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The effects of the creation of a hydroelectric dam on small mammals' communities in central Brazil

Efeitos da criação de um reservatório de usina hidrelétrica em comunidades de pequenos mamíferos no Brasil central

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Abstract

Hydroelectrics are proposed as a solution to the increasing energy demand in developing countries. However, dams interrupt river flow; emit greenhouse gases, and cause habitat loss and fragmentation. Here, we evaluated changes in the diversity of small mammals during the construction of the Luís Eduardo Magalhães hydroelectric dam in central Brazil. Two sites, both located above the maximum filling of the dam, were sampled before (2001) and after (2002) the flooding. We used wire mesh traps and sherman traps for the total capture effort of 5,940 trap-nights. We captured 88 individuals from 13 species – 5 marsupials and 7 rodents. We expected an increase in the abundance of small mammals immediately after the flooding due to the fleeing of individuals from the flooded areas, with a following increase in density dependent mortality. However, our results indicated lower values of abundance and/or richness of small mammals after the flooding. In addition, live traps were frequently found overturned and with signs of attacks from potential predators of small mammals. Results suggested that predation pressure probably increased after the flooding, thereby causing a reduction in the abundance and/or richness of small mammals.

Key words: reservoir, sustainability, flooding, marsupials, rodents, Cerrado.

Resumo

Usinas hidrelétricas são propostas como uma solução à crescente demanda de energia em países em desenvolvimento. No entanto, os reservatórios interrompem o fluxo dos rios, emitem gases do efeito estufa, e causam perda e fragmentação de habitat. Neste estudo nós avaliamos as mudanças na diversidade de pequenos mamíferos durante a construção da usina hidrelétrica Luís Eduardo Magalhães, no Brasil central. Duas áreas localizadas acima do enchimento máximo do reservatório foram amostradas antes (2001) e depois (2002) da inundação. Armadilhas de arame galvanizado e do tipo sherman foram utilizadas com um esforço total de captura de 5.940 armadilhas-noites. Foram capturados 88 indivíduos de 13 espécies (cinco marsupiais e sete roedores). Era esperado um aumento na abundância de pequenos mamíferos logo após o enchimento do reservatório, devido à fuga de indivíduos das áreas sendo inundadas, com o posterior aumento de mortalidade dependente de densidade. Entretanto, os resultados indicaram menores valores de abundância e/ou riqueza de pequenos mamíferos após o enchimento do reservatório. Adicionalmente, as armadilhas foram frequentemente encontradas tombadas e com vestígios de ataques de predadores potenciais de pequenos mamíferos. Assim, os resultados sugerem que a pressão de predação provavelmente aumentou após a inundação, resultando na redução da abundância e/ou riqueza de pequenos mamíferos.

Palavras-chave: reservatório, sustentabilidade, inundação, marsupiais, roedores, Cerrado.

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Introduction

Hydroelectrics are proposed as a solution for the increasing electricity demand in developing countries (Yüksel, 2010). In Brazil, ca. 70% of electric power is produced by hydroelectrics (ANEEL, 2010), and energy policies remain focused on hydropower. Dams contribute to global warming with the emission of greenhouse gases (Fearnside, 1995, 2002), they affect the diversity of aquatic communities by obstructing the river flow (Poff *et al.*, 1997; Suzuki *et al.*, 2011), and cause habitat loss by the permanent flooding of natural patches (Rosenberg *et al.*, 1997; Cunha and Ferreira, 2012). However, their effects on terrestrial wildlife have been poorly investigated.

The creation of a dam can change biotic interactions near the newly created edge (Marinho-Filho *et al.*, 2000). The fleeing of individuals from the flooded patches can immediately overrun some species densities in the adjacent habitat patches. This can affect the regulation of vertebrate populations since territorial behavior is commonly seen in several taxa (Burt, 1949; López-Sepulcre and Kokko, 2005; Rodrigues, 2006), including small mammals (Cerboncini *et al.*, 2011). For instance, female small mammals are usually aggressive against co-specific intruders within the limits of their territory (Wolff, 1993). Consequently, the increase in density can result in a counter effect of increasing density dependent-mortality. This is particularly important for wildlife conservation and management, since population densities are dependent upon quality and size of the habitat patches (Chiarello, 2000).

Changes in small mammal species densities are a well-documented effect of habitat loss and fragmentation in the Neotropics (Bonvicino *et al.*, 2002; Pardini, 2004; Pardini *et al.*, 2005; Passamani and Fernandez, 2011). While some species become abundant in some habitat patches, others become rare or locally extinct (Laurance, 1994). This density compensation effect can be caused as a consequence of increased competition between similar species (Pardini, 2004). It can also occur due to changes in predation rates, as a decreased abundance of carnivores in forest fragments usually leads to an increased abundance of their prey (Fonseca and Robinson, 1990).

