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Differencial efficiency of two sampling methods in capturing non-volant small mammals in an area in eastern Amazonia

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ABSTRACT

This study was the first to evaluate the efficiency of trapping methods in the study of small mammals in the Carajás National Forest, southeastern Brazilian Amazon. It is an area with a unique vegetation type (metalofilic savannah or *Canga*). The aims of this study were to compare the efficiency of two trapping methods (i.e. live-traps and pitfalls), the bait types used, and evaluate if trapping success varied seasonally. We used four sampling grids, each with six parallel transects. The trap effort for live-traps and pitfalls was 51,840 trap*nights and 10,800 bucket*nights, respectively. We used three types of bait: a paste of peanut butter and sardines, bacon, and bananas. We placed one type of bait in each trap, alternating between points. We recorded 26 species of small mammals, 11 from the order Didelphimorphia and 15 from the order Rodentia. Pitfalls captured a higher number of species compared with live-traps. The capture rate, the mortality rate and the quantity of juveniles and adults did not differ significantly between methods. Capture rate for pitfalls differed significantly between seasons. The majority of species were captured by a single method. Species were equally attracted to the traps regardless of the type of bait used. Some of our results differed significantly from other studies in Amazonia and such variation should be taken into account when designing survey methods for Amazonian small mammals.

KEYWORDS: Live-traps; pitfall-traps; Didelphimorphia; Rodentia; capture rate

Diferenças na eficiência entre dois métodos de amostragem para capturar pequenos mamíferos não-voadores em uma área na Amazônia oriental

RESUMO

Este estudo foi o primeiro a avaliar a eficiência de métodos de captura de pequenos mamíferos não-voadores na Floresta Nacional de Carajás, sudeste da Amazônia brasileira. É uma área que apresenta características fitofisionômicas exclusivas (savana metalófila ou *Canga*) e sofre pressão da atividade mineradora. Os objetivos desse estudo foram comparar a eficiência de dois métodos de captura e de três tipos de iscas, bem como se a eficiência dos métodos variou sazonalmente. Nós usamos quatro grades de amostragem, cada uma com seis trilhas paralelas. Capturas com armadilhas de gaiola (*live-traps*) e armadilhas de caída (*pitfall traps*) foram realizadas durante três estações secas e três úmidas. O esforço total de captura foi de 51.840 armadilhas*noite e 10.800 baldes*noite para *live-traps* e *pitfalls*, respectivamente. Três tipos de isca (pasta de amendoim com sardinha, bacon e banana) foram usadas de forma alternada em todas as armadilhas. Nós registramos 26 espécies de pequenos mamíferos, 11 da ordem Didelphimorphia e 15 da ordem Rodentia. *Pitfalls* capturaram mais espécies que *live-traps*. As taxas de captura e de mortalidade e a proporção de jovens e adultos não diferiram entre os métodos. O sucesso de captura diferiu sazonalmente apenas para *pitfalls*. A maioria das espécies foi capturada preferencialmente ou exclusivamente por um dos dois métodos. As espécies foram igualmente atraídas por todos os tipos de iscas. Nossos resultados diferiram de outros obtidos na Amazônia, o que deve ser levado em consideração em desenhos amostrais para pequenos mamíferos na região.

PALAVRAS-CHAVE: armadilhas de gaiola; armadilhas de caída; Didelphimorphia; Rodentia; taxa de captura

INTRODUCTION

Studies evaluating the efficiency of sampling methods when working with tropical fauna are important because of the high species richness and the fact that knowledge concerning species assemblage composition are still scarce (Umetsu *et al.* 2006; Hice and Velazco 2013; Vieira *et al.* 2014; Santos-Filho *et al.* 2015). Comparisons of study methodologies have direct conservation relevance, as they allow planning of future studies, and identifying the best methods allows the most complete sampling of the target species assemblage (Mengak and Guynn Jr 1987). To sample non-volant small mammal species, researchers commonly use pitfall traps and live-trap methods, which work in a complementary manner (Flemming 1975; Woodman *et al.* 1996; Voss *et al.* 2001). The pitfall method provides an opportunity to capture species that rarely, if ever, are captured with the live-trap method (Hice and Schmidly 2002; Voss and Emmons 1996; Voss *et al.* 2001). This is probably because captures in pitfalls occur randomly (Bury and Corn 1987; Umetsu *et al.* 2006; Santos-Filho *et al.* 2006), whereas with live-traps, animals are attracted by bait, so there are several factors that can directly influence capture success. These factors could be related to the availability of resources (Adler and Lambert 1997), species-specific bait preferences (Laurance 1992), theft of bait by non-focal animals (e.g. ants) (McClearn *et al.* 1994), and age-cohort capture bias (Boonstra and Krebs 1978).

Over the years, in tropical regions, several studies have compared the efficiency of methods for capturing small non-volant mammals (Sealander and James 1958; Hice and Schmidly 2002; Vieira *et al.* 2014). Of these studies, only Voss *et al.* (2001) and Hice and Schmidly (2002) worked in the Amazon. Both worked in lowland full-canopy forest, but other habitats exist in Amazonia and, since trap response differs between habitats, because of their patterns of heterogeneity and complexity (Myers *et al.* 2000), comparative methodological studies are also required for more open Amazonian habitats.

