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Baiting for carnivores might negatively affect capture rates of prey species in camera-trap studies

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Abstract

Surveying and monitoring of elusive animals with naturally low densities and large home ranges, such as many medium- and large-sized mammals, is challenging. Low capture rates can preclude detailed analyses. The use of bait has been used as a strategy to increase carnivore capture rates in many camera-trap surveys. Here, we test the effect of one carnivore bait type (mix of fresh sardine and egg) on the capture rates of carnivores and prey species in a camera-trap survey in the Central Brazilian Amazon. We also test if the quality of records of naturally marked felids for individual identification is enhanced by the use of bait. We found that the bait had no apparent effect on the carnivore capture rates, but it might have repelled some prey species. The number of suitable photos for individual identification of naturally marked felids was greater at baited stations than at unbaited stations, but this did not result in practical advantages for individual identification. We recommend that the use of carnivore bait should be carefully considered at the planning stage of camera-trap studies as it can negatively affect recording of prey species.

Introduction

Camera traps have become a popular method for the survey of medium- and large-sized terrestrial mammals in the last two decades (Karanth, 1995; Tobler *et al.*, 2008; O'Connell, Nichols & Karanth, 2011). They have been used for production of species lists (Lyra-Jorge *et al.*, 2008), habitat use/preference (Linkie *et al.*, 2007), relative abundance (O'Brien, Kinnaird & Wibisono, 2003), species occupancy (O'Connell *et al.*, 2006), activity patterns (Gómez *et al.*, 2005) and resource use (Tobler, Carrillo-Percastegui & Powell, 2009).

Karanth (1995) pioneered the use of camera traps to study naturally marked carnivore population, and several studies followed (Maffei *et al.*, 2005; Kelly *et al.*, 2008; Silveira *et al.*, 2010). Many carnivore species have low detection rates because of their naturally low density, large home ranges and secretive habits (Trolle & Kéry, 2005; O'Connell *et al.*, 2011). Low capture rates are a concern, as they can preclude detailed analysis (O'Connell *et al.*, 2006; Nichols *et al.*, 2008; Tobler *et al.*, 2012), especially in the Amazon, where logistics are complex and expensive.

Although camera trapping does not require the use of baits, this strategy is used to increase species capture rates (Gerber, Karpanty & Kelly, 2011; Karanth, Nichols & Kumar, 2011; du Preez, Loveridge & Macdonald, 2014). The use of a wide variety of baits and lures has been reported in the literature as an attempt to increase the probability of detection of carnivores by luring nearby animals to pass in front of camera traps (Trolle, 2003; Hegglin *et al.*, 2004; Monterroso, Alves & Ferreras, 2011).

Besides increasing carnivore detection rates in camera-trap studies, baits can potentially facilitate individual identification from camera-trap images (du Preez *et al.*, 2014). Based on individualization, several studies have estimated population parameters of naturally marked felid species, such as tigers *Panthera tigris* (Karanth & Nichols, 1998), lynx *Lynx lynx* (Pesenti & Zimmermann, 2013), jaguars *Panthera onca* (Soisalo & Cavalcanti, 2006), ocelots *Leopardus pardalis* (Trolle & Kéry, 2003) and pumas *Puma concolor* (Kelly *et al.*, 2008). To better identify individuals, the target animal has to be well positioned in front of the camera (ideally exposing its full flanks) (Hiby *et al.*, 2009). Baits can be used to improve individual identification by encouraging the target animal to stop at the right spot for enough time, allowing the cameras to take more photos at better angles.