Few studies have reported the effects of the construction of hydroelectric dams on terrestrial animals (Nilsson and Dynesius, 1994). Regarding the Neotropics, this knowledge is limited to academic grey literature and private technical reports (Sá, 1995; Carmignotto, 1999). However, scientific data on this subject can provide valuable information for decision makers and help when deciding upon efficient measures for wildlife conservation. The aim of this study was to determine whether small mammal diversity changed after the construction of a hydroelectric dam in central Brazil. We expect an increase in the abundance of small mammals immediately after the flooding, due to the fleeing of individuals from the flooded areas. This increase in density should lead to an increase in density-dependent mortality reducing small mammal diversity. We also gathered information on attacks of live traps made by the predators of small mammals, in order to determine if changes in predation rates could be affecting the abundance of small mammals after the filling of the dam.

Material and methods

Study area

The Cerrado biome is exclusively within Central Brazil and its extension represents 25% of the Brazilian territory, with an area of approximately 1.5 million m^2 (Goodland, 1971). It extends specially through four Brazilian states (Eiten, 1972) making boundaries with the Amazonia to the north, Caatinga to the northeast, Pantanal to the northwest and Chaco to the south. Different types of plant formations can be found in the Cerrado biome – from open and shrub savannas to forest formations (Alho, 1982). It is one of the richest biomes on Earth and one of the world's most threatened hotspots (Myers *et al.*, 2000). From the total of 711 different mammal species that occur in Brazil, 251 occur in the Cerrado (Paglia *et al.*, 2012).

The study sites are located in the central portion of the state of Tocantins, along the shores of the Tocantins River. Altitude in the region ranges from 200 m to 700 m and the climate is tropical. The rainy season extends from October to March and the dry season from April to September with an extremely dry climate between May and August. The main vegetation physiognomies that occur in the region are "cerradão" (a dense arborous savanna), "cerrado *sensu strictu*" (arborous open savanna), campo cerrado (shrub savanna with sparse trees) and gallery forests. The species of small mammals in this region are influenced by the biodiversity of other Brazilian biomes, such as Amazonia, Caatinga, Pantanal and Mata Atlântica, with a high diversity of small mammals (Passamani, 2004).

Two sites – named Capivara and Jacinto – located near the margins of the Luís Eduardo Magalhães hydroelectric reservoir were sampled in this study. Vegetation in the Capivara site is typical of cerradão with gallery forests at a good level of conservation. The site is located near the Capivara stream – one of the tributaries of the Tocantins river (UTM: 22L, 781192, 8877596). Vegetation in the Jacinto site is typical of cerrado *sensu strictu* (UTM: 22L, 785008, 8887216). Both sites were located above the maximum filling of the dam, which began in January 2002 and was finished 25 days later, flooding an area of 63,000 ha.

Sampling protocol

At each study site we surveyed for small mammals in a 0.56 ha grid with a total of 36 sampling points (6 x 6) placed at intervals of 15 m (Figure 1). Each sampling point received a wire mesh trap (42 x 21 x 21cm) or a sherman trap (29 x 13 x 13cm) which were alternately placed on the ground. In the Capivara site we also placed sherman traps in the medium strata (1 to 2m high) of each sampling point. The traps were baited with a mixture of bananas, peanut butter, cod-liver oil, and cassava flour or corn meal. The animals captured were marked with numbered ear tags and released back into the area of capture. Voucher specimens are housed in the Museu de História Natural do Centro Universitário Luterano de Palmas (CEULP/ULBRA). A total of 10 sampling campaigns were conducted in each study site – four before the flooding (March, August, October and December 2001) and six afterwards (February, March, July, August, October and December 2002). Campaigns were bimonthly and each one composed of eight days of sampling.

In the 5th campaign carried out right after the flooding between February 22 and 30, 2002, we established a new sampling protocol near Jacinto's site. We placed six transects parallel to the dam's margin. This procedure was taken in order to evaluate if the flooding resulted in an accumulation of individuals near the margins of the dam. The positioning of the transects was changed daily, following the level of the reservoir. Ten traps were placed in 10m intervals in each transect. The animals captured in this sampling were not taken into account for data analysis.

During the sampling campaigns we looked for any signs of attacks to the live traps made by predators of small mammals. Medium to large size mammals – mainly carnivores, snakes and birds of prey are the main predators of small mammals (Palmuti *et al.*, 2009; Silva-Pereira *et al.*, 2011; Rocha *et al.*, 2011). Disarmed traps, traps with marks or scratches, traps which had been rolled over, or even traps with small injured mammals captured inside were accounted in this sampling.

Data analyses

To test for differences in the richness and abundance of small mammals per sampling campaign per study site before and after the flooding, we used the Wilcoxon rank-sum test. The diversity of small mammals is variable throughout the year, but since we sampled periods distributed over two years – one before and the other after the flooding – differences in diversity should not be related to seasonality. To test for differences in the number of predator attacks to the live traps per campaign before and after the flooding, we used Wilcoxon rank-sum test (values reported are median, lower-upper quartiles). Similarities in species composition between the sampling campaigns for each study site were assessed by Jaccard's index and cluster dendrograms were constructed using Ward's agglomeration method.