In this context, our study was the first in the Carajás National Forest (southeastern Brazilian Amazon) to compare capture method efficiency for small mammals. It is an area with a unique vegetation type (metalofilic savannah or *Canga*) and suffers from a constant threat from mining activity by the Vale company. In this context, we aimed to compare the efficiency of two methods, three types of baits, and to see if the methods used to capture non-volant small mammals varied seasonally in the Carajás National Forest. We addressed the questions: 1) Is there a difference in capture success and small mammal richness between pitfall and live-traps? 2) Are there seasonal differences in capture success and richness of small mammals between pitfall and live-traps? 3) Does capture success vary between life stages (adults and juveniles) between capture methods? 4) Do different small mammal species prefer different baits?

MATERIAL AND METHODS

Study Area

The Carajás National Forest (CNF) covers 411,948.87 hectares and is located in southeastern Pará, Brazil (05°52’ - 06°33`S and 49°53 - 50°45`W). In the CNF, 96.3% of the area is composed of Ombrophilous Forest and 2.3% by natural clearings with metalofilic savannah or *Canga*, which is a vegetation that grows on the complex geological formations known as “*canga hematítica*” (Ab’Saber 1986; Silva *et al.* 1996). The *canga hematítica* is a rocky layer that covers iron ore deposits (Figure 1).

In general, the tree canopy in the CNF is about 30 m high, with emergent trees reaching 50 m. The understory consists of regenerating tree seedlings, palms, shrubs and lianas. The *Canga* is composed of well-defined open areas, surrounded by forest (Silva *et al.* 1996). Natural grasslands occur where the terrain is semi-flat or concave with rocky outcrops, which are highly impermeable, and water accumulates in the rainy season, thus allowing plant species with short life cycles to develop (Silva *et al.* 1996). In *Canga* formation, the surface of the ground is covered by a continuous grassy mat (Silva *et al.* 1996).

Sampling Methods

To sample non-volant small mammals we used four sampling grids divided by vegetation types, two located in the *Canga* and two in forested habitat, with six parallel trap lines on each grid. In each trap line, we placed live-traps (i.e. Sherman and Tomahawk) at 60 points with 20 m between each one. We used three sizes of Sherman traps: 25 X 8 X 9 cm, 30 X 8 X 9 cm and 43 X 12.5 X 14.5 cm; and three sizes of Tomahawk traps: 30 X 16 X 16 cm, 45 X 21 X 21 cm and 70 X 40 X 40 cm. In the forested areas only, traps were divided among three strata: ground, understory (0.5 to 2 m height) and canopy (from 5 m height) following Lambert *et al.* (2005), with a total of 20 traps in each stratum per transect. We had only one trap at each trapping station and alternated the strata along the transect. Live-traps remained open for six consecutive nights, totaling 2,160 trap-nights per area. We used three types of bait: peanut butter mixed with sardines (paste), chunks of bacon, and bananas. Each trap contained only one type of bait, and bait types were alternated along the transect. For all traps, bait was replenished every morning.

Due to the difficulty of installing pitfall traps in *Canga* habitat because of soil characteristics (hard rocky clay), we used pitfall traps only in forested areas. We installed 180 60 liter buckets in the ground in two areas of forest, 90 in each location. Six pitfall systems with 15 buckets each were installed

