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A LITERATURE REVIEW AND FIELD TEST ON THE ROLE OF BAIT TYPE ON CAPTURE SUCCESS OF ARBOREAL SMALL MAMMALS

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Abstract: Small mammals are widely studied in Brazil with well-established techniques. However, arboreal species are the least known. Yet, it is common to find studies only committed to capturing terrestrial species. Baits can influence the detection power of studies but, unlike traps, they are not usually assessed for efficiency. We compiled small mammal studies developed in Brazil from 1965 to 2011 (N=113), and we found 25 food items used as bait. Arboreal small mammals are mostly known from studies in the Atlantic Forest, and mostly use banana and peanut butter (*ca.* 75%) as bait. Only fifteen studies (13.2%) set traps in trees, and mostly used banana and peanut butter as baits. From April to June 2010, we investigated the efficiency of four food items (banana, fresh meat, mixed bait [pasta], and pineapple) to attract small arboreal mammals. We used Sherman traps in the understory and canopy, and Tomahawk traps in the canopy, on platforms suspended in tree branches, totaling 2,880 trap*nights. All traps and sampling stations received each bait for five consecutive nights of sampling, distributed into four campaigns, totaling 20 days of study. We recorded 10 small mammal species (5 arboreal and 5 scansorial), in 158 captures (capture success; CS=5.5%). Arboreal species were mostly attracted by banana bait, (CS=10.1%), it has captured more individuals (N=45; 77.6%), more times (N=73; 46%), *ca.* 30% more than the *pasta*, the second most efficient bait (N=49). Fresh meat bait was the least efficient (N=7), and pineapple bait obtained intermediate success (N=28). Sherman traps were 50% more efficient than Tomahawks. We recommend that every small mammal study perform a bait test structured by forest strata to maximize trapping success. If not possible, our results support that the best results for arboreal species can be achieved exclusively using Sherman traps baited with banana.

Keywords: Atlantic Forest; sampling method; literature review; field test; montane forest.

INTRODUCTION

In many cases, the comprehension of a biological phenomenon is only possible by capturing specimens. Regarding small mammals, live traps are generally used to capture individuals without harming them. Live-traps have been used for decades in mark-recapture studies (Fernandez 1995), which are the basis of several ecological frameworks, such as lifetime monitoring, when it is essential that physical integrity and health are not significantly altered by capturing methods (see Auricchio & Salomão 2002, Monteiro-Filho & Graipel 2006, Reis *et al.* 2010, for detailed capturing methods used for this group).

Most animals do not spontaneously enter traps or capture devices. Therefore, most studies base their captures using an attractive reward: edible baits. As the success of a professional chef depends on the flavor of its plates, a small mammal mark-recapture study will depend, among other factors, on the type and attractive power of the bait used (Monteiro-Filho & Graipel 2006). A seemingly simple decision – bait choice – may strongly affect results, especially regarding abundance and species composition (*e.g.* Fowle & Edwards 1954, Rickart *et al.* 1991, Laurance 1992).

For at least 80 years, mammalogists tested baits and trap types aiming to increase small mammals capture success (Townsend 1935, Beer 1964, Patric 1970, Wiener & Smith 1972, Laurance 1992, Fournier-Chambrillon *et al.* 2000). Mammalogists were also concerned that the capture device could inhibit or prevent some species to be captured, which was shown by field experiments using pitfall traps (Wiener & Smith 1972, Nellis *et al.* 1974, Williams & Braun 1983, Umetsu *et al.* 2006, Vieira *et al.* 2014). Other studies tried to increase the success by alternating traps and baits spatially and temporally (Sealander & James 1958, Wiener & Smith 1972, O'Farrel *et al.* 1977, Anderson *et al.* 1983, Lacher & Alho 1989, Vieira 1997, Vieira 1999). In Brazil, efforts to test and develop efficient methods for capturing small mammals have been more expressive in the last 30 years (*e.g.* Malcolm 1991, Voss & Emmons 1996, Vieira & Monteiro-Filho 2003, Santos-Filho *et al.* 2006, Vieira *et al.* 2014).

Although capture devices are considered important in determining studies success, sampling standardization is also essential to determine more attractive and efficient baits. Bait tests were most performed in USA (*e.g.*, Beer 1964, Patric 1970, Edalgo & Anderson 2007) and Europe (*e.g.* Chitty & Kempson 1949, [England]), mainly for terrestrial, rodent species (*e.g.* Pendleton & Davison 1982, O'Farrel *et al.* 1994, Risch & Brady 1996, all three in the USA). Some baits are expected to be more attractive than others, and it is assumed a correspondence between species' dietary needs and bait nutritional composition (Louw & Mitchell 1996), also demonstrated by laboratory experiments (see Astúa *et al.* 2003). Therefore, to maximize small mammal capture success more than one trap type and a mixture of low-cost food items are used (Monteiro-Filho & Graipel 2006).

Dietary habits are associated with use of vegetation by mammals, with arboreal mammal species mainly developing frugivorous or folivore life/dietary habits (Eisenberg 1978, Emmons 1980, Gautier-hion *et al.* 1980, Malcolm 1995, Kissling *et al.* 2014); and terrestrial species varying between omnivorous and carnivorous habits (Emmons 1995). Along the evolution of mammals, changes in the use of forest vertical strata occurred multiple times so arboreal and terrestrial species of mammals evolved in different lineages, hence the association of vertical stratification with dietary habits could mainly result from the unique evolutionary history of each lineage than adaptation. However, in marsupials of the Atlantic Forest, this association remains even after considering the phylogenetic relationships between lineages, favoring adaptive hypotheses (Finotti *et al.* 2018).