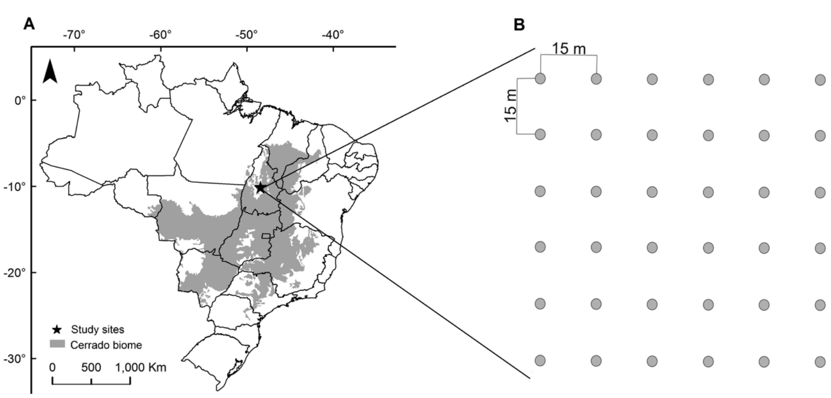

Figure 1. Location of the study sites in Central Brazil (A), and the sampling protocol used for the capture of small mammals in two sites (Capivara and Jacinto) near the Luís Eduardo Magalhães hydroelectric dam (B). Each circle represents a sampling point at 15 m intervals in a 6 x 6 grid with 0.56 ha where a wire mesh trap or a sherman trap was placed alternately on the ground. In the Capivara site sherman traps were also placed on trees (1 m - 2 m above ground) at each sampling point.

Results

The capture efforts were made up of 3,060 trap-nights in the Capivara site and 2,880 trap-nights in the Jacinto site, making a total effort of 5,940 trap-nights. Total captures summed 141, with 94 captures in the Capivara site and 47 in the Jacinto site, which represents a capture success rate of 3.07% and 1.63%, respectively. During the third campaign, in May 2001, no captures occurred in Jacinto site – probably because of a fire that had partially burned the area two days prior to sampling. Thus, we decided to leave this sample out of our analysis.

A total of 13 small mammal species and 88 individuals were captured during the study period (Table 1). Sixty two individuals were captured in Capivara site and 26 in Jacinto site. The abundance and richness of small mammals per sampling campaign decreased after the flooding in the Capivara site (Table 2; Figure 2). Abundance decreased but richness was not affected by the flooding in the Jacinto site (Table 2; Figure 3). Only one individual of *Cerradomys subflavus* (Wagner, 1842) was captured in the transects set along the margins of the reservoir during February 2002. In general, the sampling campaigns before the flooding were more similar to each other in species composition (Figure 4). Only the first campaign after the flooding in the Jacinto site

Table 1. List of small mammal species and the number of individuals captured in the Capivara and Jacinto sites near the Luís Eduardo Magalhães hydroelectric dam inTocantins, Brazil.

Taxonomic list	Capivara	Jacinto
Didelphimorphia		
Didelphis albiventris Lund, 1840	2 (3.2%)	3 (11.5%)
Didelphis marsupialis (Linnaeus, 1758)	7 (11.3%)	
Gracilinanus agilis (Burmeister, 1854)	2 (3.2%)	3 (11.5%)
Marmosa murina (Linnaeus, 1758)	11 (17.7%)	2 (7.7%)
Micoureus demerarae (O. Thomas, 1905)	7 (11.3%)	
Rodentia		
Cricetidae		
Calomys tocantinsi (Bonvicino, Lima and Almeida, 2003)		3 (11.5%)
Cerradomys subflavus (Wagner, 1842)	4 (6.5%)	2 (7.7%)
Necromys lasiurus (Lund, 1841)		3 (11.5%)
Oecomys sp.	12 (19.4%)	
Oecomys bicolor (Tomes, 1860)	6 (9.7%)	
Rhipidomys macrurus (Gervais, 1855)	1 (1.6%)	
Echimyidae		
Proechimys roberti (Thomas, 1901)	10 (16.1%)	
Trichomys sp.		10 (38.5%)
Total	62 (100%)	26 (100%)

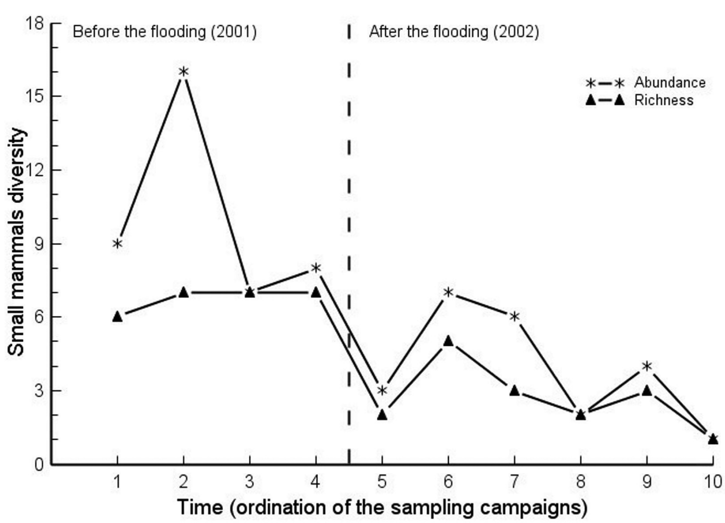

Figure 2. Abundance and richness of small mammals in the Capivara site per sampling campaign during the study period in the state of Tocantins, central Brazil. The dashed line represents the flooding of the Luís Eduardo Magalhães hydroelectric dam.

clustered within the campaigns before the flooding in this site.

