percequillo, Carmignotto & Silva, 2005	Fish-eating rat	C	DD
Oecomys bicolor (Tomes, 1860)	Bicolored arboreal rice rat	C	
Oecomys roberti (Thomas, 1904)	Robert's arboreal rice rat	C	
Oecomys sp. 1	Arboreal rice rat	C	

(continued)

Appendix 1. Continued

Taxon	Common name	Record	Red list status
Rhipidomys nitela (Thomas, 1901)	Splendid climbing mouse	M	
Cuniculidae			
Cuniculus paca (Linnaeus, 1766)	Spotted paca	S, P, T	
Dasyproctidae			
Dasyprocta croconota Wagler, 1831	Red-rumped agouti	S, P, T	
Echimyidae			
Dactylomys dactylinus (Desmarest, 1817)	Amazon bamboo rat	P, Vo	
Echimys vieirai Iack-Ximenes, Vivo, & Percequillo, 2005	Spiny tree rat	C	DD
Isothrix pagurus Wagner, 1845	Plain brush-tailed rat	C	DD
Lonchothrix emiliae Thomas, 1920	Tuft-tailed spiny tree rat	C	
Makalata macrura (Wagner, 1842)	Long-tailed tree rat	C	
Mesomys cf. *hispidus* (Desmarest, 1817)	Spiny tree rat	C	
Mesomys stimulax (Thomas, 1911)	Surinam spiny tree rat	C	
Proechimys roberti Thomas, 1901	Roberto's spiny rat	C	
Proechimys cuvieri Petter, 1978	Cuvier's spiny rat	C	
Proechimys sp. nov.	Spiny rat	C	
Proechimys sp. 1	Spiny rat	C	
Proechimys sp. 2	Spiny rat	C	
Erethizontidae			
Coendou prehensilis (Linnaeus, 1758)	Brazilian porcupine	S	
Sciuridae			
Guerlinguetus gilvigularis (Wagner, 1842)	Yellow-throated squirrel	S, P, C	DD
Sciurillus pusillus (E. Geoffroy, 1803)	Neotropical pygmy squirrel	S, P	
Urosciurus spadiceus (Olfers, 1818)	Southern Amazon red squirrel	S, P	

Note. Records: B = Burrows; C = live-capture; K = carcass; M = museum specimen; P = photographic or video record; T = Tracks or Signs; S = sighting; Vo = Vocalization; IUCN Red List (2015) or MMA Red List (2014) status: DD = Data Deficient; NT = Near Threatened; VU = Vulnerable; EN = Endangered.

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Author Contributions

Tadeu G. de Oliveira collected and analysed the data, and also wrote the paper; Fábio D. Mazim and Odgley Q. Vieira collected and analysed the data; Adrian P. A. Barnett collected the data and wrote the paper; Gilberto do N. Silva, José Bonifácio G. Soares, Jean P. Santos, Victor F. da Silva, and Pedro A. Araújo collected the data; Ligia Tchaika performed molecular analysis; Cleuton L. Miranda performed taxonomic confirmation of small nonvolant mammals and also wrote the paper.

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References

Ayres, J., & Milton, K. (1981). Levantamento de primatas e habitat no Rio Tapajós [Survey of primates and habitats in the Tapajós River]. *Boletim do Museu Paraense Emilio Goeldi, Nova Série*, *111*, 1–16.

Barnett, A. A., & da Cunha, A. C. (1994). Notes on the small mammals of Ilha-de-Maracá, Roraima state, Brazil. *Mammalia*, *58*, 131–137.

Barreto, P., Brandão, A. Jr, Martins, H., Silva, D., Souza, C. Jr, Sales, M., . . . Feitosa, T. (2011). *Risco de desmatamento associado à hidrelétrica de Belo Monte* [Risk of deforestation associated with Belo Monte hydroelectric plant]. Belém, Brazil: Instituto do Homem e Meio Ambiente da Amazônia-IMAZON.

Benchimol, M., & Peres, C. A. (2015). Widespread forest vertebrate extinctions induced by a mega hydroelectric dam in lowland Amazonia. *PLoS One*, *10*, e0129818.

Bennett, A. F. (1991). Roads, roadsides and wildlife conservation: A review. In: D. A. Saunders, & R. J. Hobbs (Eds.). *Nature conservation 2: The role of corridors* (pp. 99–117). Chipping Norton, Australia: Surrey Beatty.