Regardless of the cause for this association of dietary habits and vertical stratification, arboreal species are more likely to be attracted by fruits than nuts, grains, meat, or a mixture of ingredients. In Brazil, the few studies that performed tests of bait selection focused only on terrestrial species, without any bait tests designed specifically for arboreal small mammals (Cerqueira *et al.* 1990, Vieira 1997, Vieira *et al.* 2004, Astúa *et al.* 2006, Vieira *et al.* 2014). Arboreal mammals are the less studied group of mammals worldwide (D. Loretto, *unpublished data*), which may be related to constraints imposed to access and sample the arboreal environment.

Herein we investigate (1) which types of edible bait are used in studies of small mammals in Brazil, and (2) which is the most efficient to capture arboreal small mammals in the Atlantic Forest of South America. First, we reviewed the use of edible baits in studies of small mammals (terrestrial and arboreal) developed in Brazil (and nearby areas in neighbor countries) over three decades, aiming to find which food items are the most used in different biomes. The wide latitudinal and longitudinal ranges of Brazil encompass a variety of environmental conditions and biomes, mirroring the variety of biomes at the larger scale of South and Central America.

Secondly, we performed a manipulated field experiment to test the efficiency of frequently used food items to attract arboreal small mammals defined in the first part of the study (two types of fruit, meat, and a mixed bait). Fruits and meat were intentionally used to directly test the association between arboreal habits and frugivorous diet strategies. Thus, we expected that fruits will be far more efficient in attracting small arboreal mammals during the field experiment. We also presumed that similar edible baits should attract small mammal species with converging biology/ diet strategy: a greater arboreal specialization degree shall lead to a greater frugivory degree. As a final and integrated objective, we assembled results from both parts of the manuscript to perform general comments and guidance for further studies on small mammals, especially those aiming to obtain quality information about arboreal species.

MATERIAL AND METHODS

Literature survey

To evaluate which food items were the most used as edible baits in small mammal studies in Brazilian biomes, we surveyed the specialized literature using the databases ISI Web of Science, Scopus, and CAPES Journal Web Portal. We also searched within the bibliographic databases from investigators who have already developed studies in Brazil, through Mendeley Desktop database (during April-May 2011; Elsevier 2020). Additionally, we included papers we were aware that were not listed in the search outputs, as well as references therein. This survey was performed covering the available literature until 2011. Nevertheless, this sample captured the early phase of growth in publications on small mammals in Brazil. Field methods and sampling designs regarding trapping and bait use did not change after 2011, hence inferences based on this survey are still appropriate.

In each database we searched for the same keywords, in English and Portuguese: “bait” AND “Brazil” AND “small mammals” (“isca” AND “Brasil” AND “pequenos mamíferos”). In the Mendeley Desktop database, we used “small mammal Brazil” allowing word interaction and without a complete match, so it did not exclude papers with similar terms. We excluded from the sample multiple articles clearly using the same data set series, as well as single species bait efficiency tests. Our main targets were studies evaluating small mammal communities or abundant species from rich communities.

Data base

We collected nine descriptors from each of the studies found: (1) biome; (2) baits used; (3) study duration; (4) field trips *per* year; (5) study main objectives (ecology, survey, or method test); (6) forest strata sampled (ground, understory, canopy); (7) total trap effort; (8) capture success; (9) complementary methods if used, such as pitfall traps. Since we found a wide variety of bait descriptions among studies, we avoided bias in the bait frequencies by grouping some items. For example, within “peanut” bait type we included baits described as: peanut, peanut butter, ground peanut, peanut flour, and peanut cream. We excluded any study that did not explicitly report used baits.

Some studies did not clearly indicate the total trap effort and/or capture success. Then, when possible, we obtained that information indirectly by counting and summing the number of captures and total trap effort *per* day, study site, campaign, or study duration. We used geographic location reported by each study, or, when it was not reported, the coordinates of the nearest municipality. We also considered studies developed outside Brazil if it included at least one sample site in Brazilian lands and replicated the same methods. We also discarded studies that did not inform geographic coordinates and we were unable to get a reliable location.

Bait test

Study area

We performed the bait test between April 22 and June 26, 2010, in an Atlantic Forest area in Rio de Janeiro state, within the limits of the Serra dos Órgãos National Park, at the locality named Garrafão (22° 28’ S, 42° 59’ W). The study area is within the Evergreen Montane Forest Vegetation Complex (IBGE 2012). During the study, the mean temperature was 16.6° C (maximum: 28° C, minimum: 7.7° C), mean air moisture varied from 79.1% to 90.7%, and rainfall summed 15.6 mm (data from the automatic weather station set in the Serra dos Órgãos National Park at 990 m a.s.l., 22S 26’ 56”, 42W 59’ 14”; INMET).

Experimental design

Considering the association between frugivory and arboreal habits (Vieira 2006, Finotti *et al.* 2018), a bait efficiency test (‘bait test’ from now on) for arboreal marsupial species should use fruits. We tested the attraction of two fruits (banana and pineapple), the only fruits used in the studies on small arboreal mammals (see Results section). Two other items were tested: the “pasta” (mixture of banana, oats, peanuts, and bacon) and meat. The first was used as a control item since it had been used in the study area in the 13 previous years. This mixture is also widely used and informally replicated in many studies in all biomes (see Results section). We chose to use meat also to indirectly test the arboreal-frugivory pattern: arboreal species should not be attracted by meat because of their physiological and morphological adaptations to eat items of plant origin (Santori *et al.* 2004, Finotti *et al.* 2018). Besides that, when planning a small mammal study one may choose baits also considering economically non-restrictive items and its availability during the year (Monteiro-Filho & Graipel 2006).

Each bait was individually set in the traps, and each trap remained baited with the same bait during the entire sampling section. We did not test the efficiency of baits combined in the same trap. We drew bait position in each trap station (underground, canopy, see below) and bait exchange order between sampling sections in three steps: (1) bait replacement order between sections; (2) bait position in the trap station for each sampling grid; (3) we replicated bait replacement order for all traps and sections. Thus, all baits were used at all trap stations during a five-night sampling period. We adopted this protocol independently to understory and canopy trapping stations. Therefore, understory and canopy traps could receive the same bait at the same sampling section, which indeed happened occasionally.