Traps with signs of attacks were less frequent before (3.5%, 0-8.5%) than after the flooding (39.7%, 27.4-92%; W = 0; p = 0.01). In the two sampling campaigns after the flooding more than 90% of the traps showed signs of predator attacks (Figure 5). Footprints of the crab-eating fox *Cerdocyon thous* (Linnaeus, 1766), the crab-eating raccoon *Procyon cancrivorus* (G. Cuvier, 1798), and ocelots *Leopardus* spp. were commonly seeing next to the overturned traps. We also captured five medium size mammals after the flooding – one crab-eating raccoon *Procyon cancrivorus*, one ring-tailed coati *Nasua nasua* (Linnaeus, 1766) and three capuchin monkeys *Sapajus libidinosus* (Spix, 1823). In the Capivara site two snakes *Boa constrictor* (Linnaeus, 1758) were found wound around traps with small mammals inside during the two campaigns that occurred immediately after the flooding.

Discussion

Small mammals are not able to travel large distances in the Cerrado (Nitikman and Mares, 1987; Vieira and Marinho-Filho, 1998) or to distant habitat patches after the creation of dams (Carmignotto, 1999), so we expected that the abundance of small mammals would increase immediately after the flooding. However, this pattern was not observed. Small mammal abundance decreased and remained low in the Capivara and Jacinto sites, and only one individual was captured during the sampling in the extra transects set parallel along the dam's margin immediately after the flooding in February 2002. These results may suggest that most small mammal individuals were not able to escape from the flooding.

There were few signs of predator attacks to the live traps before the filling of the dam. On the other hand, the frequency of predator attacks to the live traps was high after the flooding. Small mammals are key components of the carnivore diet (Gatti *et al.*, 2006; Moreno *et al.*, 2006; Silva-Pereira *et al.*, 2011) and footprints from carnivore species were frequently found near overturned traps after the flooding. These findings suggest that increased predation can be the responsible for the decrease in small mammal diversity after the flooding. In fact, hydroelectrics usually create land islands in which medium and larger mammals are absent. In these islands the richness and abundance of small mammals tend to increase immediately after the flooding (Marinho-Filho *et al.*, 2000; Terborgh *et al.*,

Table 2. Comparisons of the abundance and richness of small mammals before and after the flooding of the Luís Eduardo Magalhães hydroelectric dam in Brazil. Reported values are median (lower-upper quartiles).

	Before	After	W	p
Capivara				
Abundance	8.5(7.3-14.3)	3.5(1.8-6.3)	23.5	0.02*
Richness	7(6.3-7)	2.5(1.8-3.5)	24	0.01*
Jacinto				
Abundance	5(5-7)	1(0.8-3)	18	0.02*
Richness	2(2-5)	1(0.8-2.3)	15	0.14

Note: (*) statistically significant values based on Wilcoxon rank-sum test.

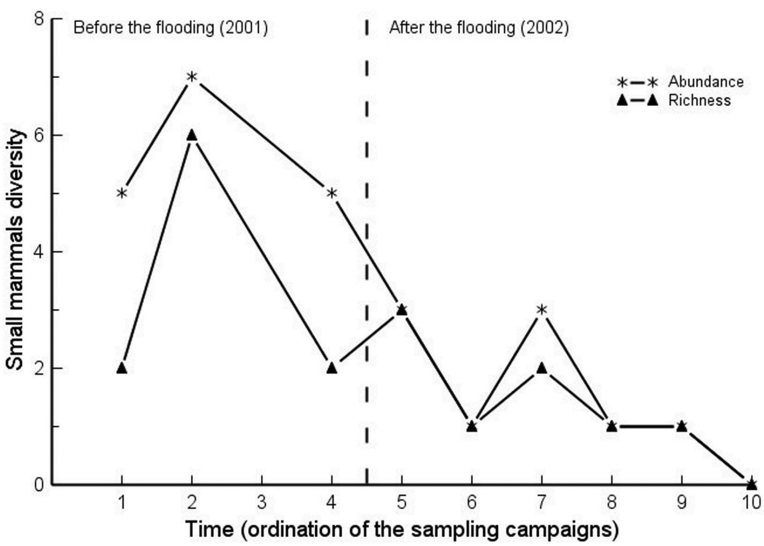

Figure 3. Abundance and richness of small mammals in the Jacinto site per sampling campaign during the study period in the state of Tocantins, central Brazil. The dashed line represents the flooding of the Luís Eduardo Magalhães hydroelectric dam.