Bergallo, H. G., Carvalho, A. S., & Martins-Hatano, F. (2012). Médios e grandes mamíferos [Medium and large sized mammals]. In: F. D. Martins, A. F. Castilho, J. Campos, F. Martins-Hatano, & S. G. Rolim (Eds.). *Fauna da floresta nacional de Carajás: Estudos sobre vertebrados terrestres* [Fauna of Carajás National Forest: Studies on terrestrial vertebrates] (pp. 180–195). São Paulo, Brazil: Nitro Imagens.

Bernard, E., Penna, L. A. O., & Araújo, E. (2014). Downgrading, downsizing, degazettement, and reclassification of protected areas in Brazil. *Conservation Biology*, *28*, 939–950.

Bonvicino, C. R., Oliveira, J. A. D., & D'Andrea, P. S. (2008). *Guia dos roedores do Brasil, com chaves para gêneros baseadas em caracteres externos* [Guide of the rodents from Brazil, with keys to genera based on external characters]. Rio de Janeiro, Brazil: Centro Pan-Americano de Febre Aftosa-OPAS/OMS.

Borges, L. H. M., Calouro, A. M., & Sousa, J. R. D. (2015). Large and medium-sized mammals from Chandless State Park, Acre, Brazil. *Mastozoología Neotropical*, *22*, 265–277.

Bruner, A. G., Gullison, R. E., Rice, R. E., & da Fonseca, G. A. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science*, *291*, 125–128.

Carvalho, A. S., Martins, F. D., Dutra, F. M., Gettinger, D., Martins-hatano, F., & Bergallo, H. D. G. (2014). Large and medium-sized mammals of Carajás National Forest, Pará State, Brazil. *Check List*, *10*, 1–9.

CNEC Worley Parsons Engenharia, S. A. (2014). EIS HD São Luiz do Tapajós: Environmental impact study, hydroelectric development São Luiz do Tapajós. São Paulo, SP, Vol. 25 Vols. + anexes.

Costa, L. P., Leite, Y. L. R., Mendes, S. L., & Ditchfield, A. D. (2005). Mammal conservation in Brazil. *Conservation Biology*, *19*, 672–679.

da Silva, C. R., Martins, A. C. M., de Castro, I. J., Bernard, E., Cardoso, E. M., dos Santos Lima, D., . . . da Cruz-Castro, K. (2013). Mammals of Amapá state, Eastern Brazilian Amazonia: A revised taxonomic list with comments on species distributions. *Mammalia*, *77*, 409–424.

da Silva, F. S., & Mendes-Oliveira, A. C. (2012). Diversidade de mamíferos de médio e grande porte da região do rio Urucu, Amazonas, Brasil [Diversity of medium and large mammals in the region of Urucu River, Amazonas, Brazil]. *Biota Neotropica*, *12*, 282–291.

Da Silva, M. N. F., Arteaga, M. C., Bantel, C. G., Rossoni, D. M., Leite, R. N., Pinheiro, P. S., . . . Eler, E. S. (2007). Mamíferos de pequeno porte (Mammalia: Rodentia and Didelphimorphia) [Small mammals (Mammalia: Rodentia and Didelphimorphia)]. In: L. R. PY-Daniel, C. P. De Deus, A. L. Henriques, D. M. Pimpão, & O. M. Ribeiro (Eds.). *Biodiversidade do médio Madeira – Bases Científicas para propostas de conservação* [Biodiversity of the Mid-Madeira—Scientific basis for conservation] (pp. 179–194). Manaus, Brazil: INPA, Ministério do Meio Ambiente, Ministério de Ciência e Tecnologia.

Dalponte, J. C., Silva, F. E., & Júnior, S. (2014). New species of titi monkey, genus *Callicebus* Thomas, 1903 (Primates, Pitheciidae), from Southern Amazonia, Brazil. *Papéis Avulsos de Zoologia (São Paulo)*, *54*, 457–472.

de Marques, A. A. B., & Peres, C. A. (2015). Pervasive legal threats to protected areas in Brazil. *Oryx*, *49*, 25–29.

de Oliveira, T. G., Vieira, O. Q., Kasper, C. B., Trevelin, L. C., & Barnett, A., et al. (2014). *EIS (Environmental Impact Study)/ EIR (Environmental Impact Report) HD (Hydroelectric Development) São Luiz do Tapajós*. São Paulo, Brazil: CNEC Engenharia.