<u>Capturing and handling</u>

We performed the bait test in the same three sampling grids where the Laboratório de Vertebrados from the Universidade Federal do Rio de Janeiro (UFRJ) maintained a small mammal population-monitoring program (PMP) from April 1997 to February 2019. Sampling stations and traps were the same. Each sampling grid has 0.64 ha (80 x 80 m), with 25 trap stations 20 m apart (details in Macedo *et al.* 2007, Kajin *et al.* 2008). During the test, we used 24 trap stations in the understory and 12 in the canopy (detailed below), equally spaced, so that sampling effort was homogeneous. We did not set traps on the ground during the test. Trap positioning was also the same between sampling sections, as canopy platforms had fixed positions in the branches of the trees where they were set, and the position of understory traps was marked with discrete colored tape strips.

Each trap station received a XLK Sherman trap (30.5 x 9.8 x 8 cm) in the understory (1.35 ± 0.31 m high, max=2.05 m; min=0.75 m; N=72). In the canopy, each trap station (11.5 ± 2.6 m high, max=18 m, min=6 m, N=36, Figure 1) received one XLK Sherman on the top of one 201 Tomahawk (41 x 14 x 14 cm). These traps are the most used in Brazil: 61% of the studies assembled in the first part of the manuscript used at least one of these two traps (see Results section), which are suitable for capturing terrestrial and arboreal species. Traps were checked and rebaited every morning.

Captured individuals were marked with ear tags (National Band and Tag Co., Newport, Kentucky). We recorded their external morphological measurements and individual characteristics (following Macedo *et al.* 2006, 2007). Capturing and handling followed biosecurity standards (Kelt & Hafner 2010, CONCEA 2016) including those of the United States Centers for Disease Control and Prevention (CDC and after measurements, individuals were released at the same trap station. We used physical contention procedures to handle individuals; no anesthesia drugs or procedures were necessary. This study was carried out using the ICMBIO/IBAMA collecting permits 02001, 004671/98-51, and 16704-1.

The test lasted four sampling sections of five-night trap effort each, during a 65-day period between April 21 and June 26, 2010. Traps remained in the field during the whole period, disabled between sampling sections. We replaced traps at each new capture event to prevent potential influences of urine and feces from individuals/species on the attractive power of the bait tested (Stoddart 1982, Tew 1987). We opted to perform all field experiment during a brief time interval to avoid substantial climatic seasonal variation, for example of temperature and rainfall, which may affect results. In fact, all sampling sections occurred under a stable climate, and by condensing the experiment duration we also prevented significant population fluctuations occur. Both climate and population dynamics could alter capture probability (*e.g.* as it occurs with the South Pacific El Niño Oscillation, OSEN; Lima *et al.* 2001, Kajin 2008, Pacheco 2009,