2001). Nevertheless, in the study sites the densities of predators probably increased near the dam after flooding, resulting in a reduced abundance and in the local extinction of small mammal species.

A standard procedure taken during the construction of a hydroelectric is wildlife rescue (Vié, 1999). However, density compensation effects should be affecting vertebrate populations after the disturbances that cause habitat loss (Pardini, 2004; Pardini *et al.*, 2005; Rodrigues, 2006; Passamani and Fernandez, 2011). Thus, wildlife rescue could result in harmful cascade effects in the adjacent habitat patches. In fact, if we consider our basic theoretical knowledge about animal behavior, territoriality and the regulation of natural populations, the actions currently taken according to governmental laws in Brazil are not logical when we consider the objectives of wildlife conservation (Rodrigues, 2006). Instead of contributing to the damage, we should prioritize actions such as increasing the protection and connectivity of nearby natural habitat patches.

Long term studies are necessary in order to evaluate how animal densities change during the several years after the building of a dam, and if these effects are permanent, resulting in some species being made locally extinct.

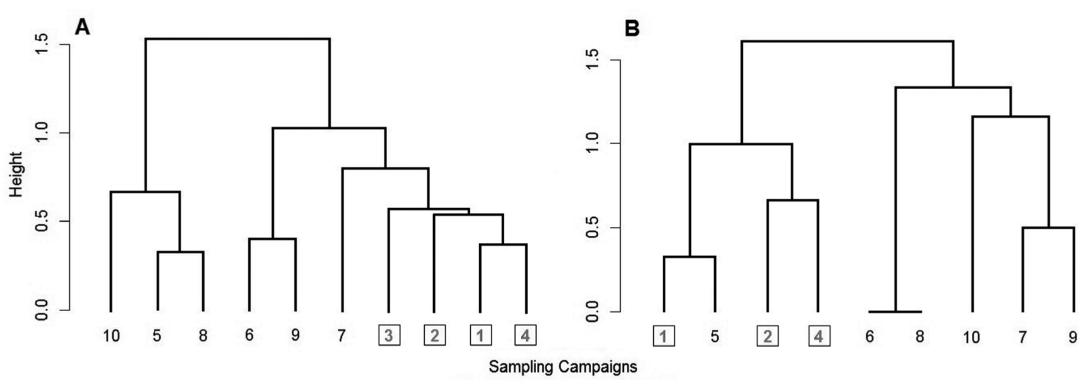

Figure 4. Cluster dendrograms of the sampling campaigns regarding small mammal species composition in the Capivara and Jacinto study sites in Central Brazil. Outlined numbers represent the sampling campaigns that occurred before the flooding of the Luís Eduardo Magalhães hydroelectric dam. During the third campaign, no captures occurred in Jacinto site.

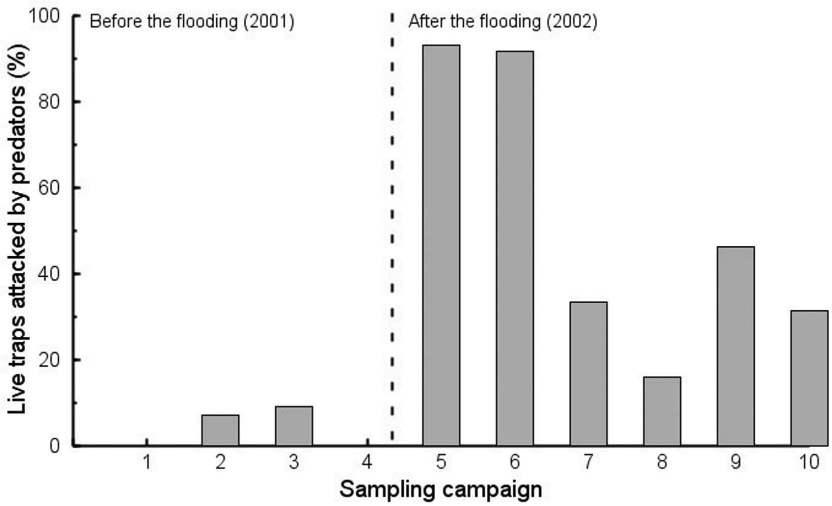

Figure 5. Percentage of live traps with signs of predator attacks per sampling campaign. The campaigns are ordered according to date, and the dashed line indicates the flooding of the Luís Eduardo Magalhães hydroelectric dam, in Tocantins, central Brazil.

Scientific data (Marinho-Filho *et al.,* 2000; Terborgh *et al.,* 2001) indicates that some populations tend to increase immediately after the flooding, changing intra and interspecific competition and causing density dependent mortality. Here we propose that predation can also affect wildlife after the flooding of a dam, just as it probably affected the abundance and richness of small mammals near the Luís Eduardo Magalhães hydroelectric. Actions planned by authorities to minimize the disturbances caused to wildlife by hydroelectric dams should consider the scientific data available to avoid unwanted effects and to act in accordance with wildlife conservation.