Eisenberg, J. F. (1999). Biodiversity reconsidered. In: J. F. Eisenberg, & K. H. Redford (Eds.). *Mammals of the neotropics: The central neotropics* (pp. 527–548). Chicago, IL: The University of Chicago Press.

Eisenberg, J. F., & Redford, K. H. (1999). *Mammals of the neotropics, the central neotropics: Ecuador, Peru, Bolivia, Brazil*. Chicago, IL: The University of Chicago Press.

Eletrobrás *Aproveitamento hidrelétrico Belo Monte: Estudo de impacto ambiental* [Hydroelectric development Belo Monte: Environmental impact study] (Vol 36). Rio de Janeiro, Brazil: Author.

Emmons, L. H., & Feer, F. (1997). Neotropical rainforest mammals *(2nd ed.)*. Chicago, IL: The University of Chicago Press.

Fearnside, P. M. (2005). Deforestation in Brazilian Amazonia: History, rates, and consequences. *Conservation Biology*, *19*, 680–688.

Fearnside, P. M. (2006). Greenhouse gas emissions from hydroelectric dams: Reply to Rosa et al. *Climatic Change*, *75*, 103–109.

Fearnside, P. M. (2015). *Hidrelétricas na Amazônia: Impactos ambientais e sociais na tomada de decisões sobre Grandes Obras* [Hydroelectric plants in the Amazon: Environmental and social impacts in decision making on major projects]. Manaus, Brazil: Editora do INPA.

Ferreira, L. V., & Prance, G. T. (1998). Structure and species richness of low-diversity floodplain forest on the Rio Tapajós, Eastern Amazonia, Brazil. *Biodiversity and Conservation*, *7*, 585–596.

Ganem, R. S. (Ed.). (2011). *Conservação da biodiversidade: Legislação e políticas públicas* [Conservation of biodiversity: Legislation and public policy] (p. 437). Brasília, Brazil: Edições Câmara.

Gardner, A. L. (2008). *Mammals of South America, volume 1: Marsupials, xenarthrans, shrews, and bats*. Chicago, IL: The University of Chicago Press.

George, T. K., Marques, S. A., de Vivo, M., Branch, L. C., Gomes, N., & Rodrigues, R. (1988). Levantamento de mamíferos do PARNA Tapajós [Mammal survey of Tapajós National Park]. *Brasil Florestal*, *63*, 33–41.

Gerwing, J. J., & Farias, D. L. (2000). Integrating liana abundance and forest stature into an estimate of total aboveground biomass for an eastern Amazonian forest. *Journal of Tropical Ecology*, *16*, 327–335.

Gettinger, D., Ardente, N. C., & Martins-Hatano, F. (2012). Pequenos mamíferos não-voadores (marsupiais e roedores) [Small non-volant mammals (marsupials and rodents)]. In: F. D. Martins, A. F. Castilho, J. Campos, F. Martins-Hatano, & S. G. Rolim (Eds.). *Fauna da floresta nacional de Carajás: Estudos sobre vertebrados terrestres* [Fauna of Carajás National Forest: Studies on terrestrial vertebrates] (pp. 144–161.). São Paulo, Brazil: Nitro Imagens.

Gregorin, R., & De Vivo, M. (2013). Revalidation of *Saguinus ursula* Hoffmannsegg (Primates: Cebidae: Callitrichinae). *Zootaxa*, *3721*, 172–182.

Gualda-Barros, J., Nascimento, F. O., & Amaral, M. K. (2012). A new species of Callicebus Thomas, 1903 (Primates, Pitheciidae) from the states of Mato Grosso and Pará, Brazil. *Papéis Avulsos de Zoologia*, *52*, 261–279.

Hice, C. L., & Schmidly, D. J. (2002). The effectiveness of pitfall traps for sampling small mammals in the Amazon Basin. *Mastozoología Neotropical*, *9*, 85–89.

IBDF/FBCN *Parque Nacional da Amazônia (Tapajós): Plano de manejo* [Amazonia National Park (Tapajós): Management plan]. Brasília, Brazil: Author.

Instituto Nacional de Pesquisas Espaciais (INPE). (2015). *Taxas Anuais de Desmatamento – 1988 até 2015* [Anual deforestation rates – 1988 to 2015]. Manaus, Brazil: Instituto Nacional de Pesquisas Espaciais.

IUCN. (2015). *IUCN red list of threatened species version 2015–4*. Retrieved from http://www.iucnredlist.org/.