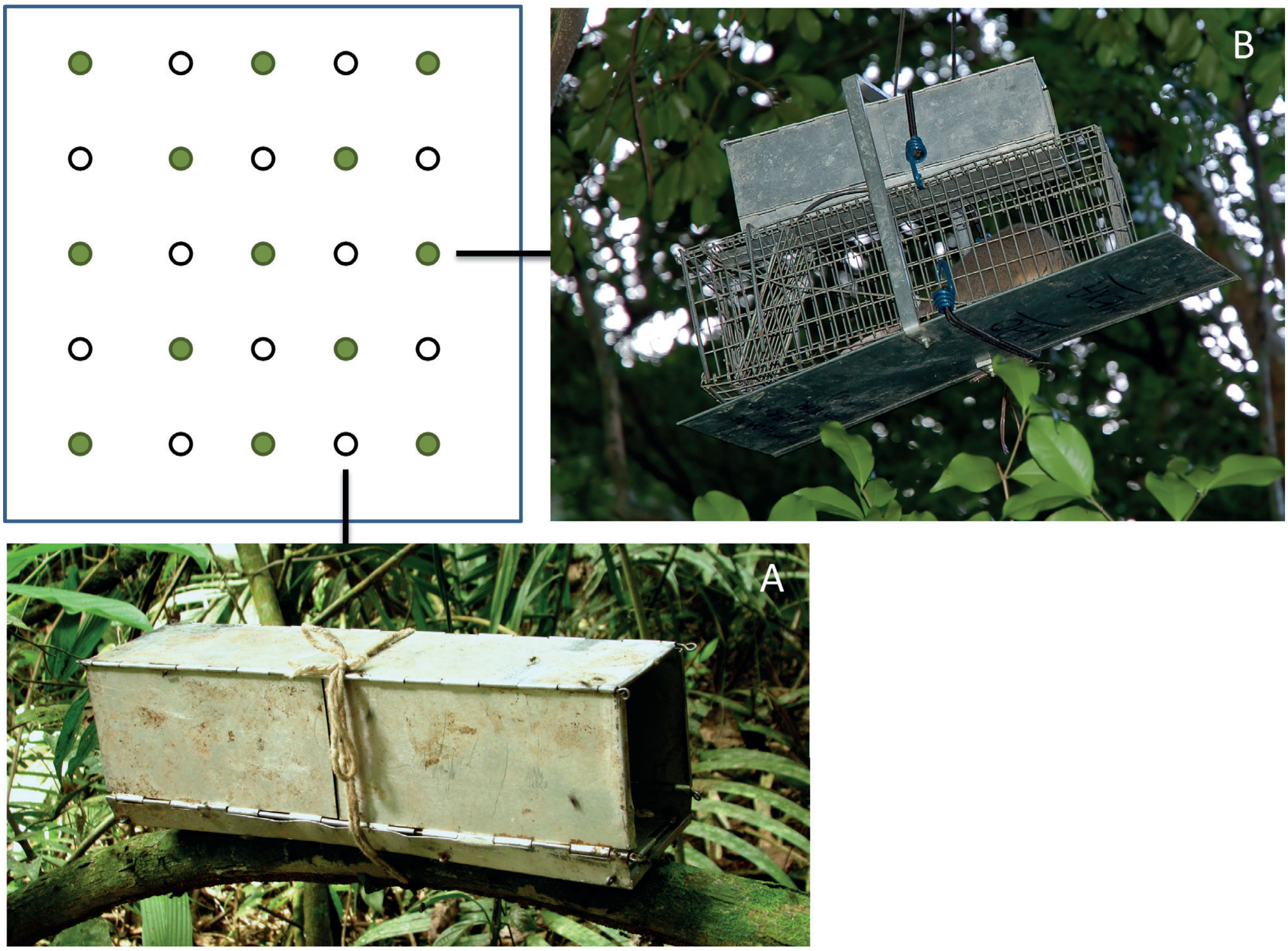

Figure 1. Sampling grid and spatial arrangement of trap stations (upper), where we set Sherman traps (canopy – A; understory - B) and Tomahawk traps (canopy – A) at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil. Photos by Diogo Loretto (A) and Ramon Campos (B).

Zangrandi 2011), violating the assumption of minimal variation of independent factors of each treatment under test.

Data analysis

Literature review

We grouped the data set collected in the literature review by biome and classified *per* research theme. We extracted descriptive parameters of each study and compared them among research theme categories using Kruskal-Wallis test, since data set did not fit homoscedasticity requirements.

Bait test

To distinguish and control any abrupt shift between the population-monitoring program (PMP) and the baits test, we compared the data set obtained during the field test with data from 12 sampling sections of the PMP (February 2009 to December 2010). We used the number of captures, effort, and capture success *per* forest strata and trap type, species richness, composition, and abundance.

We considered the total number of individuals of a species, instead of total captures, as a measure of the attractiveness of a bait. By doing this, we expected to avoid biases caused by trap-happy individuals (Pianka 2011). The capture success of each trap type used in the canopy was compared using the chi-square test. We expected a similar capture success of each trap, as they are set one above the other, thus sharing position and all conditions. We also did not have evidence to assume species preferences for any trap type.

We compared the total number of captures between sampling sections to discard any abrupt shift, if clearly associated with continued sampling. We did the same considering the population monitoring study campaigns, before, during, and after the bait test (April, June, and August 2010).

RESULTS

Literature review

We gathered 113 studies on small mammals sampling using live traps and baits developed in Brazilian biomes (Figure S1, Table S1), mostly coming from the last 35 years before 2011. As in most scientific knowledge areas, it is noticeable the gradual increase in the number of studies during the 1990's (Figure S2).

The Atlantic Forest concentrated most studies (N=69, 59.5%), followed by the Cerrado (N=27, 23.2%), Amazon (N=13, 11.2%), Caatinga (N=5, 4.3%), and Pantanal (N=2, 1.7%, Table S2), without any study in the Pampa biome at least until 2011. Population Ecology and Community Ecology were the most studied subjects (N=79, 70%), followed by faunal surveys (N=28, 24.7%), and methodological tests (N=6, 5.3%). Only 15 studies (13.2%) used canopy traps to capture arboreal species: eleven in the Atlantic Forest, three in the Amazon and one in the Cerrado. Eighteen studies (15.9%) used traditional traps in addition to other methods, and just one study used traps in the three forest strata combined with pitfalls.

On average, studies lasted 17 ± 16 months of field work, in 8 ± 6 campaigns *per* year, and sampling effort of 10,800 trap-nights (min. 616; max. 57,120). Ecological studies were longer than the faunal surveys (Krusal-Wallis test: N=100, df=1, H=12.51, p=0.0004), employed greater sampling effort (KW: H=7.67; p=0.005), but they were indistinguishable from surveys concerning total captures (KW test: N=95, df=1 H=1.30, p=0.25; Table S3).

Twenty-five food items were used as bait. Peanuts and bananas were the most used items, present in *ca.* 75% of the studies (Figure 2). Four items (oats, bacon, corn, and cod liver oil) were used less frequently (20-25% of studies), and the other 19 were rarely used, in less than 15% of studies. This pattern remained *per* biome: peanuts and bananas alternated in use frequency, but they remained the most used baits in Brazilian biomes (Table S4). The number of items used as bait varied little among biomes (KW test: N=113, df=3, H=4.28, p=0.23, Figure S3), or among ecological or survey studies (N=21 *vs* N=18; Figure S4). Few studies used peanut or banana as single bait (Table S4). Most studies used both items as bait (N=59; 59%). In all biomes, the use of peanuts associated with banana resulted in a slight advantage in the capture success compared to those that used only one of these items, despite the difference of sampling efforts employed. We could only statistically compare this difference in capture success for the Atlantic Forest. Despite the apparent difference, the magnitude of effect of the use of both baits was small, compared

