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ORIGINAL ARTICLE

A New and Simple Method to Capture Small Arboreal Mammals: The Suspended Pitfall

Helder-José[1*], Iasmin Macedo[2] & Mateus Cruz Loss[3]

[1] *Faculdade Vale do Cricaré, FVC, Rua Humberto de A. Franklin, 01. São Mateus, Espírito Santo, Brasil.*
[2] *Instituto Últimos Refúgios. Rua Humberto Balbi, Ed. Renê Descartes, sala 208. Jardim Camburi, Vitória, Espírito Santo, Brasil.*
[3] *Universidade Federal do Espírito Santo, Centro de Ciências Humanas e Naturais, Programa de Pós-Graduação em Biologia Animal, Vitória, Espírito Santo, Brasil.*

**E-mail para correspondência: helderjose@ig.com.br*

RESUMO

Um método novo e simples para capturar pequenos mamíferos arborícolas: o pitfall suspenso. O *pitfall* suspenso é uma forma nova e simples para capturar pequenos mamíferos arborícolas e escansoriais. É uma versão arbórea dos *pitfalls* terrestres, tradicionalmente usados para capturar anfíbios e répteis. Baldes com isca no interior são erguidos por cordas até que atinjam um galho de árvore na altura desejada. O método foi testado na Mata Atlântica em três diferentes locais da foz do Rio Doce, em Linhares, sudeste do Brasil. Em um deles, os *pitfalls* suspensos foram colocados em galhos de cacaueiros no sub-bosque de uma plantação sombreada de cacau (cabrucas) a alturas entre 2 e 3 m. Na outra, eles foram instalados entre 5 e 15 metros de altura em uma floresta nativa. No terceiro local, no sub-bosque de outra cabruca, os *pitfalls* suspensos foram testados em conjunto com outras armadilhas usadas até então. Os marsupiais *Didelphis aurita*, *Caluromys philander*, *Marmosa (Micoureus) paraguayana*, *Gracilinanus microtarsus*, *Marmosa murina* e o roedor *Rhipidomys mastacalis* foram capturados pelos *pitfalls* suspensos. Essa armadilha foi capaz de capturar pequenos mamíferos de todos os tamanhos, inclusive indivíduos jovens. Esse método provou ser funcional para a captura de vários pequenos mamíferos arborícolas e escansoriais e pode ser uma alternativa complementar para amostragem em estratos altos de florestas.
Palavras-chave: Armadilhas suspensas, Cabruca, Foz do Rio Doce, Mata Atlântica, Métodos de captura.

ABSTRACT

The suspended pitfall demonstrates a new and simple mechanism to capture small arboreal and scansorial mammals. It is an arboreal version of the pitfalls traditionally used to capture terrestrial amphibians and reptiles. Buckets with bait inside are raised by a rope until they reach a tree branch at the desired height. Tests were performed in the Atlantic Forest at three different sites at the mouth of Doce River in Linhares, southeastern Brazil. In one of them suspended pitfalls were set up in the understory of a shaded cacao plantation (cabruca agroforest) in the branches of cacao trees between 2 and 3 m in height, and in the other they were placed in a native forest between 5 to 15 m in height. At the third site, suspended pitfalls were tested together with the other live traps used hitherto in the understory of other cabruca agroforest. The marsupials *Didelphis aurita*, *Caluromys philander*, *Marmosa (Micoureus) paraguayana*, *Gracilinanus microtarsus*, *Marmosa murina* and the rodent *Rhipidomys mastacalis* were captured by suspended pitfall. This live trap was capable of catching all sizes of small arboreal mammals, including juvenile individuals. This method proved to be functional for the capture of some small arboreal mammals and may be a complementary alternative for sampling in high forest strata.
Keywords: Arboreal live traps, Atlantic Forest, Cabruca agroforest, Mouth of the Doce River, Trapping methods.