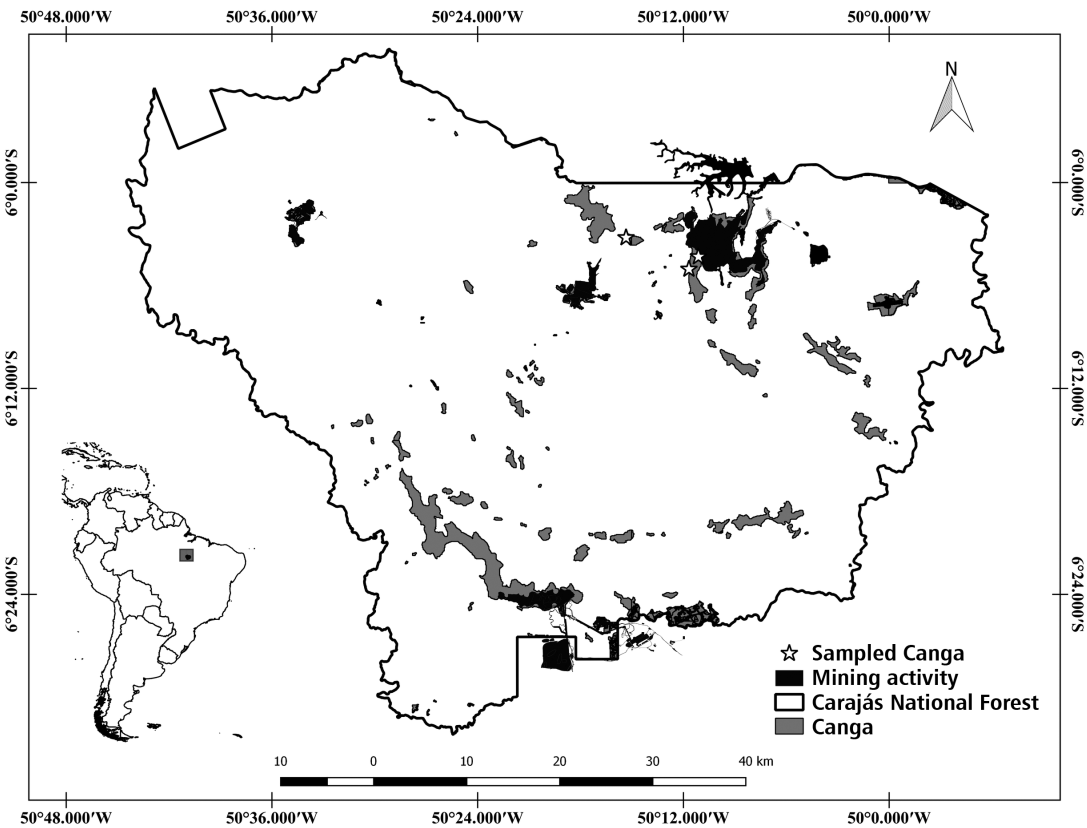

Figure 1. A map depicting the location of our study area: Carajás National Forest, southeastern Pará, Brazil. The Canga areas are highlighted on the map.

in each location. Buckets were separated from each other by 10 m, connected by a plastic sheet about one meter high. All the buckets had little Styrofoam platforms (20 X 15 cm) inside to prevent the drowning of animals during rainy periods. The buckets remained open for ten consecutive nights, making the sampling effort 900 buckets / area / year and the total effort 1,800 buckets / 20 nights / year. We carried out six samplings between January 2009 and December 2011, three in each wet and dry season.

Some small mammals described in the present study were difficult to identify at species level. So, we collected four individuals of each species per sampling campaign (License: IBAMA 009-B/2009 MAB/FAUNA, process number 02018.001735/2006-91). We identified the species using morphometric measurements of the skull and comparison with small mammals desposited in USP's Zoology Museum - MZUSP, National Museum of Rio de Janeiro - MNRJ, Mammals collection of University of Espirito Santo (UFES) and the Goeldi Museum - MPEG. Additionally, karyotypic analysis was conducted for some species using material obtained from bone marrow cells of sacrificed animals. All the collected material (skins, crania and skeletons) were deposited in the National Museum of Rio de Janeiro (MNRJ). Analyses of karyotypes were performed by Mammalogy Laboratory, Rio de Janeiro State University, coordinated by Dr. Lena Geise. Despite these attempts, it was still not possible to identify some specimens, notably of the genus *Oecomys,* where each member is a species complex.

Data Analysis

To assess whether the deployed trapping effort was sufficient to sample the CNF small mammal species assemblage, we performed a species accumulation curve for each method type. Sampling effort was measured as number of traps*night for live-traps, and in number of buckets*night for the pitfall methods. We applied a rarefaction curve to analyze the richness by using estimators obtained with 1000 data randomizations in the EstimateSWin820® program.

For live-traps, summed effort, deployed across both wet and dry seasons, was 51,840 traps*nights (1,440 traps in the four areas sampled x six nights x six seasons) and 10,800 buckets*nights (180 buckets in two forest areas sampled x ten nights x six seasons). For both methods capture success was calculated as follows: (Number of individuals captured / Number of traps*nights or buckets*nights) x 100.

The number of live-traps and buckets were not same, so to correct this error, we calculated the capture success, mortality rates (number of dead individuals in relation to the number of captured individuals per method) and number of adults and juveniles proportionally (number of adults and juveniles in relation to the number of captured individuals for method) for each method type, separately, as a percentage.

We evaluated whether capture rates varied significantly between seasons (for each method separately) through an analysis of variance (ANOVA). We also used ANOVA to test for differences in proportional mortality rates (Shapiro-Wilk test of normality=0.959; p=0.772), in the proportional capture success , in the percentage of adults and juveniles (Shapiro-Wilk test of normality=0.888; p=0.112) between sampling methods. Furthermore, we evaluated if the number of individuals captured (by species) by trap type (sherman, tomahawk or pitfall) differed (Shapiro-Wilk test of normality=0.894; p=0.135), and if for some species, the efficiency of bait type used differed using a chi-square test. All analysis was performed in Systat 13.0.

RESULTS

We recorded 26 species of non-volant small mammals, 11 belonging to the Order Didelphimorphia and 15 to the Order Rodentia. We recorded a higher richness with the pitfall method (21 species) when compared with live-trap methods (18 species). Species richness was best estimated for the live-trap method using Jackknife 1 with a rarefaction curve, with 18.38 species (16.86 ± 2.74) being estimated and 19.38 species (17.26 ± 2.97) predicted for pitfalls (Figure 2). We captured 809 individuals with live-traps (Sherman and Tomahawk), and 384 individuals with pitfalls.