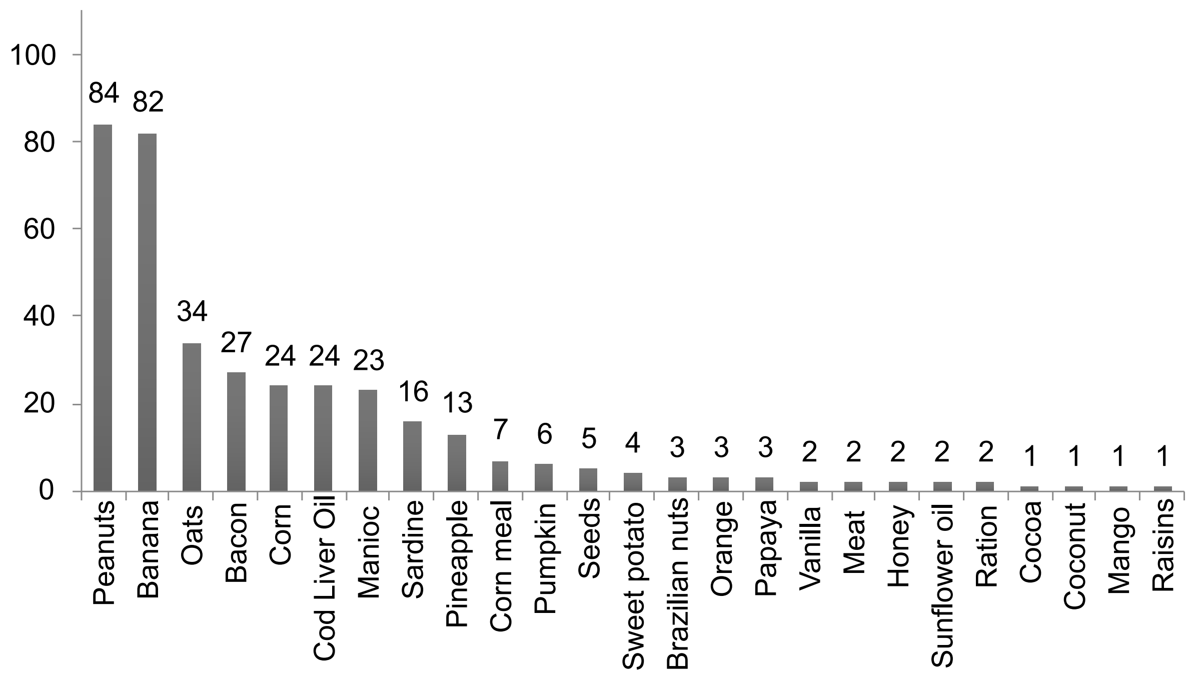

Figure 2. Bait use frequency in ecological studies concerning small mammals in Brazil. Y-axis scale resembles the total number of studies gathered.

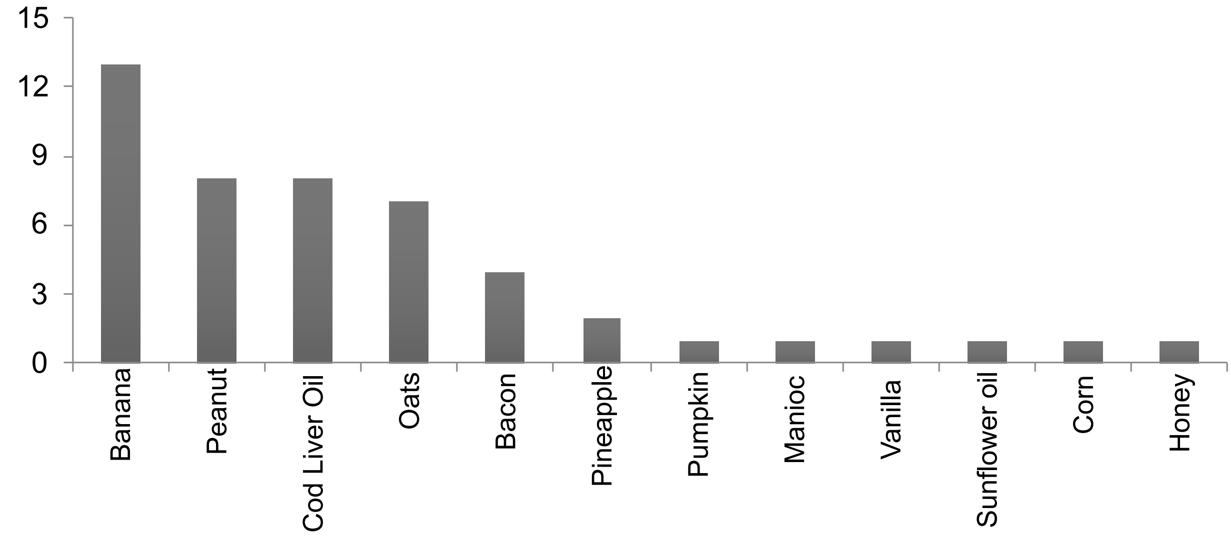

Figure 3. Bait use frequency in studies that used sampling effort to capture small arboreal mammals.

to using each bait solely (KW test: N=61, df=3, H=3.12, p=0.37).

The 15 studies that made specific efforts to capture small arboreal mammals used 12 baits. Of these, ten studies had ecological objectives, mainly population ecology and use of space. Four studies had a faunal survey as the main objective, and one tested new methods. Banana was the most used bait, present in 13 of these studies (87%, Figure 3). Peanuts, cod liver oil, and oats were frequently used, in *ca.* 50% of the studies, like what we found in the whole sample. Only pineapple was reported as an alternative to banana to attract frugivorous animals.

Field Experiment – Bait test

During the bait test, we captured 58 individuals of 10 species of small mammals (six marsupials and four rodents), in 158 events (Table 1). The total sampling effort employed was 2,880 trap*nights, 720 *per* bait tested, and cumulative capture success was *ca.* 5.5%. The number of captures varied little between sampling sections (χ^2=3.37 df=3 p=0.33; Table 2). During 12 PMP field trips, our team crew captured 128 individuals belonging to seven species of small mammals (five marsupials and two rodents) in 251 events (total effort=9,180 trap*nights [60 nights]; accumulated capture success=2.73%; Table S5).