Different species respond in different ways to the presence of baits (Schlexer, 2008) and there are potential aversion effects caused by the use of baits (Conover & Linder, 2009). Most studies investigating the effect of baits have been carnivore oriented (Long *et al.*, 2003; Monterroso *et al.*, 2011; Allen *et al.*, 2013) and the effects on the detection of prey species has been little studied (except in Australia where a considerable amount of camera trapping focused on non-carnivore species has been done; for example see Paull, Claridge & Barry, 2011). However, prey occurrence is a variable that has been used to explain predator distribution, occupancy and density (Rabinowitz & Nottingham, 1986; Karanth *et al.*, 2004; Mohamad *et al.*, 2015). Therefore, it is important to understand whether protocols designed to optimize studies of carnivores may inadvertently affect the detection of prey species, particularly in community studies. This information might be useful for designing future camera-trap surveys and interpretation of the large amount of data that has already been collected.

This study was undertaken in an old-growth forested area in the Central Brazilian Amazon and aimed to evaluate the effect of the use of one carnivore bait type (mix of fresh sardine and egg) on the capture rates of medium- and large-sized terrestrial mammalian carnivores and prey species. Additionally, we tested if the number of suitable photos for individual identification of naturally marked felids was higher at baited than at unbaited camera-trap stations.

Materials and methods

Study area

The camera-trap survey was conducted in Amanã Sustainable Development Reserve (2°21′S, 64°16′W) located between the Negro and Amazon Rivers. The reserve covers 2 350 000 ha of pristine rain forest near the confluence of the Amazon and Japurá Rivers. The surveyed area is composed of a mosaic of unflooded (*terra firme*) and floodplain (*Igapó*) forest. The *terra firme* covers approximately 84% of the reserve and includes all areas that are not seasonally flooded. *Igapó* forests are seasonally flooded by blackwater rivers. The climate in the region is tropical humid, with average monthly temperature around 26°C and average annual precipitation of 2373 mm (Ayres, 1993). The camera-trap surveys were conducted on the edges of Amanã Lake during the dry season, when the water level in the region was low.

Camera-trap survey

The survey was conducted from December 2013 to April 2014 (120 days), with a total sampling effort of 2985 camera-trap days. It was originally designed to estimate jaguar density. The surveyed area covered a polygon of 134 km^2 (minimum convex polygon) and was divided in two contiguous sampling blocks. Camera-trap stations from the first block were operational during the first 57 days of the sampling period and the camera-trap stations from the second block during the following 63 days. Each block contained a grid of 25 baited camera-trap stations, with individual stations 1.7–2 km apart (Fig. 1). Each station consisted of two cameras (model PC800 Hyperfire, Reconyx Inc., Holmen, WI, USA) facing each other 4–5 m apart. The bait was a mixture of fresh sardine and eggs (~200 ml), which was located midway between the two cameras, inside a vented container, but inaccessible for consumption and fixed to the ground. The sardine and egg mixture was chosen as a carnivore attractant because its components are cheap and accessible in this part of the Amazon. When triggered, cameras were set to take a sequence of 10 photos, one per second without delay between triggers. Stations were serviced every 14 days to change batteries, download photos and refresh baits. When possible, camera-trap stations were installed on locations with signs of medium- and large-sized mammals. Within the sampling grid, we randomly placed 14 extra camera-trap stations without bait (seven in each block), distanced at least 1 km from any other camera-trap station and following the same sampling protocol, except for the use of bait. We treated detection of the same animal at the same time by the two cameras as a single record. To minimize over representing individuals that den near a camera-trap station, we considered photos of the same species at the same station within the same day (0:00–23:59) as a single record. For the naturally marked felids, detections of different individuals at the same station within the same day were considered independent records.

Data analysis

To evaluate the effect of bait on the number of records of each carnivore and prey species, we used generalized linear models (GLM) with *Poisson* distribution, adjusting for the number of days each camera-trap station was functional in the field. Species with less than five records were excluded from the analysis due to small sample size.

For those species for which we detected an effect of bait on the number of records, we used Spearman's correlation tests to investigate the effect of bait age on the number of records. Days were counted from the day we refreshed the baits, day 14 being the day before the next service. For this analysis, we discarded incomplete 14-day periods so that all time periods had equal effort.