The mortality rate, proportionally, did not differ significantly between live- and pitfall-traps (ANOVA; $F_{1,10}$=2.700; p=0.131, Figure 3). Proportional capture success of small mammals did not differ significantly between the live-trap method (Sherman and Tomahawk; 1.66%) and the pitfall method (7.26%) (ANOVA; $F_{1,10}$=3.179; p=0.105, Figure 4). In addition, the proportion of juveniles and adults between live-traps (21.65% juveniles, 78.34% adults) and pitfalls (44.51% juveniles, 55.48% adults) (ANOVA; for juveniles and adults: $F_{1,10}$=1.000; p = 0.341, Figure 5), also showed no difference between trap types.

Capture success varied significantly between seasons for pitfalls, being higher in rainy than dry season (ANOVA; $F_{1,4}$ = 7.468; p = 0.052), but did not differ for live-traps (ANOVA; $F_{1,4}$ < 0.001; p = 0.996) (Figure 6).

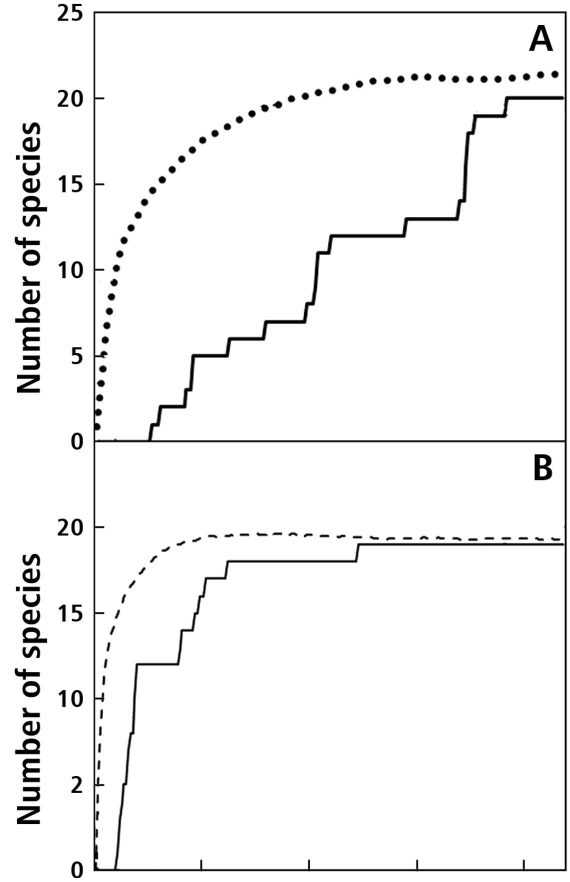

Figure 2. Accumulation and rarefaction curves of non-volant small mammal species in the Carajás National Forest, southeastern Pará, Brazil. Legend: (A) Curves using pitfall method and (B) Curves using live-trap method.

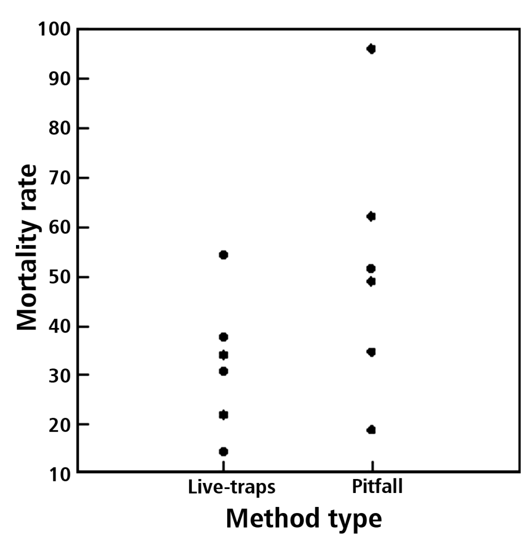

Figure 3. Mortality rate with live-trap and pitfall methods for captures of non-volant small mammals in the Carajás National Forest, southeastern Pará, Brazil.

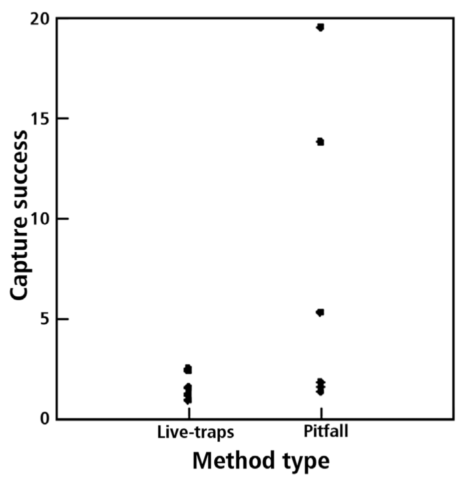

Figure 4. Capture rate with live-trap and pitfall methods for captures of non-volant small mammals in the Carajás National Forest, southeastern Pará, Brazil.