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INTRODUCTION

Many studies in Mammalogy demand fieldwork and some require the capture of specimens. In some areas, due to the difficulty of capture, several assemblages of the fauna are poorly understood, and among them are the small arboreal mammals. The vertical stratum is habitat for a high diversity of species of small mammals, used by species with different degrees of arboreality, including strictly arboreal species. The composition of small arboreal mammals in these habitats is remarkably diverse (McClearn et al., 1994; Passamani, 1995; Leite et al., 1996; Voltolini, 1997; Graipel, 2003; Grelle, 2003; Vieira & Monteiro-Filho, 2003; Hannibal & Cáceres, 2010; Passamani & Fernandez, 2011; Camargo et al., 2018). The use of forest strata by small mammals is more complex and sophisticated than simple classification by stratum (Prevedello et al., 2008). Studies on the structure of the vertical stratification of small mammals are essential for the understanding of the organization and functions of Neotropical small mammal communities.

Researches regarding small arboreal mammals are less common than those on terrestrial taxa. This is due to the logistic difficulties of placing traps in the canopy (Lambert et al., 2005), which demands greater effort. For instance, climbing trees and the selection of sites to install traps and their support platforms can be complicated and laborious (Graipel & Astúa-de-Moraes, 2004) and often does not produce enough captures for most statistical analyses. Consequently, there is a lack of data to answer most of the related questions. These difficulties have discouraged many researchers from studying the higher strata of the forests, limiting the surveys to no more than 2 m in height (Albuquerque et al., 2013; Carvalho & Oliveira, 2015; Delciellos, 2016; Helder-José et al., 2016; Leite & Costa, 2018).

Small arboreal mammals have been studied using several methods, such as direct observation, smoked paper tracking (Justice, 1961), spool-and-line (Miles, 1976; Miles et al., 1981; Boonstra & Craine, 1986), artificial nests (Loretto, 2005; Prevedello et al., 2008) and radio-tracking (Charles-Dominique et al., 1981). However, the most widely used method is live capture employing cage-like (Tomahawk® and Young®) and Sherman® traps. These live traps can be set directly on branches in the canopy or placed on wooden platforms. When tied directly on tree branches they are generally limited to 2 m of height, unless a ladder is used (Wallauer et al., 2000). If they are secured on platforms the researchers are submitted to several inconveniences, like their constructions, transportation into the forest, installation and additional costs. Improvements to the platform method were made by utilizing the pulley system (Malcolm, 1991; Vieira, 1998; Graipel, 2003; Lambert et al., 2005). Whereas the method employed by Malcolm (1991) requires climbing of the tree, that used by Vieira (1998), Graipel (2003) and Lambert’s et al. (2005) are ground-based. Suspended pitfall is a cheaper new method for the capture of small arboreal and scansorial mammals, which can be added to those used thitherto. The aims of this study were to describe and to test the functionality of the suspended pitfall. This method is easy to manipulate and quick to assemble.

MATERIALS AND METHODS

Characteristics and installation of the suspended pitfall

Plastic buckets with 63 L and top diameter of 44.5 cm, a bottom diameter of 31.5 cm, and a height of 52.5 cm are tied up and suspended from tree branches, which we refer to as suspended pitfalls. They correspond to the traditional pitfalls (buckets), which are buried in the soil for the capture of amphibians, reptiles and small mammals (Umetsu et al., 2006; Cáceres et al., 2011). For draining water that may accumulate during periods of rain, at least three or four holes should be made in the bottom of the bucket (Figure 1A). These holes should be at least 1 cm in diameter, to prevent obstruction by leaves, small branches, or debris that fall off the trees. This procedure is of paramount importance because during heavy rains a significant volume of water can collect in suspended pitfall traps and could possibly drown small animals.

