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AVALIAÇÃO DO USO DE SUBSTANCIAS ATRATIVAS PARA MAMÍFEROS NEOTROPICAIS

MACAPÁ, AP
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HERBERT DE OLIVEIRA BARBOSA DUARTE

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AVALIAÇÃO DO USO DE SUBSTÂNCIAS ATRATIVAS PARA MAMÍFEROS NEOTROPICAIS

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RESUMO

Duarte, Herbert de Oliveira Barbosa. Avaliação do uso de substâncias atrativas para mamíferos Neotropicais. Macapá, 2018. Dissertação (Mestrado em Biodiversidade Tropical) – Programa de Pós-graduação em Biodiversidade Tropical – Pró-Reitoria de Pesquisa e Pós-graduação – Universidade Federal do Amapá.

Estima-se que aproximadamente 1/3 de todas espécies de mamíferos do planeta, estão na região Neotropical. As atividades praticadas por mamíferos são fundamentais para os seus ambientes, apesar dos mamíferos serem, por vezes, considerados espécies chave para os ecossistemas**,** encontram-se ameaçados em todas as suas áreas de distribuição. Contudo, para se estudar esse grupo, frequentemente existem várias dificuldades, tanto na questão logística dos biomas Neotropicais quanto no comportamento críptico da maioria das espécies de mamíferos. Porém o uso de substancias atrativas para mamíferos têm o potencial de trazer compensação em custo-benefício em trabalhos que estudam esse grupo. Assim pretendemos fornecer, uma base clara para entender as interações entre mamíferos e atrativos, e para maximizar a comparabilidade entre os estudos, aumentando a utilidade potencial em estudos futuros em mamíferos neotropicais. Os nossos resultados mostraram que, a maioria dos estudos foram embasados em conhecimento prévio e/ou cultura cientifica, com isso, não utilizaram nenhum controle e nenhum teste estatístico para avaliar explicitamente a eficiência do atrativo utilizado. A maioria dos estudos focaram ou registraram carnívoros, e essa ordem teve o maior número de substâncias usadas em todos os estudos. Houve apenas consenso no efeito de uso e atração de morcegos frugívoros com frutos, óleos essenciais e compostos florais. Concluímos, considerando diretrizes para maximizar a comparabilidade entre os estudos, assim, tornando-as compensadoras em termos de custo-benefício, para direcionar estudos futuros que pretendam abordar grupos de mamíferos, com o uso de atrativos.

Palavras-chaves: Mamíferos, Subastâncias, Amostragem, Vida Selvagem e Conservação.

ABSTRACT

Duarte, Herbert de Oliveira Barbosa. Assessment of the attractants substances for Neotropical mammals. Macapá, 2018. Dissertation (Master's Degree in Tropical Biodiversity) – Postgraduate Program in Tropical Biodiversity – Pro-Rectory of Research and Post-Graduation – Federal University of Amapá.

It is estimated that approximately 1/3 of all mammals species on the planet are in the Neotropical region. Activities performed by mammals are fundamental to their environments, and although mammals are sometimes considered key species for ecosystems they are threatened in all their distributional ranges. Furthermore, difficulties exist at studies with mammals, through the logistical difficulties of Neotropical biomes and / or the criptic behavior of most species of mammals. However, the use of attractant substances for studies with mammals, have the potential to compensate the cost-benefits in studies with this group. Thus, we aim to provide a clear basis for understanding interactions between mammals and attractants, to maximize comparability between studies and increase the potential utility in future studies with Neotropical mammals. Our results presented that most of the studies were based on previous knowledge and / or scientific culture, and did not use any control nor statistical tests to evaluate explicitly the efficiency of the attractive used. Most of the studies focused or registered carnivores, and this order had the highest number of substances used among all studies. There was only consensus on the effect of using and attracting frugivorous bats with fruits, essential oils and floral compounds. Finally, we considered guidelines to maximize the comparability between studies, in terms of cost-benefits, in order to direct future studies that intend to study groups of mammals, with the use of attractants.

Keywords: Substances, bait, lure, sampling design, wildlife.

SUMÁRIO

INTRODUÇÃO GERAL

Estudo recente estimou-se que existem mais de 1500 espécies de mamíferos no Neotrópico, o que representa aproximadamente 1/3 de todas espécies do planeta (Patterson and Costa 2012). As atividades praticadas por mamíferos em seus ambientes, criam condições que agregam diversidade e qualidade para os ambientes, por isso, são fundamentais para os ecossistemas Neotropicais (Medellin et al. 2000, Wearn et al. 2017, Arevalo-Sandi et al. 2018). Entre as atividades, destacam-se: dispersão e predação de sementes, controle de espécies vegetais invasoras (pastagem), a modificação do solo, o forrageamento e a predação que são fundamentais para a manutenção das áreas nativas (Harrison et al. 2003, Kramer et al. 2003, Silman et al. 2003, Machicote et al. 2004, Fraser et al. 2015, Eldridge et al. 2016).

Apesar dos mamíferos serem, por vezes, considerados espécies chave para os ecossistemas (Wright 1994, Stoner et al. 2007), atividades como; agropecuária, geração de energia, incêndios e caça, estão exercendo pressão negativa sobre esses animais e levando declínios de suas populações (Michalski and Peres 2007, Prist et al. 2012, Lees et al. 2016). Consequentemente, relações intrínsecas entre mamíferos e seus ambientes vem sendo perdidas, e como resultado, diminuição da biodiversidade e perda de funções ecológicas (Lopez and Terborgh 2007, Ripple et al. 2014, Ripple et al. 2015).

Promover a conservação através de avaliação e monitoramento de populações de mamíferos é fundamental para a conservação dos ecossistemas neotropicais (Kier et al. 2009, Ahumada et al. 2011). Contudo, na maioria destas regiões encontra-se ambientes com restrições à acessibilidade, provendo dificuldades logísticas (Laurance 1992, du Preez et al. 2014). Muitas espécies de mamíferos apresentam atividades discretas, muitas populações têm baixas densidades, assim como, frequentemente os indivíduos apresentam grandes áreas de vidas, estes fatores somados as dificuldades logísticas, são os principais limitantes das pesquisas com mamíferos Neotropicais (Michalski 2010, de Oliveira et al. 2018). Outro aspecto, que também pode levar a complicações técnicas, quando se trabalha com mamíferos Neotropicais, é a falta de consistência e padronização nos métodos utilizados (Munari et al. 2011, Ahumada et al. 2013).

A relação de algumas espécies de mamíferos com a disponibilidade de recursos alimentares, é uma importante informação para subsidiar alternativas metodológicas (Kollmann et al. 2016). Diante desse cenário, atrativos se tornam uma alternativa interessante para se pesquisar espécies de mamíferos (Trolle 2003, Norris et al. 2010, Espartosa et al. 2011, Arevalo-Sandi et al. 2018). No entanto, o uso de atrativos pode influenciar alguns resultados, e a adequação de seu uso depende do objetivo do estudo (McCoy et al. 2011, Foster and Harmsen 2012).

Substâncias atrativas têm sido frequentemente utilizadas para maximizar a chance de identificar presença e quantificar a abundância de diferentes espécies (von Helversen et al. 2000, Michalski and Norris 2011, Rocha et al. 2016). Mas também apresentam potencial na redução de conflitos entre humanos e animais silvestres (Rosell and Sanda 2006). Usadas no enriquecimento ambiental, aumentam o bem-estar de animais em cativeiro (Wells and Egli 2004). Elevam a probabilidade de sucesso na reintrodução (Linklater et al. 2006), e na atração de espécies chave, para sistemas de restauração (Bianconi et al. 2012). Diferentes tipos de produtos têm sido usados para compor (em combinação ou não) os atrativos para mamíferos, são muitas vezes comestíveis, ou simulam características dos alimentos, seja de origem vegetal ou animal (Nevo et al. 2015, Rocha et al. 2016). Até mesmo, produtos mais específicos e/ou concentrados como as cadeias aromáticas com a sintetização de componentes químicos, podem trazer melhores benefícios na eficiência da atratividade (von Helversen et al. 2000, Parolin et al. 2015, Arevalo-Sandi et al. 2018).

Algumas substâncias já vêm sendo usadas em trabalhos com mamíferos, portanto já existe algumas relações estabelecidas com determinados grupos. Por exemplo, morcegos frugívoros respondem bem às substancias de origem vegetal, como compostos florais e óleos essenciais (Bianconi et al. 2012, Parolin et al. 2015). Odores de alimentos como, sardinha, ovo cozido, bacon frequentemente exercem atração sobre carnívoros (Rocha et al. 2016), assim como, perfumes comerciais (Chanel 5® e Obsession®) sobre felinos neotropicais (Cove et al. 2014). Outro exemplo é a manipulação de odores de frutos e objetos artificiais em estudos com primatas (Nevo et al. 2015).

Portanto devido à necessidade de uma avaliação sistemática dos métodos que utilizam atrativos para mamíferos, e pela falta de padronização destes métodos, neste trabalho realizamos uma análise, através de uma revisão, sobre o uso de atrativos para mamíferos, na região Neotropical nos últimos 30 anos. Dessa forma, fornecemos diretrizes, para tornar as aplicações de atrativos para mamíferos mais viáveis para a conservação.

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HIPÓTESES

a) Há necessidade de padronização e diretrizes, para o uso de atrativos em estudos com mamíferos na região Neotropical.

b) O uso de substancias atrativas pode trazer grandes benefícios para estudos com mamíferos em ambientes com dificuldades logísticas, como florestas neotropicais ou regiões andinas.

c) Substâncias iguais apresentam resultados diferentes ou opostos entre os grupos de mamíferos.

OBJETIVOS

GERAL

d) Compilar uma revisão abrangente de estudos publicados sobre mamíferos neotropicais que usaram alguma substancia atrativa.