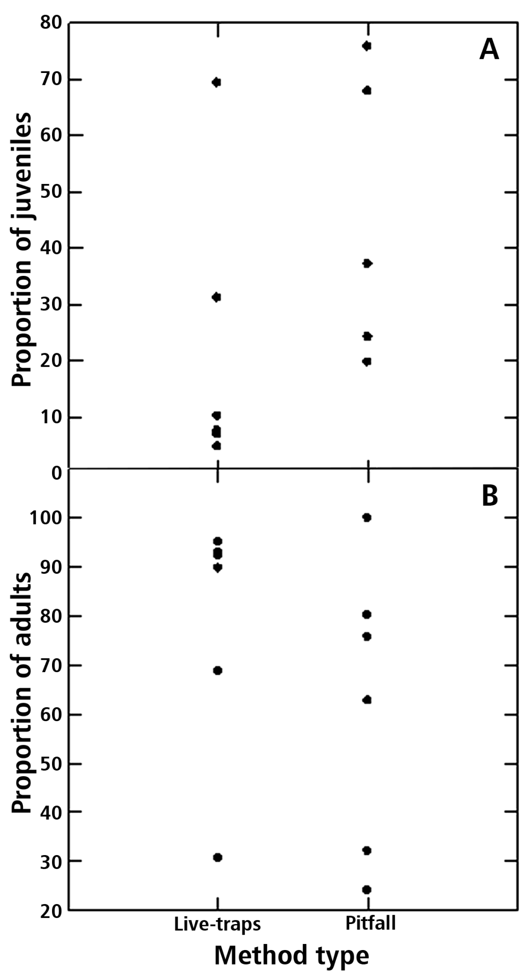

Figure 5. Proportional rate of youngs (A) and adults (B) of non-volant small mammals captured with live-trap and pitfall methods in the Carajás National Forest, southeastern Pará, Brazil.

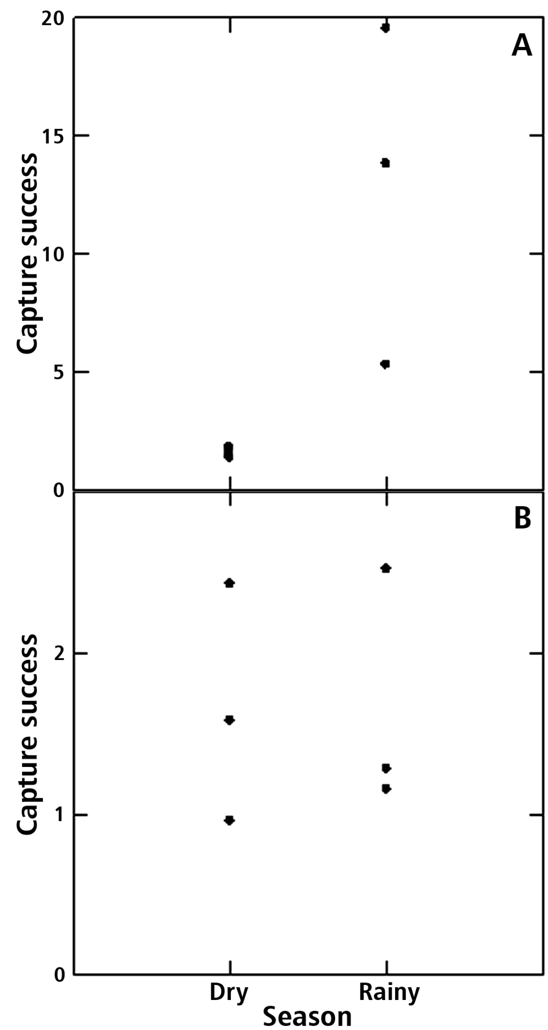

Figure 6. Capture rate by season (dry and rainy) of non-volant small mammals using pitfalls (A) and live-traps (B) in the Carajás National Forest, southeastern Pará, Brazil.

All species captured were significantly preferentially captured (Chi-squared test) by a particular trapping method (Sherman, Tomahawk or pitfall), except for *Proechimys roberti*. *Glironia venusta* was captured only in Sherman live-traps and *Monodelphis* aff. *kunsi*, *Neacomys* aff. *paracou*, *Neusticomys ferreirai*, *Makalata didelphoides* and *Mesomys stimulax* were only captured in pitfall traps. *Nectomys rattus* was recorded only with Tomahawk live-traps (Table 1). *Oecomys* sp. had the highest capture success for pitfalls, with 162 individuals captured. Three species of marsupials, *Caluromys philander*, *Glironia venusta* and *Philander opossum*, and two species of rodents, *Necromys lasiurus* and *Nectomys rattus*, were not captured in pitfall traps. *Monodelphis* aff. *kunsi* (marsupial) and *Hylaeamys megacephalus*, *Neacomys* aff. *paracou*, *Neusticomys* *ferreirai*, *Oligoryzomys microtis* and *Makalata didelphoides* (rodents) were not captured using the two types of live-traps. For many species, it was not possible to apply the chi-square test to compare the capture success with the trap method due to low sample size.

When comparing bait type and trap capture success, we found that the number of individuals varied significantly between the baits (bacon, banana and peanut butter) for only a single species, *Akodon* cf. *cursor*, that preferred paste and bananas (Table 2).