A polypropylene rope (Riomar Ropes®), 2 - 3 mm thick, can be used to lift the pitfall trap. It is lightweight, easy to handle, resistant to fraying and weather resistant. The rope is tied onto two handles or hooks on opposite sides of the top edge of the bucket, so that it is flush with the surface opening. From the central point, tie the rope that will be used to raise the pitfall trap (Figure 1B). This is a ground-based procedure. The rope is then thrown over the chosen branch. In order to place the suspended pitfalls at high heights, out of reach of manual throwing, one can use a slingshot or a bow-and-arrow technique to simply propel it over the branch. The suspended pitfall traps should be raised until one, or preferably two, contacts are made with its top edge against the branch of the tree (Figure 1C, 1D and 1E). Horizontal branches are best suited for the installation. To improve capture efficiency, choose trees with high interconnectivity with other trees. Rub the bait on the upper edge of the pitfall, and then place it inside.

Figure 1. The different steps to prepare the suspended pitfalls: a) 1 cm diameter holes in the bottom of the plastic bucket for drainage of water in case of rain; b) demonstration of how to tie a rope to the bucket for its lift; c) lateral view of installed suspended pitfall trap with one contact against the tree trunk; d) top view of installed suspended pitfall trap; e) bottom view of the installed suspended pitfall trap. Note two points of its top edge rub against the branch.

Two additional non-mandatory improvements can be made: (1) For easy lifting, a sheath of approximately 10 cm x 10 cm made from polyethylene terephthalate (PET) plastic bottles can be fixed on the branch where the rope will slide. This mounting can be made with two large nails, partially driven in, and fixed at an angle. Consequently, the rope does not come out of the limits of the plastic sheath (Figure 2A), and allows smooth movement of the rope, thereby drastically reducing friction with the branch. Fence staples can be used as a more effective alternative to the nails (Figure 2B). This type of mounting is particularly useful when using cage-type traps because it prevents the trap from disarming while being lifted and it is simpler and cheaper than the use of pulleys. However, one should use a ladder or climb the tree. (2) A rod can be tied at any point on the inside edge of the bucket, close to the rim (Figure 2C). This encourages and facilitates the descent of small animals, and decreases the height of the fall, which is especially important to prevent injury. After each capture, the remnants of bait, feces, and urine must be removed from the inside of the trap.