ESPECÍFICOS

e) Avaliar a eficiência do uso de atrativos para mamíferos em estudos nos biomas Neotropicais;

f) Apresentar a distribuição temporal e espacial dos estudos;

g) Relatar de forma detalhada as interações de mamíferos e atrativos;

h) Avaliar aspectos da experimentação dos atrativos nos estudos;

ARTIGO CIENTÍFICO

Assessment of attractants for Neotropical mammals

Artigo publicado no periódico "Tropical Conservation Science"

Assessment of attractants for Neotropical mammals

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Abstract

Mammals play important ecological roles in tropical regions but are difficult to study due to discrete habits, low population densities, and large home ranges. Thus, the use of attractive substances has frequently been adopted to quantify the distribution and abundance of elusive mammals. However, the insight generated from studies using attractants is often limited by a lack of methodological standardization. To inform the use of attractants in the Neotropics, we reviewed 30 years of the scientific literature that used some type of attractant in mammal studies. From a total of 60 studies, the majority (65%) did not use any control (or pseudocontrol) in their sampling design and only 40% used some statistical test to explicitly evaluate the efficiency of the attractant used. A wide range of edible (animal or vegetal origin) and inedible substances (e.g., scent lures) were used alone or in combination and the effects differed greatly among orders and species. Most studies (67%) targeted or registered carnivores, and this order had the largest number of substances (edible and inedible) used across all studies. There seems to be only a consensus in the use and attraction effect with frugivorous bats (Phyllostomidae) with fruits, essential oils, and floral compounds. The lack of standardization of use of attractants in mammal studies undermines the comparability of results among studies. We conclude with some general guidelines to maximize comparability among studies and to enhance the potential usefulness of the use of attractants for mammals

Keywords: Substances, bait, lure, sampling design, wildlife

Introduction

Mammals are frequently considered keystone species for their important ecological roles in tropical regions (Stoner, Riba-Hernandez, Vulinec, & Lambert, 2007; Wright, Gompper, & Deleon, 1994) as well as their association with the degree of habitat disturbance (Arevalo-Sandi, Bobrowiec, Chuma, & Norris, 2018; Medellin, Equihua, & Amin, 2000; Wearn et al., 2017). However, mammals are experiencing declines in their geographic ranges worldwide due to increasing of human population densities, agriculture, grazing and hunting (Ceballos & Ehrlich, 2002; Ripple et al., 2014; Wright, 2005). These population declines and local extinctions are likely to promote cascading effects and the loss of irreplaceable ecological functions (Lopez & Terborgh, 2007; Ripple et al., 2014, 2015).

Despite the importance of monitoring and evaluating the distribution and abundance of mammals in ecosystems, there remains a lack of consistency and standardization in the methods used in studies in tropical regions (Ahumada, Hurtado, & Lizcano, 2013; Munari, Keller, & Venticinque, 2011). This is particularly the case of mammal species that may have low densities, large home ranges, are discrete and elusive, coupled with the logistical difficulties encountered in most tropical regions, often limiting the approach of studies that can be used (de Oliveira et al., 2018; du Preez, Loveridge, & Macdonald, 2014; Laurance, 1992; Michalski, 2010).

Regardless of the focal species or the method chosen and given all the difficulty related with the chance of registering mammals in tropical forests, attractive substances have been widely used to maximize the chance of identifying presence and quantify abundance of different species (Espartosa, Pinotti, & Pardini, 2011; Lomolino & Perault, 2000; Michalski & Norris, 2011; Norris, Michalski, & Peres, 2010; Schlexer, 2008; Trolle, 2003). However, the use of attractants may bias some results, such as the case of studies that evaluate habitat use, occupancy, and density (Foster & Harmsen, 2012; McCoy, Ditchkoff, & Steury, 2011), and the appropriateness of their use will depend on the main objective of the study.

Attractive substances can also have the potential to be used to reduce human-wildlife conflicts, increase the welfare of captive animals, increase the success in release programmes, and increase the success of attracting key species to restore degraded habitats (Bianconi, Suckow, Cruz-Neto, & Mikich, 2012; Linklater et al., 2006; Rosell & Sanda, 2006; Wells & Egli, 2004). However, studies that used attractants frequently aimed to maximize their samplings and rarely tested its effects on attracting or repelling specific species (Braczkowski et al., 2016; Carter, Ratcliffe, & Galef, 2010). Thus, there is a notable difference in the proportion of publications that evaluated the influence of attractants among the different groups of mammals (Campbell & Long, 2008), with fewer articles addressing specifically the relevance of olfactory stimulus and even less studies incorporating experimental manipulation to test conservation theories for mammals (Campbell-Palmer & Rosell, 2011).

Finally, several substances have been systematically used as attractant in mammal studies, ranging from products used as bait (from vegetal or animal origin) to scent lures and chemical components (Michalski & Norris, 2011; Rocha, Ramalho, & Magnusson, 2016; von Helversen, Winkler, & Bestmann, 2000). The use of some substances is already well established for some mammal groups. For example, frugivorous bats are usually attracted by substances from vegetable origin such as floral compounds and essential oils (Bianconi et al., 2012; Parolin, Mikich, & Bianconi, 2015; von Helversen et al., 2000). However, the majority of substances used for specific groups and/or species lack replications, specific tests, are restricted to a limited number of species, and do not make use of controls (Acosta-Jamett & Simonetti, 2004; Lucherini et al., 2009; Portella, Bilski, Passos, & Pie, 2013; Trolle, 2003).

Here, we assess the wide variation in the use of attractants for mammal studies in the Neotropical region. To evaluate the relationship between attractive substances, study group (order and species), and the quality of the information reported, we compiled a comprehensive review of published studies on volant and nonvolant Neotropical mammals that used some attractive substance. We aim to provide a clear basis to understand the interactions between mammals and attractive substances and to maximize the comparability among studies, enhancing the potential usefulness in future studies on Neotropical mammals.

Methods

Compilation of studies

We reviewed the available scientific literature reporting the use of attractants with Neotropical mammals (including volant and nonvolant species). Systematic literature searches covering the last three decades (from 1987 to 2017) were performed between December 2017 and April 2018 in the ISI Web of Science, Scopus, and Google Scholar using a combination of the following terms: “scent*” or “olfact*” or “attract*” or “lure*” or “odor*,” “mammal*” or “carnivor*” or “primat*” or “herbivore*” or “ungulat*” or “bat” or “xenarthra,” “neotropic*” or “Mexico” or “Guatemala” or “Honduras” or “Panama´ ” or “Caribe” or “Nicaragua” or “El Salvador” or “Costa Rica” or “Venezuela” or “Colombia” or “Equador” or “Guiana” or “Suriname” or “Brazil” or “Peru” or “Bolivia” or “Chile” or “Argentina” or “Paraguai” or “Uruguai.” These combinations summed 150 times at each base totalizing 300 combinations. Searches using equivalent terms in Spanish and Portuguese were also used.

We examined and filtered all results returned by the Web of Science and Scopus searches to retain only those studies that used attractants with mammals in the Neotropical region. A similar procedure was used in the results returned from Google Scholar but considering only the first 50 records. The number of studies excluded and retained after our searches were recorded for each of the screening stages according to the Preferred Reported

Items for Systematic Reviews and Meta-Analyses statement (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009; Figure 1).

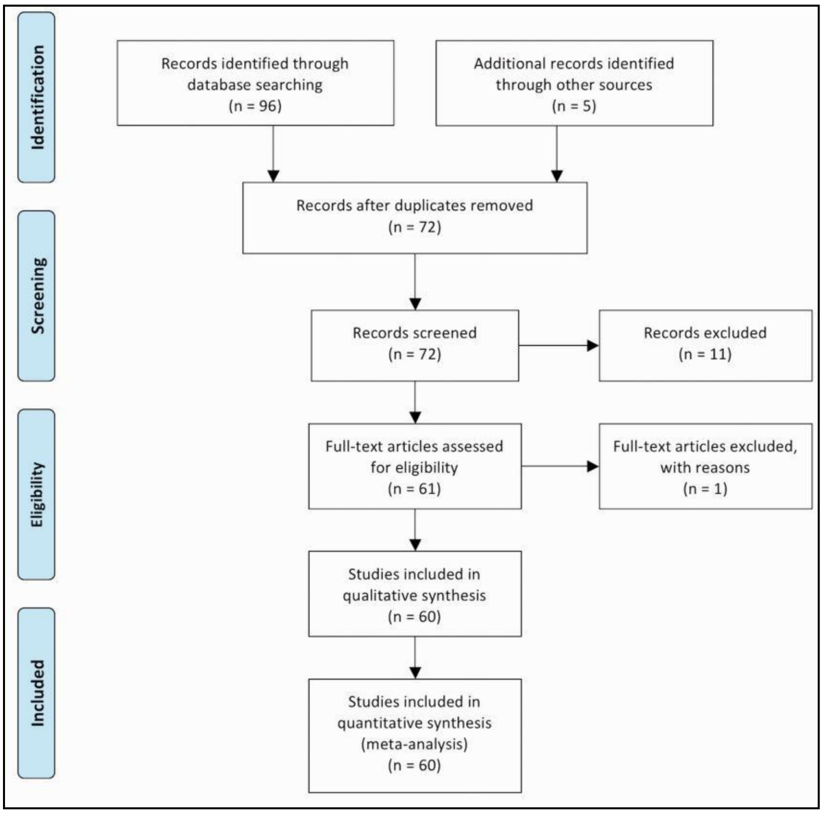

Figure 1. Flowchart using the Preferred Reported Items for Systematic Reviews and Meta-Analyses statement.

