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Source: Tropical Conservation Science, 11(1)

Published By: SAGE Publishing

URL: <https://doi.org/10.1177/1940082918800665>

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Assessment of Attractants for Neotropical Mammals

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Tropical Conservation Science
Volume 11: 1–11
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DOI: 10.1177/1940082918800665
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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; Medellín, 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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Received 12 July 2018; Accepted 24 August 2018

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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 programs, 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 (Brackowski 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 the 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 species lack replications and 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 “Panamá” 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).

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

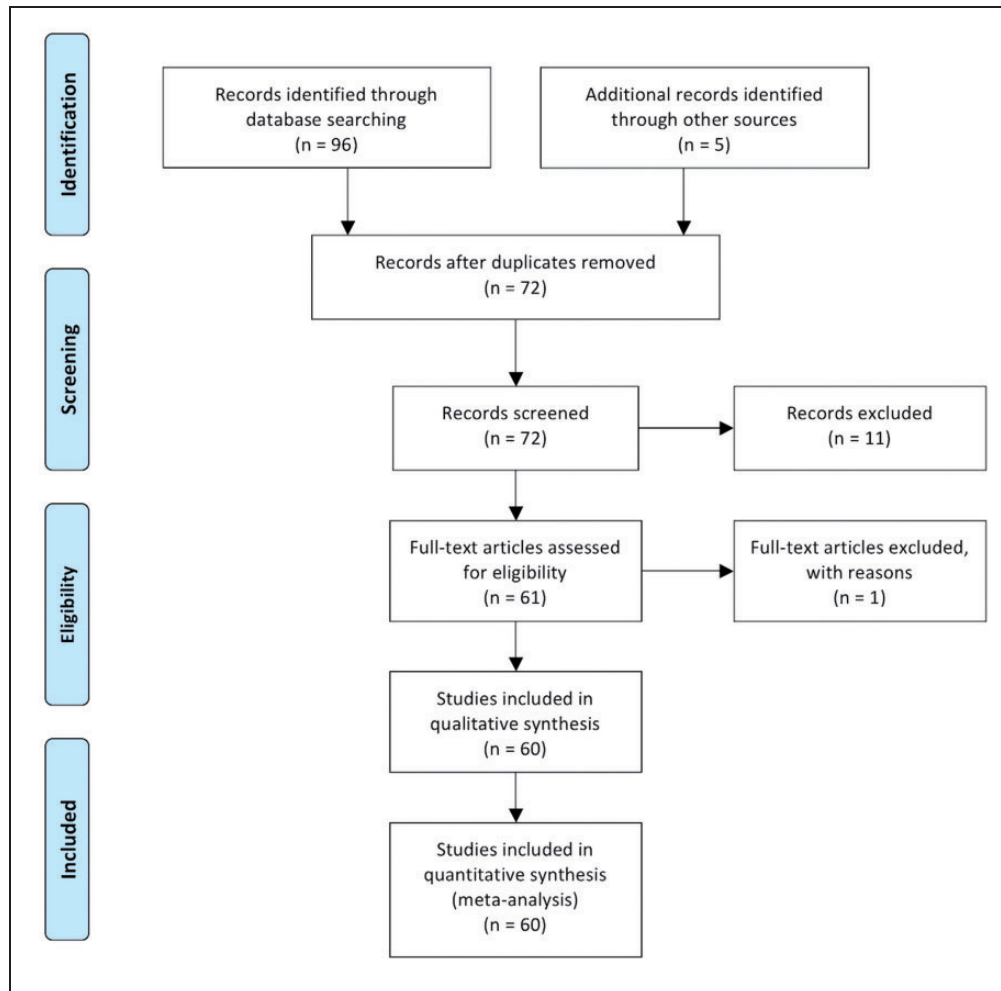


Figure 1. Flowchart using the Preferred Reported Items for Systematic Reviews and Meta-Analyses statement.

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 (mean = 174.75 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.

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.