Iwanaga, S. (2004). Levantamento de mamíferos diurnos de médio e grande porte no Parque Nacional do Jaú: Resultados preliminares [Survey of diurnal medium and large sized mammals of Jaú National Park: Preliminary results]. In: S. H. Borges, S. Iwanaga, C. C. Durigan, & M. R. Pinheiro (Eds.). Janelas para a biodiversidade no Parque Nacional do Jaú: Uma estratégia para o estudo da biodiversidade na Amazônia *[Windows for biodiversity of Jaú National Park: A strategy for the study of biodiversity in the Amazon]* (pp. 195–207). Manaus, Brazil: Fundação Vitória Amazônica.

Janson, C. H., & Emmons, L. H. (1990). Ecological structure of the non-flying mammal community at Cocha Cashu Biological Station, Manu National Park, Peru. In: A. H. Gentry (ed.) *Four neotropical rainforests* (pp. 314–338). New Haven, CT: Yale University Press.

Lambert, T. D., Malcolm, J. R., & Zimmerman, B. L. (2006). Amazonian small mammal abundances in relation to habitat structure and resource abundance. *Journal of Mammalogy*, *87*, 766–776.

Laurance, W. F., Useche, D. C., Rendeiro, J., Kalka, M., Bradshaw, C. J. A., Sloan, S. P., . . . Zamzani, F. (2012). Averting biodiversity collapse in tropical forest protected areas. *Nature*, *489*, 290–294.

Malcolm, J. R., Patton, J. L., & da Silva, M. N. F. (2005). Small mammal communities in upland and floodplain forests along an Amazonian white-water river. In: E. I. Lacey, & P. Myers (Eds.). *Mammalian diversification: From chromosomes to phylogeography* (pp. 335–380). Berkley, CA: UC Publications in Zoology Paper.

Martins, S. S., Sanderson, J. G., & Silva-Júnior, J. S. (2007). Monitoring mammals in the Caxiuanã National Forest, Brazil – First results from the Tropical Ecology, Assessment and Monitoring (TEAM) program. *Biodiversity and Conservation*, *16*, 857–870.

Maury, C. M. (Ed.). (2002). *Avaliação e identificação de áreas e ações prioritárias para a conservação, utilização sustentável e repartição dos benefícios da biodiversidade nos biomas brasileiros* [Assessment and identification of priority areas and actions for the conservation, sustainable use and benefit sharing of biodiversity in Brazilian biomes]. Brasília, Brazil: MMA/SBF.

Mendes-Oliveira, A. C., & Miranda, C. L. (2015). Pequenos mamíferos Não-Voadores da Amazônia Brasileira *[Small non-volant mammals of the Brazilian Amazon]*. Rio de Janeiro, Brazil: Sociedade Brasileira de Mastozoologia.

MINTER-IBAMA (1990). *Listagem das Unidades de Conservação a Cargo da Diretoria de Ecossistemas (DIREC). Technical Report* [List of protected areas under the supervision of the Board of Ecosystems (DIREC). *Technical Report*]. Brasília, Brazil: Author.

MMA. (2014). *Lista nacional das espécies da fauna Brasileira Ameaçadas de extinção portaria N° 444, De 17 De Dezembro de 2014, Brasília: MMA* [National list of the endangered Brazilian fauna, Ordinance N° 444, 7 December 2014, Brasília: MMA]. Retrieved from http://www.icmbio.gov.br/portal/images/stories/biodiversidade/fauna-brasileira/avaliacao-do-risco/PORTARIA_N.%C2.%BA_444_DE_17_DE_DEZEMBRO_DE_2014.pdf.

Nogueira, E. M., Yanai, A. M., Fonseca, F. O., & Fearnside, P. M. (2015). Carbon stock loss from deforestation through 2013 in Brazilian Amazonia. *Global Change Biology*, *21*, 1271–1292.

Oliveira, T. G. (2007). Carnívoros do Maranhão: Preliminares sobre distribuição, composição das comunidades e conservação no meio-norte do Brasil [Carnivores of Maranhão: Preliminaries on the distribution, community composition and conservation in the Brazilian mid-north]. In: A. C. Silva, & J. L. O. Fortes (Eds.). *Diversidade biológica, uso e conservação de recursos naturais no Maranhão* [Biological diversity, use and conservation of natural resources in the State of Maranhão] (pp. 347–366). São Luís, Brazil: Universidade Estadual do Maranhão.