We also used GLM with *Poisson* distribution to test the effect of baits on the number of photos suitable for individual identification of naturally marked felids (hereafter, suitable photos). Suitable photos were considered those in which the target animal was between both cameras, with clear focus and that showed an entire lateral view of the animal (Fig. 2). For each record, we pooled all images from both cameras at each station to evaluate whether the number of suitable photos of jaguar, ocelot, margay *Leopardus wiedii* and puma at baited stations differed to those at unbaited station. Although pumas are not naturally marked, we included puma records because other studies have successfully used photo identification of this species relying on individual features, such as scars, ear nicks, tail-tip coloration and body shape (Kelly *et al.*, 2008).

We used chi-square contingency table tests to evaluate if records from baited camera-trap stations were more likely to have at least one suitable photo for individual identification than unbaited stations, and to test if baited stations were more likely to have records with suitable photos of both lateral views of the target animal than unbaited stations. We conducted all statistical tests in R 3.1.2 (R Core Team, 2015).

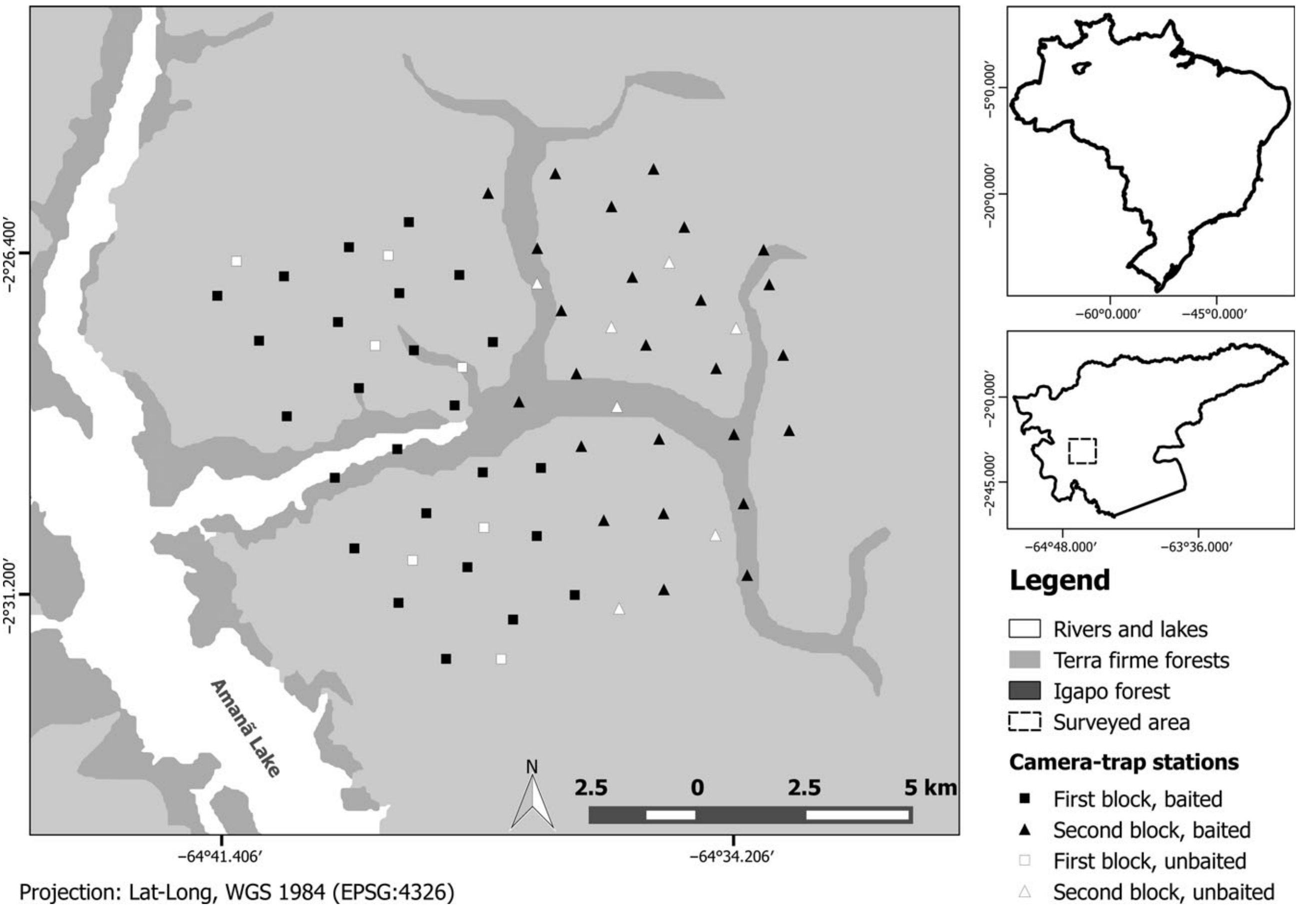

Figure 1 Map of the area surveyed to test the effect of fresh mix of sardine and egg baits on the number of records of medium- and large-sized terrestrial mammals in Amanã Sustainable Development Reserve. The inset maps indicate the position of Amanã Reserve in Brazil and the surveyed area within Amanã Reserve.

Results

We obtained 1422 independent records of medium- to large-sized terrestrial mammals (82 of carnivores and 1340 of prey species). In total, we recorded seven species of carnivores and 12 of prey, three of which are considered to be globally threatened by the UICN Red List (IUCN, 2014), and seven are categorized as vulnerable in Brazil (Chiarello *et al.*, 2008; Medici *et al.*, 2012).