We extracted the following data from the selected studies: (a) date of the publication, (b) country where the study was performed, (c) geographical coordinates of the study, (d) presence of maps of the study area, (e) if the study was related to captive or free ranging individuals, (f) the group and the species studied, (g) the substance used, (h) the efficiency of the substance used (attraction, no effect, repellent, or not evaluated), (i) if statistical tests were used in order to evaluate the efficiency of the substance, and (j) if controls (without use of attractants) were used to compare results in the same study.

When a study failed to provide a geographic coordinate of the study area, we used Google Earth (GE) to obtain an approximate coordinate supported by maps of the study area and key landmarks such as rivers, towns, and other visual features that could be clearly distinguished by GE images. When studies did not provide a map of the study area but mentioned the name of the city or name of the protected area where the study was performed, we obtained an approximate coordinate from GE images. For studies with more than one coordinate (study area), we calculated the mean positions between the study sites (Laufer, Michalski, & Peres, 2013). When studies reported more than one site or the distance among them was more than 50 km, we plotted more than one point for the same study. The mean distances among studies ranged from 2 to 1,399 km (mean¼174.75 km). We used the ArcGIS 10.1 (ESRI, 2011) in order to produce the final distribution map of the studies conducted in the Neotropical region.

We obtained the biome type where each study was conducted by overlapping the study coordinates on a map of the Earth's terrestrial ecoregions and biomes (Dinerstein et al., 2017) using ArcGIS 10.1 (ESRI, 2011). Studies where the sampling was partially or entirely conducted outside the Neotropical zone (in captivity or in the field) were excluded from the map and further analyses.

Data analysis

We used the R language with environment for statistical computing (R Development Core Team, 2018) to generate figures and analysis presented in this study. We also used the package Igraph (Csardi & Nepusz, 2006) in R (R Development Core Team, 2018) to graphically display the interactions among single or mixed, edible or inedible substances and families of mammals that were attracted by substances.

Results

Geographic and temporal distribution of studies

Our searches returned a total of 96 scientific articles, including 17 from the Web of Science, 19 from Scopus databases, 60 from Google Scholar, and an additional 5 studies from our previous knowledge. From this total, 24 studies were duplicated and 11 were excluded, as they belonged to different regions (e.g., Indo-Malay) or to aquatic species. In addition, one study was excluded due to methodological incongruences. Thus, 60 studies were retained for subsequent analysis (Figure 1).

Most of the studies (92%) were published since 2000, with the years 2007 and 2012 being the ones with most studies, 7 (12%) and 6 (10%), respectively (Figure 2). We obtained studies from Mexico to Argentina, from the Pacific to the Atlantic coast, from 13 countries, and from 10 biomes within the Neotropical region (Figures 3 and 4). The majority of the study sites were in Brazil (27 articles and 33 study sites), followed by Chile (6 articles and 11 study sites) and Bolivia (3 articles and 8 study sites) (Figure 3). The biome most represented by the studies was the tropical and subtropical moist broadleaf forests, with 47 study sites (57%; Figure 4). Only 4 of the 60 studies were conducted in captivity, and from this total, 2 of them were performed with the temporary enclosure of wild animals.

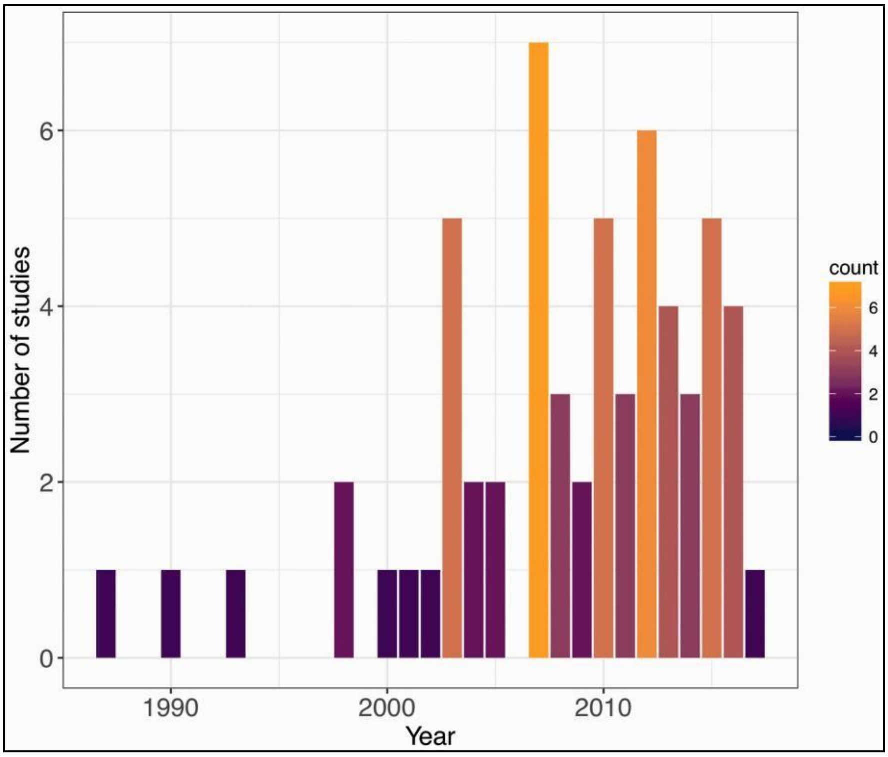

Figure 2. Annual number of studies that used attractant substances for mammals in the Neotropical region from 1987 to 2017. The color gradient is proportional to the number of studies in each year.

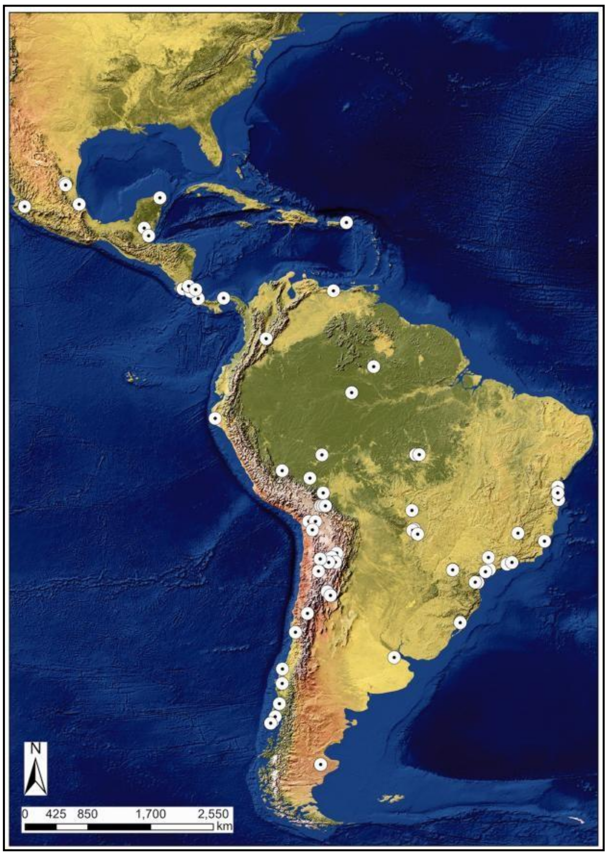

Figure 3. Spatial distribution of studies on mammals using attractant substances in the Neotropical region

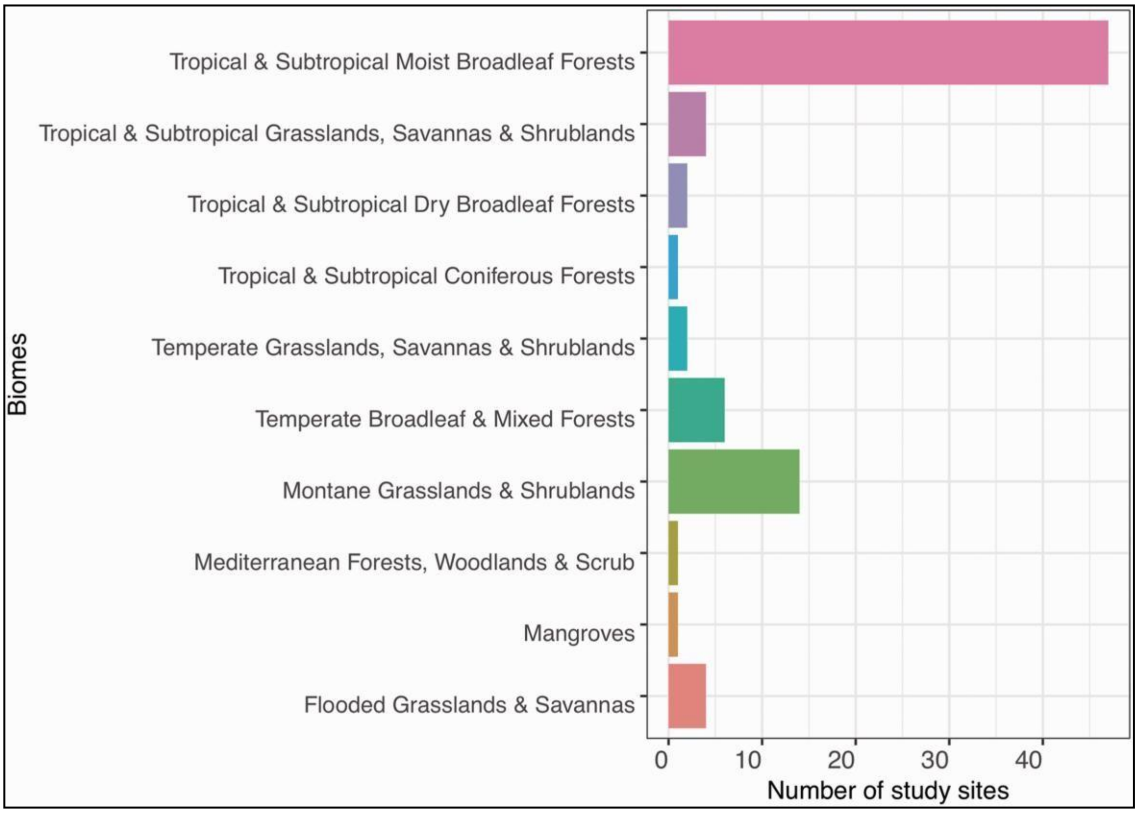

Figure 4. Number of study sites per Neotropical biome. Frequency distribution of 10 biomes from studies published from 1987 to 2017 (n = 60 articles) in the Neotropical region.