Regarding at least small mammal species in areas to be flooded, we believe that the best procedure would be the capture, collecting and housing them as voucher specimens in scientific collections, as proposed by Rodrigues (2006). Our current knowledge of biodiversity is still insignificant, we can only estimate the number of species that there may be on the planet (Mora *et al.*, 2011). Several taxa of small mammals were recently discovered in Brazil (Bonvicino *et al.*, 2003; Voss *et al.*, 2005; Weksler *et al.*, 2006; Percequillo *et al.*, 2011), and we believe that many rare or unknown species are being released during wildlife rescues. Understanding the components and the distribution of biodiversity can allow a more accurate identification of priority areas for conservation (Alho, 2000; Castro-Mello, 2003). The creation of conservation units is usually proposed as a compensatory action when a hydroelectric is built (McNeely, 1987). However, most of the dams flooded gallery forests in the Cerrado, which are regarded as the most diverse areas of the biome (Fonseca and Redford, 1984; Mares *et al.*, 1986; Marinho-Filho *et al.*, 1994; Johnson *et al.*, 1999). Therefore, it is important that new areas composed of similar habitat type (gallery forest) are contemplated for the establishment of conservation units, as linear parks along rivers, for example.

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References

ALHO, C.J.R. 1982. Brazilian rodents: their habitats and habits. *In:* M.A. MARES; H.H. GENOWAYS (eds.), *Mammalian biology in South America*. Pittsburgh, Pymatuning Laboratory of Ecology, p. 143-166.

ALHO, C.J.R. 2000. Resgate, aproveitamento, monitoramento e conservação da fauna. *In*: C.J.R. ALHO (coord.), *Fauna silvestre da região do rio Manso – MT*. Brasília, Ministério do Meio Ambiente, Edições IBAMA e Centrais Elétricas do Norte do Brasil, p. 238-251.

ANEEL. 2010. *Relatório ANEEL 2009*. Brasília, Agência Nacional de Energia Elétrica, 90 p.

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

BONVICINO, C.R.; LIMA, J.F.S.; ALMEIDA, F.C. 2003. A new species of *Calomys* Waterhouse (Rodentia, Sigmodontinae) from the Cerrado of Central Brazil. *Revista Brasileira de Zoologia*, **20**(2):301-307. http://dx.doi.org/10.1590/S0101-81752003000200021

BURT, W.H. 1949. Territoriality. *Journal of Mammalogy*, **30**(1):25-27. http://dx.doi.org/10.2307/1375192

CARMIGNOTTO, A.P. 1999. *Pequenos mamíferos terrestres do Cerrado (Rodentia; Didelphimorphia): seleção de hábitats, áreas de vida e padrões direcionais de deslocamento*. Rio de Janeiro, RJ. Dissertação de Mestrado. Unversidade Federal do Rio de Janeiro, 229 p.

CASTRO-MELLO, C. 2003. Nova espécie de *Bronia* Gray, 1845, do Estado do Tocantins, Brasil (Squamata: Amphisbaenidae). *Papeis Avulsos de Zoologia*, **43**(7):139-143. http://dx.doi.org/10.1590/S0031-10492003000700001

CERBONCINI, R.A.S.; PASSAMANI, M.; BRAGA, T.V. 2011. Use of space by the black-eared opossum *Didelphis aurita* in a rural area in southeastern Brazil. *Mammalia*, **75**:287-290. http://dx.doi.org/10.1515/mamm.2011.024

CHIARELLO, A.G. 2000. Density and population size of mammals in remnants of Brazilian Atlantic Forest. *Conservation Biology*, **14**(6):1649-1657.