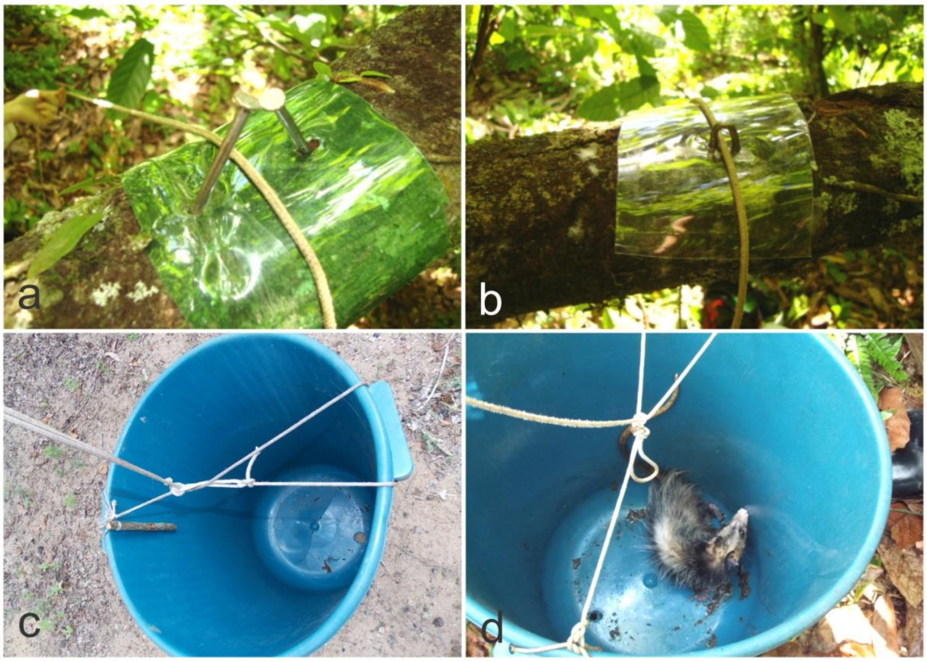

Figure 2. Additional non-compulsory techniques: a) plastic board or flat surface made with disposable bottle, fixed on a branch to facilitate sliding of the rope during ascent and descent of the suspended pitfall trap; b) plastic board on a branch attached by a fence staple; c) inside view of suspended pitfall trap, with an wooden rod to encourage and facilitate the descent of the animal. d) *D. aurita* (black-eared opossum) captured by a suspended pitfall trap.

Study sites

Suspended pitfalls were tested at three different sites in the Atlantic Forest at the mouth of the Doce River in the municipality of Linhares in the state of Espírito Santo (ES) (Figure 3). These sites were situated on alluvial soil in the lowlands. This is a poorly known region concerning the lack of knowledge of the native small animals and considered high priority for studies (IPEMA, 2011). The minimum average temperature in this region is 14.8 °C and the average maximum temperature is 34.2 °C. The average annual temperature is 23.3°C. The average annual rainfall is approximately 1200 mm, presenting a defined seasonality: a rainy season (October to March) and a dry season (April to September) (Ferreira-da-Silva, 2005).

The site A was situated in a shaded cacao plantation of the south side of the Doce River (19°31'58'' S, 39°58'53'' W). This ecosystem, known as *cabruca*, consists of understory replacement by cacao trees (*Theobroma cacao* L.) after removal of the low native trees and maintenance of some tall trees to shade the cacao trees. In this site, the sampling was conducted only using the suspended pitfalls. The suspended traps were installed between 2 and 3 m high in branches of cacao trees every 40 m along three parallel linear transects (50 m apart) of ~ 400 m, totaling 11 traps per transect. Each trap was baited and inspected for 3 - 4 days, in a total effort of 1345 pitfalls-night.