The capture success of the pasta during the bait test was 6.94%, *ca.* 2.5 times greater than obtained during the PMP (Table S5). The number of captures in the understory and in the canopy was very similar during the bait test, but the type of bait had a strong effect on total capture success (χ^2=176.92; df=3; p < 0.01). Overall, the banana bait had the greater number of captures (N=73, 46%), followed by pasta (N=49, 32%), pineapple (N=28, 18%), and meat (N=7, 4%; Table 3). The capture success was 10.1% for banana-baited traps, 6.94% for those that receive pasta, 3.89% for pineapple, and 0.97% for meat. Banana-baited traps were the most successful in capturing individuals from five of the seven arboreal species captured in the whole bait test (Table 4).

We captured 10 species of small mammals in the understory (Table S6), five of these, exclusive to this stratum: *Marmosops incanus* (Lund 1840) was the most abundant (78% of captures) during all experiment, with 17 individuals captured. The same occurred in the PMP: *M. incanus* was the most abundant species in the understory (Table S7). All the five species captured in the canopy were also captured in the understory. *Caluromys philander* (42.5%), *Marmosa paraguayana* (22.5%) and *Rhipidomys itoan* Costa et al. 2011 (17.5%) were the most abundant species in the canopy. *Marmosa paraguayana* and *R. itoan* were equally common in the understory and canopy strata, which also occurred in the PMP.

The type of bait had a stronger effect in the canopy. The capture success of banana-baited traps was *ca.* 2 times greater than in those that received the pasta (χ^2=6.45; df=1; p=0.01; Table 3) in the understory banana and pasta were not distinguishable (χ^2=0.27; df=1; p=0.60). In the canopy, pasta baited traps had a higher capture

Table 1. Small mammal species captured during the field experiment, at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil. Number of individuals and captures also presented per forest strata under parenthesis. US – understory; Can – canopy.

Species	Individuals (forest strata)	Captures (forest strata)	Capture success
Caluromys philander	9 (9 Can; 1 US)	35 (34 Can; 1 US)	1.22%
Didelphis aurita	7 (7 Can; 1 US)	9 (8 Can; 1 US)	0.31%
Eurioryzomys russatus	1 (US)	1 (US)	0.03%
Guerlinguetus brasiliensis	3 (US)	4 (US)	0.14%
Marmosops incanus	17 (US)	35 (US)	1.22%
Metachirus myosurus	1 (US)	3 (US)	0.10%
Marmosa paraguayana	8 (8 Can; 7 US)	38 (18 Can; 20 US)	1.32%
Philander quica	5 (3 Can; 3 US)	9 (6 Can; 3 US)	0.31%
Rhipidomys itoan	6 (5 Can; 5 US)	22 (14 Can; 8 US)	0.76%
Trinomys dimidiatus	2 (US)	2 (US)	0.07%
Total	58 (32 Can; 40 US)	158 (80 Can; 78 US)	5.49%

Table 2. Number of individuals captured (Ind.), total number of captures (Capt.), capture success (CS) and species richness obtained per sampling section during the field experiment, at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil.

Sampling session	Effort	Ind.	Capt.	CS (%)	Richness
1	720 trap*nights	23	36	5.0	7
2		24	34	4.7	8
3		28	49	6.8	9
4		21	39	5.4	5

Table 3. Number of individuals (Ind.) and number of captures (Capt.) per edible bait used during the bait test developed at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil.

Bait	Understory		Canopy		Total	
	Ind.	Capt.	Ind.	Capt.	Ind.	Capt.
Pineapple	13	15	10	13	23	28
Banana	25	32	20	41	45	73
Meat	3	4	2	3	5	7
Pasta	17	28	14	21	31	49

success than banana only for *R. itoan*, but overall pineapple bait captured most of the individuals of this species. An analogous situation occurred for *M. incanus* in the understory, which was more often captured in pasta-baited traps, but overall, most of the individuals were captured by those traps that received bananas.

Regarding life habits, the four arboreal species (*C. philander*, *Guerlinguetus brasiliensis* [Thomas, 1901], *M. paraguayana* and *R. itoan*) were captured in 63% (N=99) of the events. Banana was the most effective bait for these species, capturing both a greater number of individuals in the understory (56%; χ^2=3.85; df=1; p=0.049) and in the canopy (45%; χ^2=112.09; df=1; p <0.01).

Overall, Sherman traps captured more arboreal species than Tomahawk traps in both studies. On the ground, the difference between traps was *ca.* 10 times, and in the canopy two times (χ^2=11.05; df=1; p < 0.01; Table S5). This effect was also stronger considering only banana baited traps, Sherman traps being more efficient (χ^2=11.30; df=1; p < 0.01). However, for pineapple and pasta this effect of trap type was weak (pineapple χ^2=0.077; df=1; p=0.78;

Table 4. Small mammals captured during the bait test, at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil. Ind. - number of individuals captured; Capt. - number of captures; Bait – most successful bait attracting the given species; CS – capture success of the best bait; In parenthesis, CS for all bait test; PI – preference index (ratio between the CS of the best bait by the CS of the species).

Species*	Locomotor habits	Ind.	Capt.	Bait	CS	PI
Caluromys philander	Arboreal	9	35	Banana	3.61% (1.21%)	2.98
Guerlinguetus brasiliensis	Arboreal	4	4	Banana	0.41% (0.13%)	3.15
Marmosa paraguayana	Arboreal	8	38	Banana	2.91% (1.31%)	2.22
Rhipidomys itoan	Arboreal	6	22	Pineapple	1.11% (0.76%)	1.46
Didelphis aurita	Scansorial	7	7	Banana	0.41% (0.24%)	1.70
Marmosops incanus	Scansorial	17	36	Banana	1.80% (1.25%)	1.44
Philander quica	Scansorial	5	9	Pineapple, meat, pasta	0.28% (0.31%)	**

* We did not consider terrestrial species. ** *Philander quica* did not have preference index, since 3 of the 4 baits tested were equally successful in capturing it.

pasta χ^2=0.25; df=1; p=0.61) regarding the three arboreal species captured in the canopy during the bait test (*C. philander, M. paraguayana* and *R. itoan*), Shermans also had a strong effect on the total number of captures than Tomahawks (χ^2=6.06; df=1; p=0.01).