Quality of the information reported

The information on the study area reported by authors varied greatly as well as the quality of the maps presented in the studies (Online Appendix 1). From all the studies we reviewed, 47 (78%) provided geographic coordinates of the study area, 23 (38%) provided a map of the study area, and only 18 (30%) provided both a geographic coordinate and a map of the study area. In addition, the use of a control (or pseudocontrol) involving experiments without attractants or sampling period in the same study area without the use of any attractant was conducted by only 21 (35%) studies and from these, 10 studies were performed with the order Chiroptera. Thus, the majority of the studies reviewed (39 studies or 65%) did not use any control (or pseudocontrol) in their sampling design. Similarly, only 24 (40%) studies used some statistical test to explicitly evaluate the efficiency of the attractant used, and from these total, 10 studies were conducted specifically with the order Chiroptera.

Type of substances used and interactions with mammals

A wide range of substances were used in the studies and some studies used more than one type either in isolation A wide range of substances were used in the studies and some studies used more than one type either in isolation or in combination (mixed; Table 1). Overall, the 60 studies provided information about attractants and interactions (attraction, no attraction, and repellence) for 9 orders, 26 families, and 76 genus or species of mammals. More than half of the studies (30% or 50%) did not evaluate the efficiency or response of the substances used and the mammal records.

Order	Edible	Inedible
Carnivora	Cooked meat	Ammonia and urea
	Egg	Animal excreta
	Fish	Animal urine
	Fruit	Carbachol
	Live bait	Commercial cologne
	Raw fish	Compact disk
	Raw meat	Fatty acid scent
	Salt	Flower extract
	Scott emulsion	Fruit extract
	Seeds	Herb extract
	Tomato sauce	Scent lure
	Vegetable	
Cetartiodactyla	Cooked meat	Ammonia and urea
	Egg	Animal urine
	Fish	Commercial cologne
	Fruit	Herb extract
	Live bait	Scent lure
	Raw meat	
	Salt	
	Scott emulsion	
	Seeds	
	Vegetable	
Chiroptera	Blood	Extract of ripe fruits
	Ripe fruits	Feaces
	Unripe fruits	Floral compound
		Fruit essential oil
		Hair
		Raw meat
Cingulata	Cooked meat	Ammonia and urea
	Egg	Animal urine
	Fish	Commercial cologne
	Fruit	Herb extract
	Raw meat	Scent lure
	Salt	
	Scott emulsion	
	Seeds	
	Vegetable	
Didelphimorphia	Cooked meat	Ammonia and urea
	Egg	Commercial cologne
	Fish	Herb extract
	Fruit	Scent lure
	Salt	
	Scott emulsion	
	Seeds	
	Sugar	
	Vegetable	
Lagomorpha	Fish	Ammonia and urea
	Fruit	Commercial cologne
	Salt	Herb extract
	Vegetable	Scent lure
Perissodactyla	Cooked meat	Animal urine
	Fruit	Scent lure
	Raw meat	
	Salt	
	Seeds	
	Vegetable	
Pilosa	Cooked meat	Ammonia and urea
	Egg	Commercial cologne
	Fish	Scent lure
	Fruit	
	Salt	
	Vegetable	
Primates	Ripe fruit	Flower extract
	Unripe fruit	Herb extract
		Plastic banana
Rodentia	Cooked meat	Ammonia and urea
	Egg	Animal urine
	Fish	Commercial cologne
	Fruit	Flower extract
	Raw meat	Fruit extract
	Salt	Scent lure
	Scott emulsion	
	Seeds	
	Sugar	
	Vegetable	

Table 1. List of Edible and Nonedible Substances Used for Each Order of Mammals in Neotropical Studies from 1987 to 2017.

A total of 32 (53%) studies used edible substances (animal or vegetal origin) alone or a combination of edible and inedible substances (e.g., scent lures) (Figure 5). From this total, 17 studies showed results of attraction for species from the order Carnivora, Cetartiodactyla, Chiroptera, Cingulata, Didelphimorphia, Lagomorpha, Primates, and Rodentia. When only inedible substances were used (40 studies), the attraction was confirmed in more than half (n= 23) of the studies for species from the order Carnivora, Cetartiodactyla, Chiroptera, Cingulata, Didelphimorphia, Pilosa, Primates, and Rodentia. Repulsion was experimentally tested and confirmed only in one study and specifically for *Herpestes auropunctatus* (Carnivora and Herpestidae).

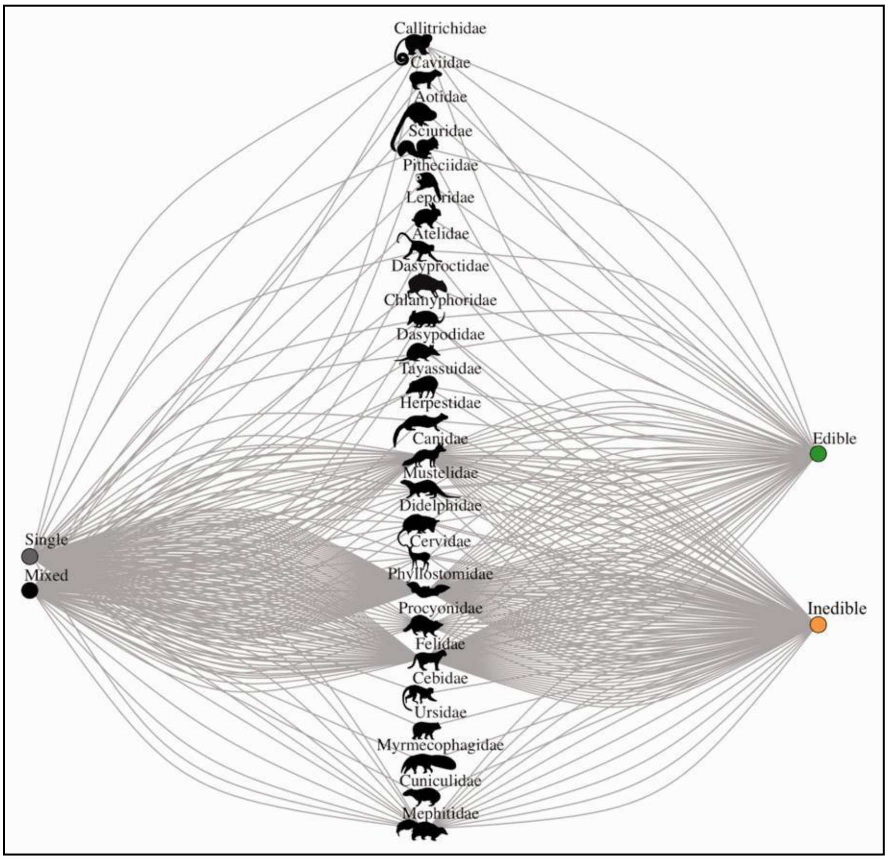

Figure 5. Interactions among mixed, single, edible, inedible substances, and mammal families that were attracted by substances according to the studies reviewed.

Overall, 40 (67%) studies target or registered species of carnivores, turning this group the one with the largest number of edible and inedible substances used across all studies (Table 1). Frugivorous bats (Chiroptera: Phyllostomidae) was the only group that had a consistency of substances used across all studies reviewed. For this group, the use of fruits of Ficus spp. and Piper spp. as well as essential oil of Piper spp. and floral compounds was a consensus, with all studies presenting the success of attraction of frugivorous bats (Online Appendix 2).

Discussion

Our review across the Neotropical region showed that (a) in the past three decades, several studies targeting several groups of mammals (but largely carnivores) used a wide variety of edible and inedible substances to maximize the possibility of detection, (b) the majority of studies (apart from those with Chiroptera) did not use a control (or pseudocontrol) to test the efficiency of the substances used as attractants, and (c) the responses of mammals to different attractants are highly variable (except for the order Chiroptera) and there is no general consensus on which substance is best used for use with a particular group or species. The use of potentially attractant or repellent substances emerged during the 70s and 80s, when pioneering studies assessed the interaction of mammals with different substances (Jorgenson et al., 1978; Whitten et al., 1980). After these pioneer studies, it became common to use substances as a way to improve methodological and logistical efficiency when dealing with the low densities, large home ranges usually found in Neotropical mammals (Laurance, 1992; Patric, 1970; Willan, 1986).

Attractants are still frequently used to increase the chance of capturing or registering mammals in tropical forests (Espartosa et al., 2011; Michalski, 2010; Norris et al., 2010; Rocha et al., 2016; Trolle, 2003). However, to date, there is no consensus on which substance can be used for which group or species and what is the general interaction or reaction of the target group or species. We first turn to discuss the temporal and geographical distribution of studies using attractants for mammals in the Neotropics and then explore the different use of substances and how they interact with group or species of different mammals.

Geographic and temporal distribution of studies

The use of attractants in mammal research is relatively recent for the Neotropical region with more than 90% of the studies in our review published since 2000, with only one study published prior to 1990, and knowledge about specific interactions among substances and mammals is still emerging. In fact, the majority of studies pioneering the use of attractants for surveying and monitoring mammals were conducted in North America, Australia, and Africa (Jorgenson et al., 1978; Nicolaus & Nellis, 1987; Willan, 1986).