There was no significant difference in the mean number of records between baited and unbaited camera-trap stations for any species of carnivore (Table 1). For six species of prey (lowland tapir *Tapirus terrestris*, giant anteater *Myrmecophaga tridactyla*, spotted paca *Cuniculus paca*, black agouti *Dasyprocta fuliginosa*, green acouchi *Myoprocta pratti* and red brocket deer *Mazama americana*), the mean number of records at baited stations was significantly lower than at unbaited stations (Fig. 3). The common opossum *Didelphis marsupialis* and the nine-banded armadillo *Dasypus novemcinctus* had higher numbers of records at baited camera-trap stations, though the difference was not statistically significant at $P = 0.05$ for the armadillo (Table 1).

Of the seven species for which there was a statistically significant difference in the number of records at baited and unbaited camera-trap stations, there was a detectable effect of bait age only for common opossum. Days on which the bait was fresher had a higher number of records than days on which the bait was older ($r_s = -0.73$, $P = 0.004$).

In total, there were 64 records of felids (44 of ocelots, 11 of pumas, 7 of jaguars and 2 of margay). The mean number of suitable photos per record used for individual identification of the four felid species was significantly higher at baited stations (5.2 photos) than at unbaited stations (3.1 photos) ($z = 0.52$, df = 63, $P = 0.005$). Nonetheless, the likelihood that a record had at least one suitable photo did not differ between baited and unbaited stations ($\chi^2 = 0.16$, df = 1, $P = 0.68$). The likelihood that a record had suitable photos of both sides of the animal also did not differ between baited and unbaited stations ($\chi^2 = 0$, df = 1, $P = 0.99$).