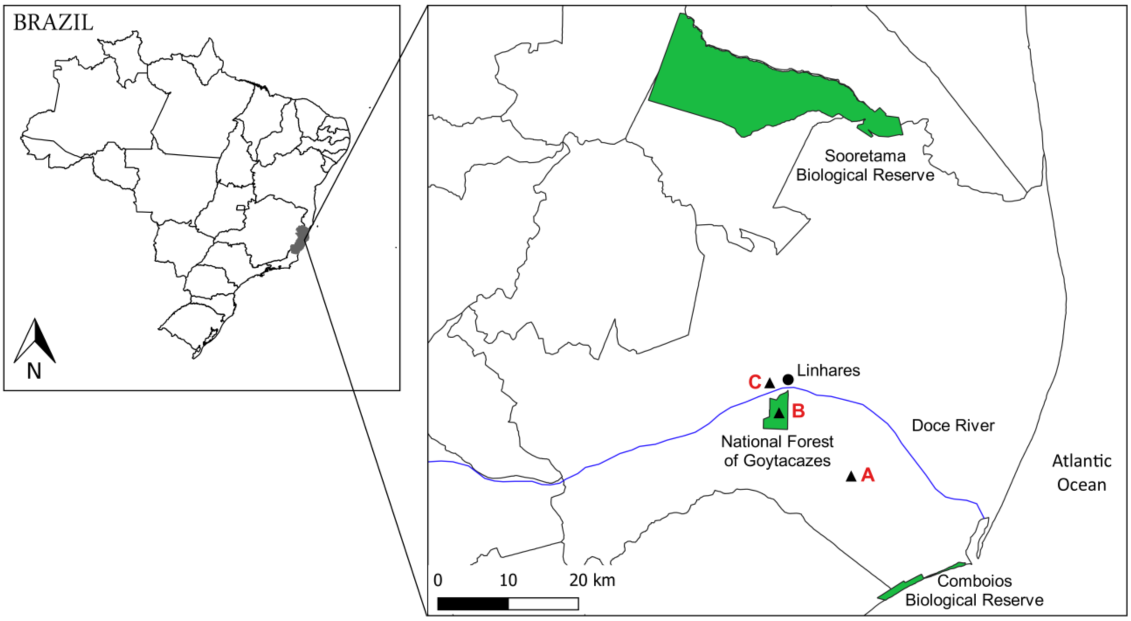

Figure 3. Geographical location of the study area at the mouth of Doce River. The letters A, B and C near the city of Linhares indicate the study sites.

Sampling at the site B (coordinates 19°26'49'' S, 40°04'45'' W) was conducted within the National Forest of Goytacazes (FLONA - 1423.96 ha). In this site, the structure of the vegetation is dense ombrophyllous forest with tall trees and trunks covered by large amounts of epiphytes and creepers (Ross, 2019). Three line transects were arranged in the form of a 'Y'. 21 suspended pitfalls were raised to heights between 5 - 15 m, equally divided across the three arms of the 'Y' (seven traps on each arm), whose capture points were 40 m apart. Each trap was baited and inspected for 3 - 4 days, in a total effort of 420 suspended pitfalls-night.

The habitat of site C was similar to that of site A, however, it was located on the north bank of the Doce River at the coordinates 19°24'22'' S, 40°05'31'' W. In this area, suspended pitfalls were tested together with other live trap types: the cage-type traps with two entrances and measured 42.5 x 12.5 x 12 cm; and the Sherman folding traps measured 41 x 10 x 13 cm. Three parallel line transects, 30 m apart, were built. Each one had 20 capture points, 15 m equidistant of each other. Twenty traps of each type were used (60 in total). The types of traps were arranged alternately, following the order: cage-type trap, suspended pitfall and Sherman. Cage traps and Shermans were tied to the branches of cocoa trees with bungee cords at heights ranging from 1.6 to 3 m with the help of a ladder, while the suspended pitfalls were hung up to 5 m high, as previously described. The whole trapping effort was 780 traps-night, during

13 consecutive days.

Cavendish bananas and peanut butter were used as bait for all traps. The traps were set in the morning and inspected the next day at the same time. Each captured specimen was identified, sexed, had mass and biometric data recorded, reproductive stage determined, ear tagged and released. In each site, the capture success rate was calculated by multiplying the number of captures by 100, divided by the number of pitfalls-night (capture effort). The taxonomic arrangement and nomenclature followed Gardner (2007).

RESULTS

We captured 60 specimens of six species, and had a capture success of 4.46% in site A. *Rhipidomys mastacalis* was the unique rodent and the most captured species, comprising 39% of captures (Table 1). *Rhipidomys mastacalis* is a small arboreal rodent with average body mass of 68.9 g (± 18.8; n = 23; range: 26 - 103 g). We also captured five marsupial species, of which the scansorial *Marmosa (Micoureus) paraguayana* was the most common (Table 1). The average body mass was 150 g (± 13.6; n = 8; range: 125 - 164 g). *Marmosa murina* is another scansorial small mammal, and body mass averaged 70.2 g (n = 5; range: 54 - 92 g). *Didelphis aurita* was the largest captured species, whose mean body mass was 1037.2 g (± 584; n = 10; range: 174 - 1950 g). *Caluromys philander* is a strictly arboreal species, and adult body mass ranged between 152 - 180 g. *Gracilinanus microtarsus* is among the smallest neotropical small mammals. Its mean body mass was 30 g (± 3.94; n = 5; range: 24 - 35 g). In this area, the animals were caught between 2 and 3 m high.