Most of the study sites of our review were in Brazil, which is likely to be a reflection of the extensive territory of this country within the Neotropical region. Brazil, has large extensions of Tropical & Subtropical Moist Broadleaf Forests (Dinerstein et al., 2017), biomes with the highest number of study sites in our review. This biome stands out in terms of number of studies because it is frequently common to use substances to attract mammals to maximize the sampling efficiency in these areas due to logistic difficulties encountered in this type of environment (Pacheco, Guerra, & Rıos-Uzeda, 2003; Rocha et al., 2016).

Quality of the information reported

The use of attractants can be a good alternative to maximize sampling of hard to detect mammals in the field (du Preez et al., 2014). The use of attractants can also be used to estimate the size, spatial distribution, and density of target populations, to reduce conflicts between humans and wildlife, and to increase the success of restoration projects by adding key dispersal species (Bianconi et al., 2012; Gehrt & Prange, 2007; Long, MacKay, Ray, & Zielinski, 2012).

However, the use of these substances may introduce a systematic bias that depending on the question being addressed may require careful consideration or controls. The adoption of adequate sampling designs is vital for any survey, and for the studies using attractants, a lack of controls (65%) and/or statistical tests (40%) limits the insight possible. Although the primary objective was not always to evaluate the efficiency of attractants (for 63% of the manuscripts), our results clearly show that much of the knowledge about interactions of mammal species and attractants in the Neotropical region is still not properly tested, and much more evidence is necessary to achieve reliable results.

In our review, only few studies of mammals had experiments conducted in captivity or in field cages. Studies with attractive substances for carnivores in captivity often target animal welfare through environmental enrichment (Wells & Egli, 2004), but other studies (Nicolaus & Nellis, 1987; Portella et al., 2013), evaluated interactions between species and substances in order to develop and evaluate noninvasive sampling methods (Portella et al., 2013) or to limit the impacts of pest species in the field (Nicolaus & Nellis, 1987). The relative ease of handling certain groups (e.g., bats) facilitates the development of experiments to test interactions with a variety of attractive substances. For example, Parolin et al. (2015), evaluated the visual, olfactory and spatial interactions between frugivorous bats and substances of vegetable origin, demonstrating the use of innovative approaches beyond the evaluations of echolocation and spatial search, often carried out with captive animals (Schnitzler & Kalko, 2001).

Attraction with edible substances can be very efficient due to the energetic reward (Gerber, Karpanty, & Kelly, 2012), but this can also condition some “trap-happy” individuals, that can generate a heavily biased sample (Rocha et al., 2016). While most edible substances in our reviewed studies were used only to maximize sampling efficiency, most of the inedible substances were used with the aim of testing the effect of substance and mammal interactions. Overall, the efficiency of edible or inedible substances at attracting mammals is difficult to interpret, as several studies used a mix of substances and several combined edible and inedible substances together while lacking controls to separate the effects.

Type of substances used and interactions with mammals

Frugivorous bats are fundamental for the maintenance of biodiversity and environmental services, such as seed dispersal in Neotropical ecosystems (Bianconi et al., 2012). Based on a detailed knowledge of bat fruit interactions, substances from vegetable origin (fruits, essential oils, and floral compounds) have become a useful attractant for frugivorous bats, increasing the potential for restoration projects (Bianconi et al., 2012; Parolin et al., 2015). Our results corroborated these assumptions as all studies with frugivorous bats showed attraction for at least one substance of vegetable origin used. Previous studies with hematophagous bats showed that the heat of their prey is a strong attractant orient (Fenton, 1997). Experiments with the only hematophagous bat (*Desmodus rotundus*) studied in our review showed that the odor of blood with other organic substances also exerts attraction (Bahlman & Kelt, 2007).

Overall, studies with Neotropical primates were the least representative compared with the other groups studied, even considering that these animals have great potential for maximizing forest restoration. Except for the study by Nevo et al. (2015) which showed significant attraction of *Ateles geoffroyi* with ripe fruits of *Couma macrocarpa* and of *Leonia cymosa*, other not surprising result was the positive interaction between primates and fruits (i.e., bananas), which highlights the lack of well-defined alternative approaches to attract primate species. For example, our review did not uncover studies adopting experimental approaches to manipulate substances to understand their influence on the activity and ranging of Neotropical primates. In addition, there were no experiments to understand mark-scent behavior, which is an important aspect that influences primate populations (Gosling & Roberts, 2001).

A wide variety of inedible scent lures were used among the studies targeting or registering carnivores. A number of commercial substances such as Cat Passion have been developed and used to maximize sampling efficiency and attract target carnivores (McDaniel, McKelvey, Squires, & Ruggiero, 2000). Attractive effects of scent lures were corroborated by the high success rate when attracting carnivores in the studies evaluated, which were also statistically tested and controlled. In contrast, potential prey such as species from the orders Cetardiotactyla and Rodentia notably avoided this substance, confirming premise about negative effects on potential prey species (Rocha et al., 2016). The use of other commercial lures, such as Canine Call and Wild Cat, did not present significant attraction of carnivore species but instead attracted prey species such as *Pecari tajacu* and *Cuniculus paca*. Thus, the use and efficacy of commercial and noncommercial attractants remains a matter for experimental tests in future studies.

The use of edible attractants, such as sardine with eggs, can be an interesting alternative for studies with carnivores, but it is known that such a strong smelling bait can also negatively affect the capture rate of some prey species (Rocha et al., 2016). Other omnivorous species such as *Pecari tajacu* and *Didelphis marsupialis* were also attracted to the edible sardine with egg bait. Thus, this type of attractant is not limited to carnivores. As expected, herbivorous mammals and those with a more specialized diet, such as *Tapirus terrestris* (Henry, Feer, & Sabatier, 2000; Tobler, Janovec, & Cornejo, 2010), avoided sardine with egg, confirming the potential bias effect of some attractants for some species (Rocha et al., 2016).

Implications for conservation

The use of attractant substances can bring great benefits for studies with mammals in environments with logistic difficulties, such as Neotropical forests or Andean regions. Despite the significant positive interaction between attractive substances and some important mammal seed dispersers (e.g., frugivorous bats and substances of vegetable origin such as fruits, essential oils and floral compounds), there is no consensus on the use of substances, potential interactions, and target groups or species. The use of attractants for mammals in the Neotropics is still emerging and there is no established standardization of techniques, with most of the studies using substances from previous knowledge based on scientific culture rather than robust experimentation. This is even more evident when we review the number of articles that used controls or statistical tests to access the efficiency and interaction between the attractant and the target group or species. Our review provides a systematic assessment that enhances the potential of future studies to use attractive substances to elucidate the distribution, abundance, and activity of Neotropical mammals. Finally, our study indicates important interactions between mammals and several substances but also highlights groups that still require reliable experimentations in the field. We consider the use of controls and field experiments critical for future studies to evaluate the use of attractants for mammals. The replication and comparability of studies with mammals in the Neotropics and other regions depend on the standardization of methods used, turning the applications for the mammal conservation and their ecosystems more feasible.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Conclusões

Em nossa revisão, apresentamos que o uso de substâncias atrativas pode trazer grandes benefícios para estudos com mamíferos em ambientes com dificuldades logísticas. Apesar da interação positiva e significativa entre substâncias atrativas e alguns grupos de mamíferos, não há consenso sobre o uso de atrativos e potenciais interações entre espécies e atrativos. Consideramos que o uso de atrativos para mamíferos no Neotrópico ainda está emergindo e não há padronização estabelecida de abordagens, isso fica evidente pelo baixo número de experimentos que usaram controles ou testes estatísticos para avaliar a eficiência e a interação entre o atrativo e o grupo-alvo ou espécie.

Aqui fornecemos uma avaliação sistemática, para subsidiar estudos futuros com uso de substâncias atrativas para mamíferos neotropicais. Assim, indicamos importantes interações entre mamíferos e várias substâncias, mas também destacamos grupos que necessitam da realização de experimentos com a utilização de análises estatísticas e/ou controle para os experimentos campo. Consideramos o uso de controles e experimentos de campo críticos para estudos futuros para avaliar o uso de atrativos para mamíferos. Por fim sugerimos que a replicação e comparabilidade de estudos com mamíferos no Neotrópico e outras regiões vai depender da padronização dos métodos utilizados, para assim, tornar as aplicações para a conservação de mamíferos e seus ecossistemas mais viáveis.

Assessment of attractants for Neotropical mammals

Herbert de Oliveira Barbosa Duarte, Darren Norris and Fernanda Michalski

Appendix 1. List of reviewed studies using attractants for mammals in the Neotropical region.