Table 1. Number of individuals captured by species for each capture method used for small mammals in Carajás National Forest, southeastern Pará, Brazil. Methods are pitfall traps and live-traps (Sherman and Tomahawk traps). $\chi 2$ is the chi-square test value, *p* is the significance level.

Taxon	Pitfall	Sherman	Tomahawk	χ2	p
Order Didelphimorphia					
Family Didelphidae					
Caluromys philander	0	1	2	-	-
Glironia venusta	0	1	0	-	-
Didelphis marsupialis	2	2	3	-	-
Marmosa murina	2	61	34	53.959	<0.001
Marmosa demerarae	1	14	10	10.640	0.005
Marmosops pinheiroi	38	4	0	27.524	<0.001
Metachirus nudicaudatus	1	0	3	-	-
Monodelphis glirina	12	276	109	269.506	<0.001
Monodelphis "sp. D"*	36	18	3	28.737	<0.001
Monodelphis aff. *kunsi*	2	0	0	-	-
Philander opossum	0	1	2	-	-
Order Rodentia					
Family Cricetidae					
Akodon cf. *cursor*	8	25	15	9.125	0.010
Euryoryzomys emmonsae	49	3	4	73.964	<0.001
Hylaeamys megacephalus	5	0	0	-	-
Neacomys aff. *paracou*	37	0	0	-	-
Necromys lasiurus	0	55	25	11.250	0.001
Nectomys rattus	0	0	2	-	-
Neusticomys ferreirai	1	0	0	-	-
Oecomys sp.	162	5	5	286.616	<0.001
Oligoryzomys microtis	1	0	0	-	-
Oxymycterus amazonicus	13	54	41	24.389	<0.001
Rhipidomys emiliae	3	9	1	8.000	0.018
Family Echimyidae					
Echimys chrysurus	1	0	0	-	-
Makalata didelphoides	1	0	0	-	-
Mesomys stimulax	2	0	0	-	-
Proechimys roberti	7	11	10	0.929	0.629

* according to Pine and Handley 2007

Table 2. Number of individuals captured per species for each type of bait used (peanut butter/sardine paste, bacon, and banana). χ2 is the chi-square test value, *p* is the significance level.

Taxon	Banana	Peanut butter	Bacon	χ2	*p*
Akodon cf. *cursor*	13	21	8	6.143	0.046
Euryoryzomys emmonsae	3	6	5	1.00	0.607
Marmosa murina	35	26	42	5.540	0.063
Marmosa demerarae	5	12	9	2.846	0.241
Monodelphis glirina	146	152	158	0.474	0.789
Monodelphis "sp. D"*	6	7	8	0.286	0.867
Necromys lasiurus	34	30	24	1.727	0.422
Oxymycterus amazonicus	26	31	36	1.613	0.446
Rhipidomys emiliae	3	8	0	2.273	0.132
Proechimys roberti	8	15	7	3.800	0.150

* according to Pine and Handley 2007

DISCUSSION

Both rarefaction and accumulation curves indicate stabilization for estimating species capture success. This could be because most of the of non-volant small mammals expected to occur in the southeastern Amazon were recorded in our study. However, according to Emmons and Feer (1990), Eisenberg and Redford (1999), Bonvicino *et al.* (2008) and Paglia *et al.* (2012) there are other species that have been recorded for the Amazon region that could potentially be captured in CNF, such as *Holochilus sciureus*, *Gracilinanus agilis*, the genus *Thylamys* and arboreal species of Echimyidae such as *Isothrix*, *Lonchothrix*, and *Toromys* genus.

Although capture success rates were not significantly different, pitfall traps captured a higher number of species of small mammals than live-traps. This supports our hypothesis that the two method types are complementary; there would be no differences in capture success between trap methods. Another factor that corroborates our hypothesis was the occurrence of certain species exclusively in pitfalls or in live-traps. For example, only in pitfalls we captured canopy foraging species such as *Makalata didelphoides, Mesomys stimulax* and *Echimys chrysurus*, even though there were live-traps installed in canopy. Live-traps represented a more selective method, with the animals attracted by bait, smell of other animals, or simply by curiosity. On the other hand, the pitfall traps were the less selective and more random method. Our results run counter to the results of Hice and Schmidly (2002), who, with similar methodologies, found pitfall traps to have a higher capture success of Amazonian small mammals. However, our data supports the importance of using pitfall traps to increase overall species richness estimates (Vargas *et al.* 2003). For example, there are arboreal species that are captured exclusively in pitfall traps (Marshal 1978; Emmons and Feer 1997; Bernarde and Rocha 2003), making it imperative that multiple sampling methods be included in sampling designs for Amazonian small non-volant mammals.

Mortality rates did not differ proportionally between methods. This result is likely due to our constant attention to the pitfall use; for example, daily removal of water from buckets and the use of Styrofoam platforms inside of buckets to avoid animals drowning in the rainy season, and making daily pitfall surveys during the first hours after sunrise. White *et al.* (1982) considered Sherman traps to offer more protection to animals. Barros *et al.* (2015) believe that animals captured in pitfall traps are more exposed to predation, aggressive interactions within the captured assemblage, and inclement weather conditions than those in live-traps. Nevertheless, it is possible to deploy some simple measures that avoid water accumulation, protect animals from rain and sun, and avoid starvation in pitfalls.