http://dx.doi.org/10.1046/j.1523-1739.2000.99071.x
CUNHA, D.A.; FERREIRA, L.V. 2012. Impacts of the Belo Monte hydroelectric dam construction on pioneer vegetation formations along the Xingu River, Pará State, Brazil. *Brazilian Journal of Botany*, **35**(2):159-167. http://dx.doi.org/10.1590/S1806-99592012000200005
EITEN, G. 1972. The cerrado vegetation of Brazil. *Botanical Review*, **38**:201-341. http://dx.doi.org/10.1007/BF02859158
FEARNSIDE, P.M. 1995. Hydroelectric dams in the Brazilian Amazon as sources of 'greenhouse' gases. *Environmental Conservation*, **22**(1):7-19. http://dx.doi.org/10.1017/S0376892900034020
FEARNSIDE, P.M. 2002. Greenhouse gas emissions from a hydroelectric reservoir (Brazil's Tucuruí dam) and the energy policy implications. *Water, Air & Soil Pollution*, **133**(4):69-96. http://dx.doi.org/10.1023/A:1012971715668
FONSECA, G.A.B.; REDFORD, K.H. 1984. The mammals of IBGE'S Ecological Reserve, Brasília, and analysis of the role of gallery forests in increasing diversity. *Revista Brasileira de Biologia*, **44**(4):517-523. http://dx.doi.org/10.1016/0006-3207(90)90097-9
FONSECA, G.A.B; ROBINSON, J.G. 1990. Forest size and structure: competitive and predatory effects on small mammal communities. *Biological Conservation*, **53**:265-294.
GATTI, A.; BIANCHI, R.; ROSA, C.R.X.; MENDES, S.L. 2006. Diet of two sympatric carnivores, *Cerdocyon thous* and *Procyon cancrivorus*, in a restinga area of Espirito Santo State, Brazil. *Journal of Tropical Ecology*, **22**:227-230. http://dx.doi.org/10.1017/S0266467405002956
GOODLAND, R. 1971. A physiognomic analysis of the "cerrado" vegetation of central Brazil. *Journal of Ecology*, **59**:411-419. http://dx.doi.org/10.2307/2258321
JOHNSON, M.A.; SARAIVA, P.M.; COELHO, D. 1999. The role of gallery forests in the distribution of cerrado mammals. *Revista Brasileira de Biologia*, **59**(3):421-427. http://dx.doi.org/10.1590/S0034-71081999000300006
LAURANCE, WF. 1994. Rainforest fragmentation and the structures of small mammal communities in tropical Queensland. *Biological Conservation*, **69**:23-32. http://dx.doi.org/10.1016/0006-3207(94)90325-5
LÓPEZ-SEPULCRE, A.; KOKKO, H. 2005. Territorial defense, territory size, and population regulation. *The American Naturalist*, **166**(3):317-329. http://dx.doi.org/10.1086/432560
MARES, M.A.; ERNEST, K.A.; GETTINGER, D.D. 1986. Small mammals community structure and composition in the Cerrado province of central Brazil. *Journal of Tropical Ecology*, **2**:289-300. http://dx.doi.org/10.1017/S0266467400000948
MARINHO-FILHO, J.; REIS, M.L.; OLIVEIRA, P.S.; VIEIRA, E.M.; PAES, M.N. 1994. Diversity standards and small mammals number: conservation of the Cerrado biodiversity. *Anais da Academia Brasileira de Ciências*, **66**(1):149-157.
MARINHO-FILHO, J.; ARAUJO, A.F.B.; CAVALCANTE, R. 2000. *Estudos de populações animais na área de influência do AHE Serra da Mesa: Caracterização e avaliação dos impactos sobre a fauna de répteis, aves e mamíferos*. Relatório Técnico, Fundação Pró-Natureza, Brasília, 49 p.
MCNEELY, J.A. 1987. How dams and wildfire can coexist: natural habitats, agriculture and major water resource development projects in tropical Asia. *Conservation Biology*, **1**:228-238. http://dx.doi.org/10.1111/j.1523-1739.1987.tb00037.x
MORA, C.; TITTENSOR, D.P.; ADL, S.; SIMPSON, A.G.B.; WORM, B. 2011. How many species are there on Earth and in the Ocean? *PLoS Biology*, **9**(8):1-8. http://dx.doi.org/10.1371/journal.pbio.1001127
MORENO, R.S.; KAYS, R.W.; SAMUDIO, R. 2006. Competitive release in diets of ocelot (*Leopardus pardalis*) and puma (*Puma concolor*) after jaguar (*Panthera onca*) decline. *Journal of Mammalogy*, **87**(4):808-816. http://dx.doi.org/10.1644/05-MAMM-A-360R2.1
MYERS N.; MITTERMEIER, R.A.; FONSECA, G.A.B.; KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**:853-858. http://dx.doi.org/10.1038/35002501
NILSSON, C.; DYNESIUS, M. 1994. Ecological effects of river regulations on mammals and birds: a review. *River Research and Applications*, **9**(1):45-53.
NITIKMAN, L.Z.; MARES, M.A. 1987. Ecology of small mammals in a gallery forest of central Brazil. *Annals of Carnegie Museum*, **56**:75-95.
PAGLIA, A.P.; FONSECA, G.A.B.; RYLANDS, A.B.; HERRMANN, G.; AGUIAR, L.M.S.; CHIARELLO, A.G.; LEITE, Y.L.R.; COSTA, L.P.; SICILIANO,S.; KIERULFF, M.C.M.; MENDES, S.L.; TAVARES, V.C.; MITTERMEIER, R.A.; PATTON J.L. 2012. *Annotated Checklist of Brazilian Mammals.* 2nd ed., Arlington, Arlington, Conservation International, 76 p. (Occasional Papers in Conservation Biology, No. 6).
PALMUTI, C.F.S.; CASSIMIRO, J.; BERTOLUCI, J. 2009. Food habits of snakes from the RPPN Feliciano Miguel Abdala, an Atlantic forest fragment in southeastern Brazil. *Biota Neotropica*, **9**(1):263-269. http://dx.doi.org/10.1590/S1676-06032009000100028
PARDINI, R. 2004. Effects of forest fragmentation on small mammals in an Atlantic Forest Landscape. *Biodiversity and Conservation*, **13**:2567-2586. http://dx.doi.org/10.1023/B:BIOC.0000048452.18878.2d
PARDINI, R.; SOUZA, S.M.; BRAGA-NETO, R.; METZGER, J.P. 2005. The role of forest structure, fragment size and corridors in maintaining small mammal abundance and diversity in an Atlantic forest landscape. *Biological Conservation*, **124:**253-266. http://dx.doi.org/10.1016/j.biocon.2005.01.033
PASSAMANI, M. 2004. Levantamento de pequenos mamíferos não-voadores da região central do Tocantins. *Humanitas*, **4/6**:55-62.
PASSAMANI, M.; FERNANDEZ, F.A.S. 2011. Abundance and richness of small mammals in fragmented Atlantic forest of southeastern Brazil. *Journal of Natural History*, **45**(9-10):553-565. http://dx.doi.org/10.1080/00222933.2010.534561
PERCEQUILLO, A.R.; WEKSLER, M.; COSTA, L.P. 2011. A new genus and species of rodent from the Brazilian Atlantic Forest (Rodentia: Cricetidae: Sigmodontinae: Oryzomyini), with comments on oryzomyine biogeography. *Zoological Journal of the Linnean Society*, **161**:357-390. http://dx.doi.org/10.1111/j.1096-3642.2010.00643.x
POFF, N.L.; ALLAN, J.D.; BAIN, M.B.; KARR, J.R. PRESTEGAARD, K.L. RICHTER, B.D.; SPARKS, R.E.; STROMBERG, J.C. 1997. The natural flow regime: a paradigm for river conservation and restoration. *BioScience*, **47**:769-784. http://dx.doi.org/10.2307/1313099
ROCHA, R.G.; FERREIRA, E.; LEITE, Y.L.R.; FONSECA, C.; COSTA, L.P. 2011. Small mammals in the diet of barn owls, *Tyto alba* (Aves: Strigiformes) along the mid-Araguaia river in central Brazil. *Zoologia*, **28**(6):709-716.
RODRIGUES, M. 2006. Hidrelétricas, ecologia comportamental, resgate de fauna: uma falácia. *Natureza & Conservação*, **4**(1):29-38.
ROSENBERG, D.M.; BERKS, F.; BODALY, R.A.; HECKY, R.E.; KELLY, C.A.; RUDD, J.W.M. 1997. Large-scale impacts of hydroelectric development. *Environmental Reviews*, **5**:27-54. http://dx.doi.org/10.1139/a97-001
SÁ, R.M.L. 1995. *Effects of the Samuel Hydroelectric dam on mammals and bird communities in a heterogeneous Amazonian lowland forest*. Florida, USA. Ph.D. thesis. The University of Florida, 139 p.
SILVA-PEREIRA, J.E.; MORO-RIOS, R.F.; BILSKI, D.; PASSOS, F.C. 2011. Diets of three sympatric Neotropical small cats: food niche overlap and interspecies differences in prey consumption. *Mammalian Biology*, **76**(3):308-312. http://dx.doi.org/10.1016/j.mambio.2010.09.001
SUZUKI, F.M.; PIRES, L.V.; POMPEU, P.S. 2011. Passage of fish larvae and eggs through the Funil, Itutinga and Camargos reservoirs on the upper Rio Grande (Minas Gerais, Brazil). *Neotropical Ichthyology*, **9**(3):617-622. http://dx.doi.org/10.1590/S1679-62252011000300014
TERBORGH, J.; LOPEZ, L.; NUÑEZ, V.P.; RAO, M.; SHAHABUDDIN, G.; ORIHUELA, G.; RIVEROS, M.; ASCANIO, R.; ADLER, G.H.; LAMBERT, T.D.; BALBAS, L. 2001. Ecological meltdown in predator-free forest fragments. *Science*, **294**:1923-1926. http://dx.doi.org/10.1126/science.1064397