Source	**Country**	**Aimed to test attractant**	**Coordinate provided**	**Map provided**	**Control used**	**Stats used**	**Biome**	**Latitude**	**Longitude**
Nicolaus and Nellis (1987)	United States - Virgin Islands	Yes	No	No	No	Yes	Tropical & Subtropical Moist Broadleaf Forests	18.3591	-64.8971
Jiménez, Marquet, Medel, and Jaksic (1990)	Chile	No	Yes	No	No	No	Temperate Broadleaf & Mixed Forests	-37.7500	-72.7333
Jiménez et al. (1990)	Chile	No	Yes	No	No	No	Temperate Broadleaf & Mixed Forests	-42.4000	-73.9000
Martinez, Rau, and Jaksic (1993)	Chile	No	Yes	No	No	Yes	Mediterranean Forests, Woodlands & Scrub	-31.5000	-71.1000
Thies, Kalko, and Schnitzler (1998)	Panama	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	9.1500	-79.8500
Kalko and Condon (1998)	Venezuela	Yes	Yes	No	Yes	No	Tropical & Subtropical Moist Broadleaf Forests	10.0500	-66.4667
von Helversen, Winkler, and Bestmann (2000)	Costa Rica	Yes	No	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	10.4213	-84.0214
Travaini, Peck, and Zapata (2001)	Argentina	Yes	Yes	No	Yes	Yes	Temperate Grasslands, Savannas & Shrublands	-47.6345	-68.0374
Boddicker, Rodriguez, and Amanzo (2002)	Peru	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-11.8397	-72.7138

Source	Country	Aimed to test attractant	Coordinate provided	Map provided	Control used	Stats used	Biome	Latitude	Longitude
Naughton-Treves, Mena, Treves,	Peru	No	No	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-12.7691	-69.3292
Alvarez, and Radeloff (2003)									
Mikich, Bianconi, Maia, and Teixeira (2003)	Brazil	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-23.9167	-51.9500
Pacheco, Guerra, and Ríos-Uzeda (2003)	Bolivia	Yes	Yes	No	Yes	Yes	Montane Grasslands & Shrublands	-16.1500	-68.0250
Pacheco et al. (2003)	Bolivia	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-16.1450	-67.7500
Pacheco et al. (2003)	Bolivia	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-16.1400	-67.4500
Trolle (2003)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	0.8063	-61.5630
Acosta-Jamett and Simonetti (2004)	Chile	No	Yes	Yes	No	No	Temperate Broadleaf & Mixed Forests	-35.9833	-72.6833
Bicca-Marques and Garber (2004)	Brazil	Yes	No	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-9.9358	-67.8680
Fasola, Bello, and Guichón (2005)	Argentina	No	Yes	No	No	No	Temperate Grasslands, Savannas & Shrublands	-34.5833	-59.0667
Korine and Kalko (2005)	Panama	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	9.1500	-79.8500

Source	Country	Aimed to test attractant	Coordinate provided	Map provided	Control used	Stats used	Biome	Latitude	Longitude
Bianconi, Mikich, Teixeira, and Maia (2007)	Brazil	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-23.9167	-51.9500
Michalski andPeres (2007)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-9.8833	-56.4667
Bahlman and Kelt (2007)	Costa Rica	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	10.2831	-84.8167
Faller-Menéndez et al. (2007)	Mexico	No	Yes	No	No	No	Tropical & Subtropical Dry Broadleaf Forests	21.3610	-87.6164
Trolle, Bissaro, and Prado (2007)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Grasslands, Savannas & Shrublands	-19.4666	-44.0169
Trolle, Noss, Lima, and Dalponte (2007)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Grasslands, Savannas & Shrublands	-19.4666	-44.0169
Trolle, Noss, et al. (2007)	Brazil	No	Yes	No	No	No	Flooded Grasslands & Savannas	-16.6850	-56.9180
Castro-Arellano, Madrid-Luna, Lacher Jr, and León-Paniagua (2008)	Mexico	Yes	Yes	No	No	Yes	Tropical & Subtropical Moist Broadleaf Forests	23.1480	-99.1920
Sánchez-Lalinde and Pérez-Torres (2008)	Colombia	No	No	Yes	No	No	Tropical & Subtropical Dry Broadleaf Forests	4.2233	-74.6776
Lucherini et al. (2009)	Bolivia	No	No	Yes	No	No	Montane Grasslands & Shrublands	-18.0333	-69.5000

Source	Country	Aimed to test attractant	Coordinate provided	Map provided	Control used	Stats used	Biome	Latitude	Longitude
Lucherini et al. (2009)	Bolivia	No	No	Yes	No	No	Montane Grasslands & Shrublands	-18.0333	-68.6660
Lucherini et al. (2009)	Chile	No	No	Yes	No	No	Montane Grasslands & Shrublands	-19.0533	-69.0500
Lucherini et al. (2009)	Bolivia	No	No	Yes	No	No	Montane Grasslands & Shrublands	-21.8812	-66.0990
Lucherini et al. (2009)	Bolivia	No	No	Yes	No	No	Montane Grasslands & Shrublands	-22.4279	-66.9806
Lucherini et al. (2009)	Argentina	No	No	Yes	No	No	Montane Grasslands & Shrublands	-22.4144	-66.6919
Lucherini et al. (2009)	Argentina	No	No	Yes	No	No	Montane Grasslands & Shrublands	-23.0000	-66.2306
Lucherini et al. (2009)	Chile	No	No	Yes	No	No	Montane Grasslands & Shrublands	-23.0333	-67.0500
Lucherini et al. (2009)	Chile	No	No	Yes	No	No	Montane Grasslands & Shrublands	-22.5839	-68.0871
Lucherini et al. (2009)	Chile	No	No	Yes	No	No	Montane Grasslands & Shrublands	-24.0826	-68.2915
Lucherini et al. (2009)	Argentina	No	No	Yes	No	No	Montane Grasslands & Shrublands	-26.5686	-67.2312
Lucherini et al. (2009)	Argentina	No	No	Yes	No	No	Montane Grasslands & Shrublands	-27.0275	-66.8446
Lucherini et al. (2009)	Argentina	No	No	Yes	No	No	Montane Grasslands & Shrublands	-29.2349	-69.6420
Michalski (2010)	Brazil	No	No	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-9.8833	-56.4667

Source	Country	Aimed to test attractant	Coordinate provided	Map provided	Control used	Stats used	Biome	Latitude	Longitude
Norris, Michalski, and Peres (2010)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-9.8833	-56.0333
Silva-Rodríguez, Ortega-Solís, and Jiménez (2010)	Chile	No	Yes	No	No	No	Temperate Broadleaf & Mixed Forests	-40.2333	-73.0666
Torres and Prado (2010)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-23.2208	-45.3372
Nallar (2010)	Bolivia	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-14.5666	-67.7333
Michalski and Norris (2011)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-9.8833	-56.0333
Espartosa, Pinotti, and Pardini (2011)	Brazil	Yes	Yes	Yes	No	Yes	Tropical & Subtropical Moist Broadleaf Forests	-23.8750	-47.4720
Olifiers, Loretto, Rademaker, and Cerqueira (2011)	Brazil	No	Yes	No	No	No	Flooded Grasslands & Savannas	-18.9833	-56.6500
Olifiers et al. (2011)	Brazil	No	Yes	No	No	No	Flooded Grasslands & Savannas	-19.1333	-56.8166
Olifiers et al. (2011)	Brazil	No	Yes	No	No	No	Flooded Grasslands & Savannas	-19.5666	-56.2333
González-Maya et al. (2012)	Costa Rica	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	9.1000	-82.9500
Barcelos, Perônico, and Eutrópio (2012)	Brazil	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-20.4422	-40.7789

Source	Country	Aimed to test attractant	Coordinate provided	Map provided	Control used	Stats used	Biome	Latitude	Longitude
Brocardo, Rodarte, Bueno, Culot, and Galetti (2012)	Brazil	No	Yes	Yes	Yes	No	Tropical & Subtropical Moist Broadleaf Forests	-24.1333	-47.9666
Delciellos et al. (2012)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	-23.0163	-44.7500
Ramírez-Vargas, Artavia-Villar, and Piedra-Castro (2012)	Costa Rica	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	9.9983	-83.8744
Bianconi, Suckow, Cruz-Neto, and Mikich (2012)	Brazil	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-23.9257	-51.9424
Cove, Spínola, Jackson, Sàenz, and Chassot (2013)	Costa Rica	No	No	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	10.6115	-84.1095
Portella, Bilski, Passos, and Pie (2013)	Brazil	Yes	No	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-25.4450	-48.9186
Hodgkison et al. (2013)	Panama	Yes	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	9.1500	-79.8500
Soares, Faneca, Barreto, and Alvarez (2013)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-13.8333	-39.1667
Soares et al. (2013)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-15.2333	-39.1333
Soares et al. (2013)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-15.3833	-39.0833

Soares et al. (2013)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-14.5500	-39.1666
Cove, Spinola, Jackson, and Saenz (2014)	Costa Rica	Yes	No	No	No	Yes	Tropical & Subtropical Moist Broadleaf Forests	10.6115	-84.1095
Ramírez-Martínez, Iñiguez-Dávalos, and Ibarra-López (2014)	Mexico	No	Yes	Yes	No	No	Tropical & Subtropical Coniferous Forests	20.3040	-104.0769
Palomo-Muñoz, García-Anleu, PonceSantizo, and MoreiraRamírez (2014)	Guatemala	No	No	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	17.7017	-89.5334
Parolin, Mikich, and Bianconi (2015)	Brazil	Yes	No	No	No	Yes	Tropical & Subtropical Moist Broadleaf Forests	-25.4354	-49.2184
Rocha, Ramalho, Alvarenga, Gräbin, and Magnusson (2015)	Brazil	No	Yes	Yes	Yes	No	Tropical & Subtropical Moist Broadleaf Forests	-2.3500	-64.2667
Vergara, Valenzuela, Parragué-Migone, and Langenscheidt (2015)	Chile	No	Yes	Yes	No	No	Temperate Broadleaf & Mixed Forests	-41.8050	-73.5660

Source	**Country**	**Aimed to test attractant**	**Coordinate provided**	**Map provided**	**Control used**	**Stats used**	**Biome**	**Latitude**	**Longitude**
Vergara et al. (2015)	Chile	No	Yes	Yes	No	No	Temperate Broadleaf & Mixed Forests	-42.5867	-74.1208
Chávez-Villavicencio, García-Olaechea, and Casas-Mena (2015)	Peru	No	Yes	Yes	No	No	Mangroves	-5.4811	-80.8899