Oliveira, T. G. (2011). Alerta vermelho à conservação da última fronteira da Amazônia Tocantina: Avaliação do estado de conservação do Gurupi e da Amazônia maranhense [Red alert to the conservation of the last frontier of the Tocantins River Amazonia: Evaluation of the conservation status of the Gurupi and the Amazon in Maranhão State]. In: M. B. Martins, & T. G. de Oliveira (Eds.). *Amazônia maranhense: Diversidade e conservação* [The Amazon in Maranhão: Diversity and conservation] (pp. 283–295). Belém, Brazil: Museu Paraense Emílio Goeldi.

Oliveira, T. G., & Cassaro, K. (2005). *Guia de Campo dos Felinos do Brasil* [Field guide of felids from Brazil]. São Paulo, Brazil: Instituto Pró-Carnívoros.

Oliveira, T. G., de Paula, R. C., & Figueira, C. (1998). *Levantamento mastofaunístico da área do empreendimento florestal da CELMAR, Maranhão* [Mammalian survey of the area of CELMAR forest enterprise, Maranhão]. Unpublished report, Instituto de Pesquisa em Vida Silvestre, Piracicaba, Brazil.

Pacheco, V., & Vivar, E. (1996). Annotated checklist of the non-flying mammals at Pakitza, Manu Reserved Zone, Manu National Park, Peru. In: D. E. Wilson, & A. Sandoval (Eds.).

Manu, the biodiversity of southeastern Peru (pp. 577–592). Washington, DC: Smithsonian Institute.

Padial, J. M., Miralles, A., De la Riva, I., & Vences, M. (2010). The integrative future of taxonomy. *Frontiers in Zoology*, *7*, 16 doi:10.1186/1742-9994-7-16.

Paglia, A. P., Fonseca, G. A. B., Rylands, A. B., Herrmann, G., Aguiar, L. M. S., Chiarello, A. G., . . . Patton, J. L. (2012). Annotated checklist of Brazilian mammals. *Occasional Papers in Conservation Biology*, *6*, 1–76.

Patton, J. L., Da Silva, M. N. F., & Malcolm, J. R. (2000). Mammals of the Rio Juruá and the evolutionary and ecological diversification of Amazonia. *Bulletin of the American Museum of Natural History*, *244*, 1–306.

Patton, J. L., Pardiñas, U. F. J., & D'Elia, G. (2015). *Mammals of South America: Rodents*. Chicago, IL: The University of Chicago Press.

Pavan, S. E., Jansa, S. A., & Voss, R. S. (2014). Molecular phylogeny of short-tailed opossums (Didelphidae: *Monodelphis*): Taxonomic implications and tests of evolutionary hypotheses. *Molecular Phylogenetics and Evolution*, *79*, 199–214.

Peres, C. A. (1999). The structure of non-volant mammal communities in different Amazonian forest types. In: J. F. Eisenberg, & K. H. Redford (Eds.). *Mammals of the neotropics: The central neotropics* (pp. 564–581). Chicago, IL: The University of Chicago Press.

Pezzuti, J. C., Lima, J. P., Félix-Silva, D., Rebêlo, G. H., Borges, S., Iwanaga, S., . . . Pinheiro, M. (2004). A caça e a pesca no Parque Nacional do Jaú, Amazonas [Hunting and fishing in Jaú National Park, Amazonas]. In: S. H. Borges, S. Iwanaga, C. C. Durigan, & M. R. Pinheiro (Eds.). *Janelas para a biodiversidade no Parque Nacional do Jaú: Uma estratégia para o estudo da biodiversidade na Amazônia* [Windows for biodiversity of Jaú National Park: A strategy for the study of biodiversity in the Amazon] (pp. 213–230). Manaus, Brazil: Fundação Vitória Amazônica.

Pimenta, C. S. (2012). Uso do habitat e ocupação por carnívoros em uma reserva de uso sustentável na Amazônia Central, Brasil [Habitat use and occupation by carnivores in a sustainable use reserve in central Amazonia, Brazil]. Instituto Nacional de Pesquisa da Amazônia, Manaus, Brazil.

Ribeiro-Júnior, M. A., Rossi, R. V., Miranda, C. L., & Ávila-Pires, T. C. S. (2011). Influence of pitfall trap size and design on herpetofauna and small mammal studies in a Neotropical Forest. *Zoologia (Curitiba)*, *28*, 80–91.

Rylands, A. B. (1991). *The status of conservation areas in the Brazilian Amazon*. Washington, DC: World Wildlife Fund.