VIÉ, J.C. 1999. Wildlife rescue – the case of the Petit Saut hydroelectric dam in French Guiana. *Oryx*, **33**(2):115-126.

VIEIRA, E.M.; MARINHO-FILHO, J. 1998. Pre and post-fire habitat utilization by rodents of Cerrado from central Brazil. *Biotropica*, **30**(3):491-496. http://dx.doi.org/10.1111/j.1744-7429.1998.tb00086.x

VOSS, R.; LUNDE, D.P.; JANSA, S.A. 2005. On the contents of *Gracilinanus* Gardner and Creighton, 1989, with the description of a previously unrecognized clade of small didelphid marsupials. *American Museum Novitates*, **3482**:1-34. http://dx.doi.org/10.1206/0003-0082(2005)482[0001:OTCOGG]2.0.CO;2

WEKSLER, M.; PERCEQUILLO, A.R.; VOSS, R. 2006. Ten new genera of oryzomyine rodents (Cricetidae: Sigmodontinae). *American Museum Novitates*, **3537**:1-29. http://dx.doi.org/10.1206/0003-0082(2006)3537[1:TNGOOR]2.0.CO;2

WOLFF, J.O. 1993. Why are female small mammals territorial? *Oikos*, **68**(2):364-370. http://dx.doi.org/10.2307/3544853

YÜKSEL, I. 2010. Hydropower for sustainable water and energy development. *Renewable and Sustainable Energy Reviews*, **14**:462-469. http://dx.doi.org/10.1016/j.rser.2009.07.025

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