Nevo et al. (2015)	Mexico	Yes	No	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	20.5776	-97.4377
Daniel G.Rocha, Ramalho, and Magnusson (2016)	Brazil	Yes	Yes	Yes	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-2.3500	-64.2667
Arroyo-Arce, Thomson, Fernández, and Salom-Pérez (2016)	Costa Rica	No	Yes	Yes	No	No	Tropical & Subtropical Moist Broadleaf Forests	10.1860	-83.2533
Cabral, Dellagnese, Bordignon, Forneck, and Cademartori (2016)	Brazil	Yes	Yes	Yes	Yes	Yes	Tropical & Subtropical Grasslands, Savannas & Shrublands	-30.2690	-51.0560
Jacomassa (2017)	Brazil	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	-22.4235	-47.6031
Bicca-Marques and Garber (2003)	Brazil	No	Yes	No	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-9.9417	-67.8689
Downey, Hellgren, Caso, Carvajal, and Frangioso (2007)	Mexico	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	22.9250	-99.0972
Faria-Corrêa, Balbueno, Vieira, and de Freitas (2009)	Brazil	No	Yes	Yes	No	No	Tropical & Subtropical Grasslands, Savannas & Shrublands	-30.3667	-51.0333
Source	**Country**	**Aimed to test attractant**	**Coordinate provided**	**Map provided**	**Control used**	**Stats used**	**Biome**	**Latitude**	**Longitude**
Rocha, Sollmann, Ramalho, Ilha, and Tan (2016)	Brazil	No	Yes	Yes	Yes	Yes	Tropical & Subtropical Moist Broadleaf Forests	-2.3500	-64.2667

Dillon and Kelly (2008)	Belize	No	Yes	No	No	No	Tropical & Subtropical Moist Broadleaf Forests	16.7314	-88.9864

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Assessment of attractants for Neotropical mammals

Herbert de Oliveira Barbosa Duarte, Darren Norris and Fernanda Michalski

Appendix 2. Specific interactions between single and/or combination of attractants and Neotropical mammals reported across the 60 reviewed studies. Only statistically tested interactions are reported.

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Bassariscus astutus*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Bassariscus astutus*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Canis lupus familiaris*	Carbonated ammonia and urea with catnip	-	-
Carnivora	*Canis lupus familiaris*	Banana or banana with corn and salt	-	-
Carnivora	*Cerdocyon thous*	Carbonated ammonia and urea with catnip	-	-
Carnivora	*Cerdocyon thous*	Banana or banana with corn and salt	-	-
Carnivora	*Conepatus chinga*	Canine Call lure	-	-
Carnivora	*Conepatus chinga*	Cat Passion lure	-	-
Carnivora	*Conepatus chinga*	Wild cat lure	-	-
Carnivora	*Conepatus chinga*	Wild cat and Canine Call lures	-	-
Carnivora	*Conepatus leuconotus*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Conepatus leuconotus*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Eira barbara*	Carbonated ammonia and urea with catnip	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Eira barbara*	Banana or banana with corn and salt	-	-
Carnivora	*Eira barbara*	Sardine and eggs	-	-
Carnivora	*Galictis cuja*	Banana or banana with corn and salt	Carbonated ammonia and urea with catnip	-
Carnivora	*Herpailurus yagouaroundi*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Herpailurus yagouaroundi*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Herpailurus yagouaroundi*	Catnip	-	-
Carnivora	*Herpailurus yagouaroundi*	Cinnamon	-	-
Carnivora	*Herpailurus yagouaroundi*	Vanilla	-	-
Carnivora	*Herpestes auropunctatus*	Vanilla	-	Anise
Carnivora	*Herpestes auropunctatus*	Chicken egg	-	Mint
Carnivora	*Herpestes auropunctatus*	-	-	Carbachol
Carnivora	*Leopardus* spp.	Carbonated ammonia and urea with catnip	-	-
Carnivora	*Leopardus* spp.	Banana or banana with corn and salt	-	-
Carnivora	*Leopardus colocolo*	-	Canine Call lure	-
Carnivora	*Leopardus colocolo*	-	Cat Passion lure	-
Carnivora	*Leopardus colocolo*	-	Wild cat lure	-
Carnivora	*Leopardus colocolo*	-	Wild cat and Canine Call lures	-
Carnivora	*Leopardus jacobita*	Canine Call lure	-	-
Carnivora	*Leopardus jacobita*	Cat Passion lure	-	-
Carnivora	*Leopardus jacobita*	Wild cat lure	-	-
Carnivora	*Leopardus jacobita*	Wild cat and Canine Call lures	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Leopardus pardalis*	Canine Call lure	Wild cat and Canine Call lures	-
Carnivora	*Leopardus pardalis*	Cat Passion lure	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-
Carnivora	*Leopardus pardalis*	Wild cat lure	Catnip	-
Carnivora	*Leopardus pardalis*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Leopardus pardalis*	Cinnamon	-	-
Carnivora	*Leopardus pardalis*	Vanilla	-	-
Carnivora	*Leopardus pardalis*	Sardine	-	-
Carnivora	*Leopardus pardalis*	Compact disk	-	-
Carnivora	*Leopardus pardalis*	Obsession cologne	-	-
Carnivora	*Leopardus pardalis*	Sardine and eggs	-	-
Carnivora	*Leopardus tigrinus*	Canine Call lure		
Carnivora	*Leopardus tigrinus*	Cat Passion lure		
Carnivora	*Leopardus tigrinus*	Wild cat lure		
Carnivora	*Leopardus tigrinus*	Wild cat and Canine Call lures		
Carnivora	*Leopardus tigrinus*	Catnip		
Carnivora	*Leopardus tigrinus*	Cinnamon		
Carnivora	*Leopardus tigrinus*	Vanilla		
Carnivora	*Leopardus wiedii*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	Catnip	-
Carnivora	*Leopardus wiedii*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	Cinnamon	-
Carnivora	*Leopardus wiedii*	Vanilla	-	-
Carnivora	*Leopardus wiedii*	Sardine and eggs	-	-
Carnivora	*Lycalopex culpaeus*	Bobcat urine lure	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Lycalopex culpaeus*	Fox#1 urine lure	-	-
Carnivora	*Lycalopex culpaeus*	Minced meat with fatty acid scent	-	-
Carnivora	*Lycalopex culpaeus*	Minced meat with Cat Passion	-	-
Carnivora	*Lycalopex culpaeus*	Minced meat	-	-
Carnivora	*Lycalopex culpaeus*	FoxOff bait	-	-
Carnivora	*Lycalopex culpaeus*	Canine Call lure	-	-
Carnivora	*Lycalopex culpaeus*	Cat Passion lure	-	-
Carnivora	*Lycalopex culpaeus*	Wild cat lure	-	-
Carnivora	*Lycalopex culpaeus*	Wild cat and Canine Call lures	-	-
Carnivora	*Lycalopex griseus*	Bobcat urine lure	-	-
Carnivora	*Lycalopex griseus*	Fox#1 urine lure	-	-
Carnivora	*Lycalopex griseus*	Minced meat with fatty acid scent	-	-
Carnivora	*Lycalopex griseus*	Minced meat with Cat Passion	-	-
Carnivora	*Lycalopex griseus*	Minced meat	-	-
Carnivora	*Lycalopex griseus*	FoxOff bait	-	-
Carnivora	*Mephitis macroura*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Mephitis macroura*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Mustela frenata*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Mustela frenata*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Nasua narica*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Nasua narica*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Nasua nasua*	Cat Passion lure	Canine Call lure	-
Carnivora	*Nasua nasua*	Carbonated ammonia and urea with catnip	Wild cat lure	-
Carnivora	*Nasua nasua*	Banana or banana with corn and salt	Wild cat and Canine Call lures	-
Carnivora	*Panthera onca*	Catnip	-	-
Carnivora	*Panthera onca*	Cinnamon	-	-
Carnivora	*Panthera onca*	Vanilla	-	-
Carnivora	*Panthera onca*	Sardine and eggs	-	-
Carnivora	*Procyon cancrivorus*	Carbonated ammonia and urea with catnip	-	-
Carnivora	*Procyon cancrivorus*	Banana or banana with corn and salt	-	-
Carnivora	*Procyon lotor*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Procyon lotor*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Puma concolor*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	Catnip	-
Carnivora	*Puma concolor*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	Cinnamon	-
Carnivora	*Puma concolor*	Sardine and eggs	Vanilla	-
Carnivora	*Spilogale putorius*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Spilogale putorius*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Carnivora	*Tremarctos ornatus*	Cat Passion lure	Canine Call lure	-
Carnivora	*Tremarctos ornatus*	-	Wild cat lure	-