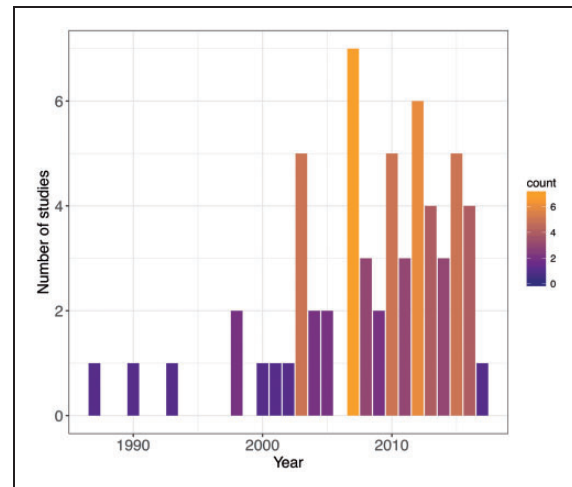


Figure 2. Annual number of studies that used attractant substances for mammals in the Neotropical region from 1987 to 2017. The color gradient is proportional to the number of studies in each year.

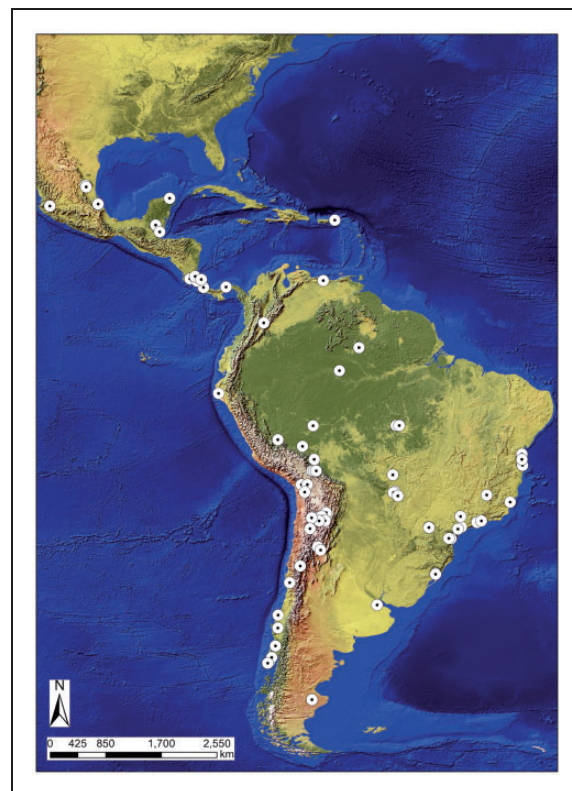


Figure 3. Spatial distribution of studies on mammals using attractant substances in the Neotropical region (see Online Appendix I for references).

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

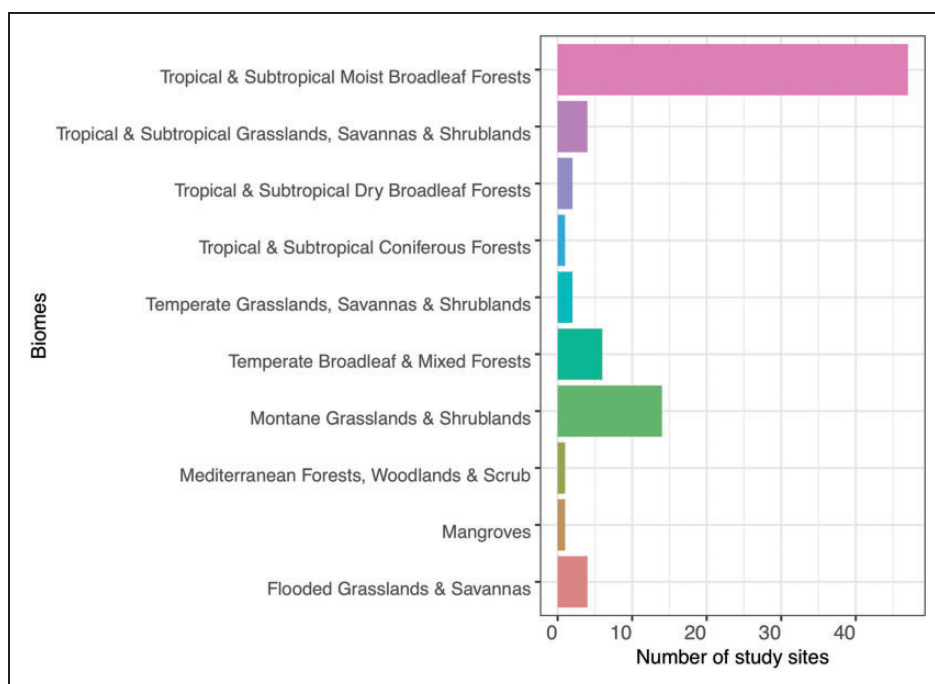


Figure 4. Number of study sites per Neotropical biome. Frequency distribution of 10 biomes from studies published from 1987 to 2017 ($n = 60$ articles) in the Neotropical region.

or in combination (mixed; Table 1). Overall, the 60 studies provided information about attractants and interactions (attraction, no attraction, and repulsion) 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.