DISCUSSION

Literature review

This is the first study in Brazil to evaluate, quantitatively and qualitatively, food items used as bait in studies concerning the biology of small mammals. We recorded a wide variety of items (N=25), but peanuts and bananas were the most frequent. We suppose it is mainly an attempt to standardize bait use across the country, since it is common sense, among investigators, that a standard bait is necessary to allow comparison between studies, even if sample design vary.

We think that a pilot study and a bait test in each area (or biome) is more important than a unique bait for different areas, increasing capture success and favoring comparisons among studies achieving maximized capture success. If small mammal communities vary between biomes, as a reflect of species historical distribution and human modern land use, bait attraction may also vary between used items. A standard bait for all biomes is not likely to emerge, and well-succeeded baits *per* sample site would favor spatiotemporal comparison between different sites, but with maximized capture success before the beginning of the study. We presume at least two factors may be associated with this: (1) unprepared professionals to perform quality and standard study design, not predicting the need for a pilot study and a bait test before the start of data collection; or (2) lack of editorial space for methodological tests to be published in indexed journals. In both cases the result is equal: none of these studies are reported and data remain unavailable. In fact, the representativeness of the methodological tests in the sample was low (6%), but it is not possible to define how many tests are enough. Three studies reported *per* biome, testing each method or approach, would produce the minimum variation needed to chart the planning of future studies. Such target is clearly feasible considering a universe of more than 2,000 PhDs in Brazil studying mammals, according to the Lattes Platform data from the National Council for Scientific and Technological Development (CNPq). It seems more a problem of planning or reporting.

Although diverse, there is great convergence in most used baits. Peanuts and bananas were the most used, regardless of the biome. Bait use variation is quite small and did not reflect a possible unusual preference of small mammals inhabiting different biomes. We cannot assure there was a standardization of the methods used in the evaluated studies, but there was repetition in the use of food items. Divergent methods, execution problems of field experimental designs and protocols, and subsampling compromise the comparability of the studies, especially for wide range of biodiversity analyses (see Dennis & Ruggiero 1996). Thus, it is unlikely to extract a unifying and efficient protocol to be equally used all over the country as unique fauna and abiotic characteristics may need unique design protocol and methods.

We recorded a great increase of studies on the biology of small mammals performed in Brazil during the last 35 years up to 2011, like other knowledge fields. Although growing, there is still a large shadow on major biomes of the country, such as the Pantanal, Caatinga, and Pampa. These biomes are undersampled mostly because of the historical human demographic voids, and an international focus on the Amazon. Most of these biomes are classified as Conservation Priority Areas in Brazil by the Ministry of the Environment (MMA 2018). The Atlantic Forest is the best-studied Brazilian biome concerning small mammals, which correlates with our larger urban areas, where most of universities, research centers, and financial investments are concentrated, and historically where scientific research was initiated in the country (Filgueiras 1990).

Ecological studies lasted longer and employed much more sampling effort than surveys. However, capture success differed weakly, despite a tendency to favor ecological approaches. One possible reason is the behavior of trap-happiness, more likely to occur in mark-recapture ecological studies (Tanaka 1980). Planning may also be another reason, if medium to long term ecological studies invest more time in experimental design. Ecological studies also represented most of the literature obtained, although it is a study subject directly dependent on a prior survey in the study area.

Another possibility for the smaller number of faunal studies is underreporting. Despite recent efforts in reporting data collection and surveys datasets, we still have reduced editorial space as also known for negative results. Additionally, survey data may have been reported united to subsequent data from monitoring without clearly dividing these distinct study phases. Sampling design inconsistencies in surveys may also respond for part of this underreport we observed, as it is claimed for most of the environmental impact studies performed in Brazil (Silveira *et al.* 2010). Also, in spite of the massive increase of environmental licensing studies performed in Brazil over the last three decades (Carmo & Silva 2013), most of these datasets are considered confidential, voucher specimens are housed by scientific collections but without public reports of these results. Therefore, underreporting and lack of information may indirectly influence the conservation of natural areas.

Field Experiment – Bait test

This is the first field test committed with determining the efficiency of edible baits for the attraction of small arboreal mammals. The banana was the most successful bait, attracting more individuals, and more species, resulting in a greater capture success. Our expectation was confirmed, fruits were more efficient, although pineapple was not efficient for most species. This result confirms, with formal data collection, the diffuse preference of investigators for the use of banana when studying small mammals. We suggest, then, that future studies on small arboreal mammals (understory and canopy traps) use just banana as standard edible bait.

We also demonstrated that efficient baits for terrestrial small mammals may not be as efficient for arboreal species, and it is probably related to their diet habits, morphological, and physiological adaptations. For example, *C. philander* and *M. paraguayana*, both captured during the bait test, have carbohydrates-rich diets related to their digestive tract (Santori *et al.* 2004). Their relatively large-sized cecum is understood as responsible for microbial fermentation processes (Hume 1999), and water absorption of consumed fruits (Astúa *et al.* 2003).

The banana also revealed a high local abundance of *C. philander*, never recorded before with that frequency. It was considered rare in the study area (Macedo *et al.* 2007). In addition, we also succeeded capturing *G. brasiliensis* with this bait, the first captures of this species in almost 15 study years in the area. Although *G. brasiliensis* is commonly recognized as an abundant species in the Atlantic Forest, it is unlikely to be captured with traditional live-traps and baits usually used throughout the country. In fact, none of the 113 studies analyzed in the first part of the manuscript reported capture events of *G. brasiliensis* or closely related species. Changes in the detection of small arboreal mammals due to the use of alternative methods have already been reported in the Amazon (Malcolm 1991, 1995), and similar results can be obtained in other environments and biomes just by changing bait type. The present bait test demonstrates the same change in detection in the Atlantic Forest by a slight change in sampling methods. We used the same procedures and protocols of the Population Monitoring Program developed by the Laboratório de Vertebrados during 20-night sampling, and we obtained more than twice PMP's capture success. One may suggest trap-happy individuals or great shifts in population parameters could be the cause. This is unlikely because the experiment duration was short and overall population oscillation showed the same decreasing pattern shown every year during the spring and summer in the study area (see Loretto & Vieira 2011, Ferreira *et al.* 2016), and other sites (*e.g.* O'Connell 1989, Andreazzi *et al.* 2011).