In area B of the alluvial forest, individuals were captured at different heights: two *M. paraguayana* and one *D. aurita* at about 6 m high and two *D. aurita* and one *C. philander* between 10 and 15 m high. The captures comprised 1.43%. Area C (*cabruca* agroforest) tested the functionality of the three kinds of live traps together. 780 traps-night resulted in the capture of 19 specimens of three orders, three families and six species (Tables 1 and 2), with a capture success of 2.4%. Although *Callithrix geoffroyi* captured in this site is very common in the *cabruca* agroforest, individuals only enter the traps occasionally, and it was also found in other areas. *M. paraguayana* was the most captured species, and the only species captured by the three kinds of traps (Table 2). Sherman and cage-like traps captured more specimens than suspended pitfalls, while cage-like trap captured the most species (four species) (Table 2). The animals at this site were caught between 1.6 and 3 m in height, but the *C. philander* was captured at 5 m above the ground.

Table 1. Species, first captures (recaptures) and total captures of small arboreal mammals recorded in forests of the lowland of the mouth of Doce River (Linhares, ES).

SPECIES	First captures (recaptures)	Total of captures
Area A (only suspended pitfalls)		
Order DIDELPHIMORPHIA		
Family Didelphidae		
Caluromys philander (Linnaeus, 1758)	2 (0)	2
Didelphis aurita (Wied-Neuwied, 1826)	4 (6)	10
Gracilinanus microtarsus (Wagner, 1842)	4 (4)	8
Marmosa murina (Linnaeus, 1758)	3 (3)	6
Marmosa (Micoureus) paraguayana (Tate, 1931)	7 (4)	11
Order RODENTIA		
Family Cricetidae		
Rhipidomys mastacalis (Lund, 1840)	15 (8)	23
Total Area A	35 (25)	60
Area B (only suspended pitfalls)		
Order DIDELPHIMORPHIA		
Family Didelphidae		
Didelphis aurita	3 (0)	3
Marmosa (Micoureus) paraguayana	2 (0)	2
Caluromys philander	1	1
Total Area B	6	6
Area C (suspended pitfalls, Sherman and cage-like traps)		
Order DIDELPHIMORPHIA		
Family Didelphidae		
Caluromys philander	1	1
Marmosa murina	5 (0)	5
Marmosa (Micoureus) paraguayana	9 (0)	9
Gracilinanus microtarsus	2 (0)	2
Order RODENTIA		
Family Muridae		
Rattus rattus (Linnaeus, 1758)	1	1
Order PRIMATES		
Family Callitrichidae		
Callithrix geoffroyi (Humboldt, 1812)	1	1
Total Area C	19	19

Table 2. Captures of small arboreal mammals by suspended pitfall, Sherman and cage-like traps in a cocoa plantation (area C - cabruca forest) at the mouth of Doce River (Linhares, ES).

Species	Suspended pitfall	Sherman	Cage-like trap	Total captures/species
Caluromys philander	1	-	-	1
*Marmosa murina**	-	3	2	5
Marmosa paraguayana	3	3	3	9
*Gracilinanus microtarsus**	-	2	-	2
*Callithrix geoffroyi**	-	-	1	1
Rattus rattus	-	-	1	1
Total captures/trap	4 (21.1%)	8 (42.1%)	7 (36.8%)	19

* Also captured by suspended pitfall in site *A. C. geoffroyi* was possibly captured, but probably escaped from the suspended pitfall.

DISCUSSION

This is the first use of suspended pitfall traps, which showed themselves to be functional at capturing small arboreal mammals. They do not depend on sensitive triggers, wooden platforms or pulleys, in addition to the low cost - they are about four to five times cheaper than the current standard live traps (including the wooden platforms and pulleys), considering the Brazilian artefacts. Animals of a wide range of sizes can be captured by one size of bucket. On the other hand, this method requires reasonable effort to transport the buckets into the forest. Each of our 63L-buckets weighted 1 kg, and a person was capable of transporting ten of them at once when engaged inside one another. In addition, there is the vulnerability of the captured animals to possible predation, and the possibility of some captures eating other captures.