Our data showed no significant difference in the proportion of juveniles and adults of small mammals captured between trapping methods. There was no selective capture of either life stage in live-traps. Other studies detected a bias for adult capture in live-traps (Boonstra and Krebs 1978; O'Connel 1989; Vieira 1996; Quental *et al.* 2001) or that juveniles were more captured with pitfalls (Barros *et al.* 2015). Due to their smaller body size, juveniles could get away from live-traps even after they were closed (Umetsu *et al.* 2006). Alternatively, adults are more abundant than juveniles in small mammal populations (Gentile *et al.* 2000; Feliciano *et al.* 2002; Barros *et al.* 2008), leading to correspondingly higher numbers of captured adults (Barros *et al.* 2015).

Prior neotropical small-mammal samplings had higher capture rates for pitfalls in the rainy season and for live-traps in the dry season (McClearn *et al.* 1994; Hice and Schmidly 2002;

Santos-Filho *et al.* 2006; 2008). While our results confirmed the trend with slightly higher capture rates in the rainy season, live-traps did not differ significantly in capture rates between seasons, which may be related to the plant diversity and structural complexity of the *Canga* areas in Carajás National Forest, where half of the live-traps were installed.

Baited traps were more attractive for live-traps in the dry than in the rainy period (McClearn *et al.* 1994; Hice and Schmidly 2002; Santos-Filho *et al.* 2006; 2008). *Canga* areas are characterized by low resource availability (e.g. water and soil moisture) (Silva *et al.* 1996), which may explain why the attractive function of baits in our live-traps appeared to be the same in both seasons, and did not differ significantly between the types of bait (except for the generalist rodent, *Akodon* cf. *cursor*, that probably occurred by chance).

CONCLUSIONS

Our comparison between live traps and pitfall traps in Carajás National Forest showed both methods to be equivalent in terms of capture rates of Didelphimorphia and Rodentia, as well as in mortality rates and proportions of juvenile and adult individuals captured. However, both methods tended to be selective in the species they atracted, thus both should be employed for small mammal diversity assessments. Pitfalls captured a higher number of species and were significantly more efficient in the rainy season. Contrary to previous knowledge, capture rates with live traps did not vary between the rainy and dry seasons, which was likely related to the characteristics of the unique *Canga* habitat, where most traps were set.

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REFERENCES

Ab'Saber, A. 1986. Geomorfologia da região. *Carajás: Desafio Político, Ecologia e Desenvolvimento*, 5: 88-124.

Adler, G.H.; Lambert, T.D. 1997. Ecological correlates of trap response of a Neotropical Forest rodent, *Proechimys semispinosus*. *Journal of Tropical Ecology*, 13: 59-68.

Barros, C.S.; Crouzeilles, R.; Fernandez, F.A.S. 2008. Reproduction of the opossums *Micoureus paraguayanus* and *Philander frenata* in a fragmented Atlantic Forest landscape in Brazil: is seasonal reproduction a general rule for Neotropical marsupials? *Mammalian Biology*, 73: 463-467.

Barros, C.S.T.; Pinotti, B.T.; Pardini, R. 2015. Determinants of capture-recapture success: an evaluation of trapping methods to estimate population and community parameters for Atlantic Forest small mammals. *Zoologia*, 32: 334-344.

Bonvicino, C.; Oliveira, J.A.D.; D'andrea, P.S. 2008. *Guia dos roedores do Brasil, com chaves para gêneros baseados em caracteres externos.* 1st ed. Organização Pan-Americana da Saúde, Rio de Janeiro, 120p.

Boonstra, R.; Krebs, C.J. 1978. Pitfall trapping of *Microtus townsendii*. *Journal of Mammalogy*, 59: 136-148.

Bury, R.B.; Corn, P.S. 1987. Evaluation of pitfall trapping in northwestern forests: traps arrays with drift fences. *Journal of Wildlife Management,* 51: 112-119.

Eisenberg, J.F.; Redford, K.H. 1999. *Mammals of the neotropics*. The central neotropics: Ecuador, Peru, Bolivia, Brazil. 3th ed. University of Chicago Press, Chicago, 609p.

Emmons, L.; Feer, F. 1990. *Neotropical rainforest mammals*. 1st ed. University of Chicago Press, Chicago, 281p.

Emmons, L.; Feer, F. 1997. Neotropical rainforest mammals: a field guide. 2th ed. University of Chicago Press, Chicago, 307p.

Feliciano, B.R.; Fernandez, F.A.S.; Freitas, D.; Figueiredo, M.S.L. 2002. Population dynamics of small rodents in grassland between Atlantic Forest Fragments in southeastern Brazil. *Mammalian Biology,* 67: 304-314.

Flemming, T.H. 1975. The role of small mammals in tropical ecosystems. In: Golly, F.B.; Petrusewicz, K.; Ryszkowski, L. (Eds.) *Small mammals their productivity and population dynamics*. v.1. Cambridge University Press, London, p.269-298.