Rylands, A. B., & Pinto, L. P. S. (1998). *Conservação da biodiversidade na Amazônia brasileira: Uma análise do sistema de unidades de conservação* [Biodiversity conservation in Brazilian Amazonia: An analysis of the system of conservation units] (Vol 1). Rio de Janeiro, Brazil: Fundação Brasileira para o Desenvolvimento Sustentável.

Sampaio, R., Rohe, F., Pinho, G., Silva-Júnior, J. S., Farias, I. P., & Rylands, A. B. (2015). Re-description and assessment of the taxonomic status of *Saguinus fuscicollis cruzlimai* Hershkovitz, 1966 (Primates, Callitrichinae). *Primates*, *56*, 131–144.

Santos-filho, M., Lázari, P. R. D. E., Pedro, C., Sousa, F. D., & Canale, G. R. (2015). Trap efficiency evaluation for small mammals in the southern Amazon. *Acta Amazonica*, *45*, 187–194.

Santos-Filho, M., Peres, C. A., da Silva, D. J., & Sanaiotti, T. M. (2012). Habitat patch and matrix effects on small-mammal persistence in Amazonian forest fragments. *Biodiversity and Conservation*, *21*, 1127–1147.

Santos-Filho, M., Silva, D. D., & Sanaiotti, T. (2006). Efficiency of four trap types in sampling small mammals in forest fragments, Mato Grosso, Brazil. *Mastozoología Neotropical*, *13*, 217–225.

Sayre, R., Bow, J., Josse, C., Sotomayor, L., & Touval, J. (2008). Terrestrial ecosystems of South America. *North America land cover summit: A special issue of the Association of American Geographers*, Washington, DC, 131–152.

Silva, M. E. S., Pereira, G., & da Rocha, R. P. (2015). Local and remote climatic impacts due to land use degradation in the Amazon ''Arc of Deforestation''. *Theoretical and Applied Climatology*, *120*, 1–15.

Soares-Filho, B. S., Nepstad, D. C., Curran, L. M., Cerqueira, G. C., Garcia, R. A., Ramos, C. A., . . . Schlesinger, P. (2006). Modelling conservation in the Amazon basin. *Nature*, *440*, 520–523.

Soares-Filho, B. S., Nepstad, D. C., Curran, L., Cerqueira, G. C., Garcia, R. A., Ramos, C. A., . . . McGrath, D. (2005). Cenários de desmatamento para a Amazônia [Deforestation scenarios for the Amazon]. *Estudos Avançados*, *19*, 137–152.

Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, *14*, 18–30.

Vieira, O. Q. (2012). *O componente mastofaunístico como indicador de degradação na região do Bico Do Papagaio – PA/TO/MA* [The mammalian component as indicator of environmental degradation in the ''Parrot's Beak'' region – Pará/Tocantins/Maranhão tri-state-border area]. São Luís, Brazil: Universidade Federal do Maranhão.

Vivo, M. D. (1996). How many species of mammals there are in Brazil? In: C. E. M. Bicudo, & N. A. Menezes (Eds.). *Biodiversity in Brazil, a first approach* (pp 313–321). São Paulo, Brazil: CNPQ.

Voss, R. S., & Emmons, L. H. (1996). Mammalian diversity in Neotropical lowland rainforests: A preliminary assessment. *American Museum of Natural History*, *230*, 1–115.

Voss, R. S., & Jansa, S. A. (2009). Phylogenetic relationships and classification of didelphid marsupials, an extant radiation of New World metatherian mammals. *Bulletin of the American Museum of Natural History*, *322*, 1–177.

Wilkie, D., Shaw, E., Rotberg, F., Morelli, G., & Auzel, P. (2000). Roads, development, and conservation in the Congo Basin. *Conservation Biology*, *14*, 1614–1622.

Wilson, D. E., & Reeder, D. M. (2005). *Mammal species of the world: A taxonomic and geographic reference* (Vol 1). Baltimore, MD: The Johns Hopkins University Press.

Wilson, G. J., & Delahay, R. J. (2001). A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. *Wildlife Research*, *28*, 151–164.

Woods, C. A., & Kilpatrick, C. W. (2005). Infraorder Hystricognathi. In: D. E. Wilson, & D. A. Reeder (Eds.). *Mammals species of the world, a taxonomic and geographic reference* (pp. 1538–1600). Washington, DC: Smithsonian Institute.