Suspended pitfalls were able to capture small mammals of all sizes, from the small *G. microtarsus* and *R. mastacalis* to the large *D. aurita*, including juvenile individuals. No incident regarding the suspended pitfall trapping work was recorded: no death and drown occurred. Also, there were no signs of predation. However, in four situations there were signs of animal escape. We suspect that squirrels and marmosets escape from the inside of the suspended pitfalls by jumping out of them because they have strong rear legs. *Rhipidomys* is also capable of performing great leaps, however, its ability directs the jump forward not upwards. Data on possible harm to animals are usually not reported in previous works with ground pitfalls, therefore we do not know the extent of the damages.

The abundance of small arboreal mammals captured in site A is an indication of its functionality. Among the six specimens trapped in site B there were the canopy dwelling *C. philander* and the scansorial species *D. aurita* and *M. paraguayana*. They were captured at a range of heights up to 15 m. In site C, where the Sherman and cage traps were directly tied on the tree branches, these traps provided better results. It is likely that the good performance of the traps strung on the branches is due to its position, i.e., their entrances are directly in the path where the animals roam. This greatly favours the entry of animals into traps. Although the traps strung on the branches had good results, on the other hand, they are only viable to work at the lowest stratum (up to about 2 m of height). Their combined use may be a good strategy, that is, Sherman and cage-type traps strung on the branches of trees in the lower stratum and suspended pitfalls in the higher strata.

Among the scarce works on small mammals made in cabrucas, this is the first to contemplate its arboreal fauna. Our trapping successes (4.46% in site A, 1.43% in site B and 2.4% in site C) are in line with previous works at the canopy (Stallings, 1989 (6.3%), McClearn et al., 1994 (3.7%), Vieira, 1998 (2.4%); Voltolini, 1997 (1.29%); Wallauer et al., 2000 (2.33%); Graipel, 2003 (6.9%); Hannibal & Cáceres, 2010 (1.4% in woodland savannah and 1.8% in gallery forests; Camargo et al., 2018 (3.4% in woodland savannah and 1.4% in gallery forests).

Traditional pitfalls buried at the level of the soil have been used for decades to sample small terrestrial vertebrates (Willams & Braun, 1983; Enge, 2001), and more recently in the capture of terrestrial small mammals, with good results. For example, by comparing ground pitfalls to Sherman traps in the Atlantic Forest of Brazil, Umetsu et al. (2006) captured 29 species by pitfalls, of which 16 were captured exclusively with this method, mostly represented by rare species. Pitfalls captured three times the number of species captured by Sherman traps, two times the number of individuals, and significantly more individuals of seven species. Comparing the differential trapping success among Sherman, cage-type and ground pitfall traps in a Brazilian savannah, Cáceres et al. (2011) captured 14 species. Pitfall traps sampled all 14 species. Ground pitfalls were also more effective than Sherman and Tomahawk traps in the southern Amazon. Most of the individuals and species were trapped using pitfalls (Santos-Filho et al., 2015). Despite the great effort to install ground pitfalls, its use has been increasing in recent years. Like the ground pitfall, although our sampling was not large, the results have shown the functionality of the suspended pitfall.

In a 10-year long-term study, Prevedello et al. (2008) found that traps on platforms captured only about 50% of the individuals present in the study area, and the remainder were detected by the artificial nest method. Although this fact must be confirmed by further studies, it is an indication that live traps alone are insufficient to cover the demand of research on the ecological and systematic aspects. Once again, the combined use of various methods (live traps, artificial nests, spool-and-line, direct observation, and others) could give a better overview of small arboreal mammal dynamics. The suspended pitfall is intended to integrate these methods.

CONCLUSION

We recommend the use of the suspended pitfall trap concerning the capture of small arboreal mammals. It will greatly aid and facilitate researchers by improving their sample collection, providing a useful tool that is practical and inexpensive. Comparative studies using these different models of live traps should be carried out to show their relative efficiencies.

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