Gentile, R.; D'andrea, P.S.; Cerqueira, R.; Maroja, L.S. 2000. Population dynamics and reproduction of marsupials and rodents in a Brazilian rural area: a five-year study. *Studies on Neotropical Fauna and Environment,* 35: 1-9.

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.

Hice, C.L.; Velazco, P.M. 2013. Relative effectiveness of several bait and trap types for assessing terrestrial small mammal communities in Neotropical rainforest. *Museum of Texas Tech University*, 316: 1-15.

Laurance, W.F. 1992. Abundance estimates of small mammals in Australian tropical rainforest: a comparison of four trapping methods. *Wildlife Research*, 19: 651-655.

Marshal, M.G. 1978. *Glironia venusta*. *Mammalian Species*, 107: 1-3.

McClearn, D.; Kohler, J.; McGowan, K.J.; Cedreno, E.; Carbone, L.G.; Miller, D. 1994. Arboreal and terrestrial mammal trapping on Gigante Peninsula, Barro Colorado Nature Monument, Panama. *Biotropica*, 26: 208-213.

Mengak, M.T.; Guynn Jr, D.C. 1987. Pitfalls and snap traps for sampling small mammals and herpetofauna. *American Midland Naturalist*, 118: 284-288.

Myers, N.; Mittermeier, R.A.; Mittermeier, C.G.; Fonseca, G.A.B.; Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403: 853-858.

O'Connel, M.A. 1989. Population dynamics of Neotropical small mammals in seasonal habitats. *Journal of Mammalogy*, 70: 532-548.

Paglia, A.P.; Da Fonseca, G.A.; Rylands, A.B.; Herrmann, G.; Aguiar, L.M.; Chiarello, A.G.; *et al*. 2012. *Annotated Checklist of Brazilian Mammals*. 2nd ed. Conservation International, Arlington, 76p.

Quental, T.B.; Fernandez, F.A.S; Dias, A.T.C; Rocha, F.S. 2001. Population dynamics of the marsupial *Micoureus demerarae* in small fragments of Atlantic Coastal Forest in Brazil. *Journal of Tropical Ecology*, 17: 339-352.

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

Santos-Filho, M.; Silva, D.J.; Sanaiotti, T.M. 2008. Variação sazonal na riqueza e na abundância de pequenos mamíferos, na estrutura da floresta e na disponibilidade de artrópodes em fragmentos florestais no Mato Grosso, Brasil. *Biota Neotropica*, 8: 115-121.

Santos-Filho, M.; Lázari, P.R.D.; Sousa, C.P.F.D.; Canale, G.R. 2015. Trap efficiency evaluation for small mammals in the southern Amazon. *Acta Amazonica*, 45: 187-194.

Sealander, J.A.; James, D. 1958. Relative efficiency of different small mammal traps. *Journal of Mammalogy*, 39: 215-223.

Silva, M.F.F.; Secco, R.S.; Lobo, M.G.A. 1996. Aspectos ecológicos da vegetação rupestre da Serra dos Carajás, estado do Pará, Brasil. *Acta Amazonica,* 26: 17-44.

Umetsu, F.; Naxara, L.; Pardini, R. 2006. Evaluating the Efficiency of Pitfall Traps for Sampling Small Mammals in the Neotropics. *Journal of Mammalogy,* 87: 757-765.

Vargas, T.J.; Tarifa, T.; Cortez, C. 2003. Nuevos registros de *Monodelphis adusta* y *Monodelphis kunsi* (Didelphimorphia: Didelphidae) para Bolivia. *Mastozoología Neotropical*, 10: 123-131.

Vieira, M.V. 1996. Dynamics of a rodent assemblage in a Cerrado of Southeast Brazil. *Revista Brasileira de Biologia,* 57: 99-107.

Vieira, A.L.M.; Pires, A.S.; Nunes-Freitas, A.F.; Oliveira, N.M.; Resende, A.S.; Campello, E.F.C. 2014. Efficiency of small mammal trapping in an Atlantic Forest fragmented landscape: the effects of trap type and position, seasonality and habitat. *Brazilian Journal of Biology*, 74: 538-544.

Voss, R.S.; Emmons, L.H. 1996. Mammalian diversity in neotropical lowland rainforests: a preliminary assessment. *Bulletin of the American Museum of Natural History*, 230: 1-115.

Voss, R.S.; Lunde, D.P.; Simmons, N.B. 2001. The mammals of Paracou, French Guiana: a neotropical lowland rainforest fauna— part 2: Nonvolant species. *Bulletin of* the American Museum of Natural History, 263: 3-236.

White, G.C.; Anderson, D.R.; Burnham, K.P.; Otis, D.L. 1982. *Capture-Recapture and removal methods for sampling closed populations*. Los Alamos, National Laboratory, 13p.

Woodman, N.; Timm, R.M.; Slade, N.A.; Doonan, T.J. 1996. Comparison of traps and baits for censusing small mammals in Neotropical lowlands. *Journal of Mammalogy,* 77: 274-281.

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