Order	Genus/Species	Attraction	No attraction	Repellent
Carnivora	*Tremarctos ornatus*	-	Wild cat and Canine Call lures	-
Carnivora	*Urocyon cinereoargenteus*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Carnivora	*Urocyon cinereoargenteus*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Cetartiodactyla	*Hippocamelus antisensis*	-	Canine Call lure	-
Cetartiodactyla	*Hippocamelus antisensis*	-	Cat Passion lure	-
Cetartiodactyla	*Hippocamelus antisensis*	-	Wild cat lure	-
Cetartiodactyla	*Hippocamelus antisensis*	-	Wild cat and Canine Call lures	-
Cetartiodactyla	*Mazama* spp.	Carbonated ammonia and urea with catnip	-	-
Cetartiodactyla	*Mazama* spp.	Banana or banana with corn and salt	-	-
Cetartiodactyla	*Mazama americana*	-	Canine Call lure	-
Cetartiodactyla	*Mazama americana*	-	Cat Passion lure	-
Cetartiodactyla	*Mazama americana*	-	Wild cat lure	-
Cetartiodactyla	*Mazama americana*	-	Wild cat and Canine Call lures	-
Cetartiodactyla	*Mazama americana*	-	Sardine and eggs	-
Cetartiodactyla	*Mazama chunyi*	-	Canine Call lure	-
Cetartiodactyla	*Mazama chunyi*	-	Cat Passion lure	-
Cetartiodactyla	*Mazama chunyi*	-	Wild cat lure	-
Cetartiodactyla	*Mazama chunyi*	-	Wild cat and Canine Call lures	-
Cetartiodactyla	*Mazama nemorivaga*	Sardine and eggs	-	-
Cetartiodactyla	*Odocoileus virginianus*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Cetartiodactyla	*Odocoileus virginianus*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Cetartiodactyla	*Pecari tajacu*	Canine Call lure	Cat Passion lure	-
Cetartiodactyla	*Pecari tajacu*	Sardine and eggs	Wild cat and Canine Call lures	-
Cetartiodactyla	*Tapirus terrestris*	-	Sardine and eggs	-
Chiroptera	*Artibeus* spp.	-	*Piper* essential oil	-
Chiroptera	*Artibeus fimbriatus*	*Piper amalago* oil	-	-
Chiroptera	*Artibeus jamaicensis*	Fruit scent of ripped fruits of *Ficus obtusifolia*	Fruit scent of ripped fruits of *Ficus costaricana*	-
Chiroptera	*Artibeus jamaicensis*	Fruit scent of ripped fruits of *Ficus trigonata*	-	-
Chiroptera	*Artibeus jamaicensis*	Fruit scent of ripped fruits of *Ficus variegata*	-	-
Chiroptera	*Artibeus jamaicensis*	Fruit scent of ripped fruits of *Ficus hispida*	-	-
Chiroptera	*Artibeus lituratus*	Essential oil of *Piper gaudichaudianum*	-	-
Chiroptera	*Artibeus lituratus*	Essential oil of *Ficus insipida*	-	-
Chiroptera	*Artibeus lituratus*	*Piper hispidum* fruit	-	-
Chiroptera	*Artibeus lituratus*	*Ficus insipida* fruit	-	-
Chiroptera	*Artibeus lituratus*	*Piper hispidum* oil	-	-
Chiroptera	*Artibeus lituratus*	*Piper hispidum* oil	-	-
Chiroptera	*Artibeus watsoni*	Ripe *Ficus* fruit	Unripe *Ficus* fruit	-
Chiroptera	*Artibeus watsoni*	-	Infested ripe *Ficus* fruit	-
Chiroptera	*Artibeus watsoni*	-	Infested unripe *Ficus* fruit	-
Chiroptera	*Carollia castanea*	Extract of ripe *Piper*	Extract of unripe *Piper*	-

Order	Genus/Species	Attraction	No attraction	Repellent
Chiroptera	*Carollia perspicillata*	*Piper hispidum* fruit	Unripe *Piper* fruit	-
Chiroptera	*Carollia perspicillata*	*Ficus insipida* fruit	-	-
Chiroptera	*Carollia perspicillata*	*Piper hispidum* oil	-	-
Chiroptera	*Carollia perspicillata*	*Ficus insipida* oil	-	-
Chiroptera	*Desmodus rotundus*	Pig blood with hair from tail cow, hair combed from cow body and fresh cow feces	Pig blood	-
Chiroptera	*Glossophaga commissarisi*	Floral compound (dimethyl disulphide)	Floral compound (3-hexanone)	-
Chiroptera	*Glossophaga commissarisi*	Floral compound (2,4-dithiapentane)	Floral compound ((E)-2-hexenal)	-
Chiroptera	*Glossophaga commissarisi*	Floral compound (bornyl acetate)	Floral compound (hexyl acetate)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound (benzaldehyde)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound ((+)-α-pinene)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound ((-)-α-pinene)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound ((R)-limonene)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound ((S)-limonene)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound (linalool)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound (linalyl acetate)	-
Chiroptera	*Glossophaga commissarisi*	-	Floral compound (bornyl acetate)	-
Chiroptera	*Glossophaga soricina*	*Piper amalago* oil	-	-

Order	Genus/Species	Attraction	No attraction	Repellent
Chiroptera	*Sturnira lilium*	*Piper amalago* oil	-	-
Chiroptera	*Vampyressa pusilla*	Ripe *Ficus* fruit	Unripe *Ficus* fruit	-
Chiroptera	*Vampyressa pusilla*	Infested ripe *Ficus* fruit	Infested unripe *Ficus* fruit	-
Cingulata	*Dasypus novemcinctus*	Carbonated ammonia and urea with catnip	-	-
Cingulata	*Dasypus novemcinctus*	Banana or banana with corn and salt	-	-
Cingulata	*Dasypus novemcinctus*	Sardine and eggs	-	-
Cingulata	*Euphractus sexcinctus*	Carbonated ammonia and urea with catnip	-	-
Cingulata	*Euphractus sexcinctus*	Banana or banana with corn and salt	-	-
Cingulata	*Priodontes maximus*	Sardine and eggs	-	-
Didelphimorphia	*Didelphis aurita*	Carbonated ammonia and urea with catnip	-	-
Didelphimorphia	*Didelphis aurita*	Banana or banana with corn and salt	-	-
Didelphimorphia	*Didelphis marsupialis*	Sardine and eggs	-	-
Didelphimorphia	*Didelphis virginiana*	Catnip, Canine Call lure, Wildcat lure#1, Raccoon lure#1	-	-
Didelphimorphia	*Didelphis virginiana*	Lone star cologne (Obsession imitator), Canine Call lure, Wildcat lure#1, and Raccoon lure#1	-	-
Lagomorpha	*Sylvilagus brasiliensis*	Banana or banana with corn and salt	Carbonated ammonia and urea with catnip	-
Pilosa	*Myrmecophaga tridactyla*	-	Sardine and eggs	-
Pilosa	*Tamandua tetradactyla*	Carbonated ammonia and urea with catnip	Banana or banana with corn and salt	-
Primates	*Aotus* sp.	Unpeeled banana	Plastic banana	-
Primates	*Ateles geoffroyi*	Ripe fruit of *Couma macrocarpa*	Unripe fruit of *Couma macrocarpa*	-

Order	**Genus/Species**	**Attraction**	**No attraction**	**Repellent**
Primates	*Ateles geoffroyi*	Ripe fruit of *Leonia cymosa*	Unripe fruit of *Leonia cymosa*	-
Primates	*Callicebus* sp.	Unpeeled banana	Plastic banana	-
Primates	*Saguinus fuscicollis*	Unpeeled banana	Plastic banana	-
Primates	*Saguinus fuscicollis*	Banana	-	-
Primates	*Saguinus imperator*	Unpeeled banana	Plastic banana	-
Primates	*Saguinus imperator*	Banana	-	-
Rodentia	*Cuniculus paca*	Wild cat and Canine Call lures	Canine Call lure	-
Rodentia	*Cuniculus paca*	-	Cat Passion lure	-
Rodentia	*Cuniculus paca*	-	Wild cat lure	-
Rodentia	*Cuniculus paca*	-	Sardine and eggs	-
Rodentia	*Dasyprocta azarae*	Banana or banana with corn and salt	Carbonated ammonia and urea with catnip	-
Rodentia	*Dasyprocta fuliginosa*	-	Sardine and eggs	-
Rodentia	*Hydrochaeris hydrochaeris*	Banana or banana with corn and salt	Carbonated ammonia and urea with catnip	-
Rodentia	*Lagidium viscacia*	-	Canine Call lure	-
Rodentia	*Lagidium viscacia*	-	Cat Passion lure	-
Rodentia	*Lagidium viscacia*	-	Wild cat lure	-
Rodentia	*Lagidium viscacia*	-	Wild cat and Canine Call lures	-
Rodentia	*Myoprocta pratti*		Sardine and eggs	

ANEXOS

Anexo1: Artigo publicado referente ao único capitulo da dissertação.

Review Article

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Assessment of Attractants for Neotropical Mammals

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Abstract

Mammals play important ecological roles in tropical regions but are difficult to study due to discrete habits, low population densities, and large home ranges. Thus, the use of attractive substances has frequently been adopted to quantify the distribution and abundance of elusive mammals. However, the insight generated from studies using attractants is often limited by a lack of methodological standardization. To inform the use of attractants in the Neotropics, we reviewed 30 years of the scientific literature that used some type of attractant in mammal studies. From a total of 60 studies, the majority (65%) did not use any control (or pseudocontrol) in their sampling design and only 40% used some statistical test to explicitly evaluate the efficiency of the attractant used. A wide range of edible (animal or vegetal origin) and inedible substances (e.g., scent lures) were used alone or in combination and the effects differed greatly among orders and species. Most studies (67%) targeted or registered carnivores, and this order had the largest number of substances (edible and inedible) used across all studies. There seems to be only a consensus in the use and attraction effect with frugivorous bats (Phyllostomidae) with fruits, essential oils, and floral compounds. The lack of standardization of use of attractants in mammal studies undermines the comparability of results among studies. We conclude with some general guidelines to maximize comparability among studies and to enhance the potential usefulness of the use of attractants for mammals.

Keywords

substances, bait, lure, sampling design, wildlife

Introduction

Mammals are frequently considered keystone species for their important ecological roles in tropical regions (Stoner, Riba-Hernandez, Vulinec, & Lambert, 2007; Wright, Gompper, & Deleon, 1994) as well as their association with the degree of habitat disturbance (Arevalo-Sandi, Bobrowiec, Chuma, & Norris, 2018; Medellin, Equihua, & Amin, 2000; Wearn et al., 2017). However, mammals are experiencing declines in their geographic ranges worldwide due to increasing human population densities, agriculture, grazing, and hunting (Ceballos & Ehrlich, 2002; Ripple et al., 2014; Wright, 2005). These population declines and local extinctions are likely to promote cascading effects and the loss of irreplaceable ecological functions (Lopez & Terborgh, 2007; Ripple et al., 2014, 2015).

Despite the importance of monitoring and evaluating the distribution and abundance of mammals in ecosystems, there remains a lack of consistency and standardization in the methods used in studies in tropical regions (Ahumada, Hurtado, & Lizcano, 2013; Munari, Keller, & Venticinque, 2011). This is particularly the case of mammal species that may have low densities, large home ranges, are discrete and elusive, coupled with the logistical difficulties encountered in most tropical regions, often limiting the approach

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