Capture success of canopy Sherman traps, in both PMP and bait test, was greater than Tomahawks. In the first study dataset, the success was twice as great and, during the bait test, 70% higher. Sherman traps are more successful in capturing the smallest species of small mammals, especially rodents (*e.g.* Charles-Dominique *et al.* 1981, Astúa *et al.* 2006), but until now there was no consensus on the best trap to capture and study small arboreal mammals. As we set both traps in the same platform, with the same bait, when an individual was attracted to eat the bait, both traps had the same position and condition, which means, the same chance of capturing the individual. Sherman traps were better succeeded, and it may reflect a particular preference behavior of small arboreal mammals. These species widely use hole-like cavities as shelter, dens, or nest sites (method details in Loretto 2005, Delciellos *et al.* 2006), and the cavity-like shape of Sherman traps may resemble it, making it the likely choice. These traps also had greater success in capturing small arboreal mammals in other two sites, one in the Atlantic forest (Vieira & Monteiro-Filho 2003) and another in the Amazon (Lambert *et al.* 2005). We, then, recommend that only Sherman traps be used for capturing small arboreal mammals, which seems logistically feasible for studies in all biomes.

Two arboreal species (*M. paraguayana* and *R. itoan*) were equally common in the three sampling strata during PMP, and both were abundant during the bait test in the two strata sampled (understory and canopy). *Caluromys philander* was mostly captured in the canopy, *G. brasiliensis* and *M. incanus* exclusively captured in the understory. We observed a low influence of terrestrial or scansorial species on the capture success of traps set in the understory and canopy, representing less than 1% of the sample. Therefore, we recommend future field studies interested in evaluating small arboreal mammals' biology use only Sherman traps on the understory and canopy strata.

CONCLUSIONS

There has been a wide divergence in the use of traps, sample designs, and edible baits used in small mammal studies in Brazil. It has occurred both within and between biomes. Most of them were insufficiently sampled as our literature survey showed, which has not changed much over the last years, as most recent studies demonstrate (Bovendorp *et al.* 2017). We presented here specific advances in most of these issues and expect they help the design and execution of future field studies. We remark the importance of reporting census results obtained in environmental impact studies over the country, especially on those void study areas, as well as the report of voucher numbers and scientific collections housing these samples. It is time to finally include and consider this massive source of information on biodiversity evaluations by the Brazilian academy. If it is necessary to address regulatory standards to prevent private organizations to hold indefinitely biodiversity datasets arguing confidentiality or some sensitive interest.

For at least 60 years, traps have been considered an important source of bias in sampling results and variation in data (Sealander & James 1958).

However, the greater capture success during the bait test in pasta-baited traps may be considered evidence of no problem in the study method itself, but in its execution. It is difficult to control and standardize the work of a large team in the field, and some empirical problems arise, such as the sensitivity adjustment and positioning of traps, the quantity of baits offered, and the periodicity of the exchange of aged baits, among others (Atkinson 1997). It generates sampling bias and can affect the capture rates *per* device, the overall capture success, and population parameters estimation. Thus, besides the standardization of used baits based on this manuscript, we may also recommend strict attention to method execution protocols.

Yet, it remains to be compared the effectiveness of mixed edible baits against simple baits, such as banana. The former is usually required by Environmental Agencies in Reference Terms of Environmental Impact Studies, but without any scientific support. Mixed edible baits are thought to be more successful than single baits assuming it combines the nutritional and attractive properties of the used items. It is also presumed more species can be attracted and captured doing so. Our results showed the opposite: mixed edible baits are not always more efficient than single baits. In fact, during our test, the mixed bait was never equally well-succeeded.

Finally, we recommend that new studies perform bait tests during pilot campaigns *per* forest strata studied. We need good, accurate estimates of population and community parameters, such as survival of individuals, density *per* species, and species richness, all depending on the largest possible coverage of individuals and species present in the study area. This is what we mean by sampling success, which will not be achieved by using a standardized attractor to different species and habitats. Comparing communities and sites requires sampling success, which is maximized with bait's best choice.

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SUPPLEMENTARY MATERIAL

A

Geographic distribution of the studies evaluated in the literature review (black spots). Colored areas sign the main Brazilian biomes.

B

Number of studies per biome in Brazil, mean ± SE of food items used as baits (Baits), classification according to main subject areas (Ecol – Ecological studies; Surv – Faunal surveys), application of methodological tests (MT); use of complementary sampling methods (CM), and use of traps for arboreal small mammals (Can).

C

Bait use frequency for attraction and capture of small mammals in Brazil. Figures A, B, C and D indicate the situations in each biome.

D

Table VI. Data summary of the small mammal population-monitoring program (PMP) developed at Garrafão locality, Serra dos Órgãos National Park, Rio de Janeiro, Brazil. We also present the data summary of the bait test carried out at the same site. Bait test data are presented combined, and splited, to the pasta results (bait test pasta), bait shared with the PMP. US – understory; Can – canopy; Sample effort – showed in total traps-nights; PMP – 12 campaigns (Feb 2009 to Dec 2010); Restricted PMP – 3 field trips (Apr, Jun, Aug 2010); in parenthesis – number of exclusive species per stratum.

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