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).

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

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

| 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 | | | |
| Chiroptera | Blood | Extract of ripe fruits | |
| | Ripe fruits | Feaces | |
| | Unripe fruits | Floral compound | |
| | | Fruit essential oil | |
| 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 | | | |
| 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 | | |

(continued)

Table 1. Continued.

| Order | Edible | Inedible | |
|----------|----------------|--------------------|----------------|
| Pilosa | Seeds | | |
| | Vegetable | | |
| | 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 | | |

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 and subtropical moist broad-leaf forests (Dinerstein et al., 2017), biome with the highest number of study sites in our review. This biome

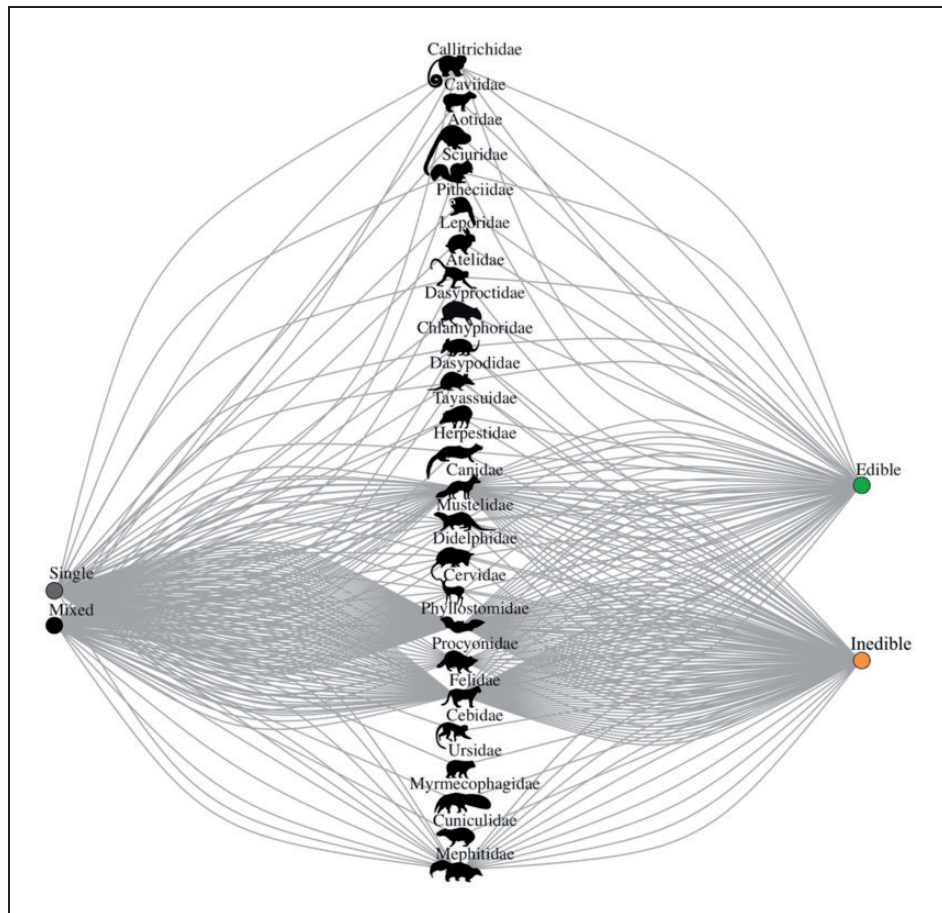


Figure 5. Interactions among mixed, single, edible, inedible substances, and mammal families that were attracted by substances according to the studies reviewed.

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, & Ríos-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 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*, the 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 Cetartiodactyla 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.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The data presented here were collected during HOBD's master study, which was funded by a studentship from the National Council for Scientific and Technological Development (CNPq—Grant 132802/2017–1). FM receives a productivity scholarship from CNPq (Grant 301562/2015–6) and is funded by CNPq (Grant 403679/2016–8).

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