Discussion

Low capture rates are a common problem in studies targeting carnivores and strategies to increase the number of records are

Figure 2 An example of a suitable photo for individual identification of an ocelot *Leopardus pardalis*, in which the target animal was between the cameras, with clear focus, and showing an entire lateral view of the animal.

frequently employed. Baited camera traps often record more carnivores than unbaited ones. Gerber *et al.* (2011) and du Preez *et al.* (2014) had higher photo-detection rates of their target carnivore species (Malagasy civet *Fossa fossana* and African leopard *Panthera pardus*) using meat as bait (chicken and zebra *Equus* sp. respectively). Monterroso *et al.* (2011) also found that valerian extract and lynx urine increased detection rates of carnivores. However, contrary results were observed in Australia, where relative abundance of dingoes *Canis lupus dingo* was higher at unbaited track plots than baited ones (Allen, Engeman & Krupa, 1996). Braczkowski *et al.* (2016) also found that scent trail of decomposed entrails from the main leopard prey species did not increased leopard photographic capture rates. In our study, baited camera-trap stations were no more effective in recording carnivores than unbaited camera-trap stations. Possibly, there is a weak bait effect on attracting carnivores, but, in that case, it would be necessary to have a much larger number of records of some species to detect a slight difference between baited and unbaited camera-trap stations. We believe that local environmental conditions of the Amazon forest may have contributed to the low effectiveness of our bait. The warm and humid weather, which quickens the degradation process, might make the bait inedible for carnivores shortly after it is made available. The local availability of food may also be important as baits will have greater appeal in sites with low food availability.

Baits with sardines have been used to attract carnivores to camera-trap stations (Trolle & Kéry, 2003, 2005; Botelho *et al.*, 2012). However, our fresh mix of sardine and egg bait seems to be avoided by several prey species in Amanã Reserve. Among the species that had lower capture rates on baited stations than unbaited stations, the green acouchi, the black agouti and the spotted paca are mainly frugivorous (Silvius, Fragoso & Trees, 2003; Dubost & Henry, 2006; Beck-King, Von Helversen & Beck-King, 2012), the red brocket deer is frugivorous and a browser (Barbanti *et al.*, 2012), the lowland tapir is a browser and grazer (Padilla & Dowler,

Table 1 List of species of medium- and large-sized terrestrial mammals recorded in the camera-trap survey in Amanã Sustainable Development Reserve, with mean number of records (records), number of camera-trap stations at which the species was recorded (stations), estimated difference between means of records (estimate) at baited and unbaited camera-trap stations, respective standard error (SE) and *P*-values for the GLM (with Poisson distribution)

Group/Species	Common name	Records	Stations	Estimate	SE	*P*-value
Prey						
Tapirus terrestris	Lowland tapir	28	20	−0.8	*0.39*	**0.04**
Myrmecophaga tridactyla	Giant anteater	34	22	−1.27	*0.34*	**<0.01**
Tamandua tetradactyla	Southern tamandua	4	4		Small sample size	
Pecari tajacu	Collared peccary	58	34	0.43	0.38	0.25
Mazama americana	Red brocket deer	38	21	−0.74	0.34	**0.02**
Mazama nemorivaga	Brown brocket deer	14	10	−0.48	0.59	0.41
Cuniculus paca	Spotted paca	57	25	−0.93	*0.27*	**<0.01**
Dasyprocta fuliginosa	Black agouti	251	52	−1.00	*0.12*	**<0.01**
Myoprocta pratti	Green acouchi	156	42	−1.60	*0.16*	**<0.01**
Priodontes maximus	Giant armadillo	23	19	−0.57	*0.45*	*0.20*
Dasypus novemcinctus	Nine-banded armadillo	85	32	0.61	0.33	0.06
Didelphis marsupialis	Common opossum	592	51	2.61	*0.26*	**<0.01**
Carnivores						
Eira barbara	Tayra	14	12	0.39	0.76	0.60
Nasua nasua	South American coati	2	2		Small sample size	
Speothos venaticus	Bush dog	2	2		Small sample size	
Leopardus wiedii	Margay	2	2		Small sample size	
Leopardus pardalis	Ocelot	44	31	0.44	0.43	0.30
Panthera onca	Jaguar	7	6	0.39	1.08	0.71
Puma concolor	Puma	11	8	0.10	0.78	0.89

Bold values indicate $P < 0.05$. GLM, generalized linear model.

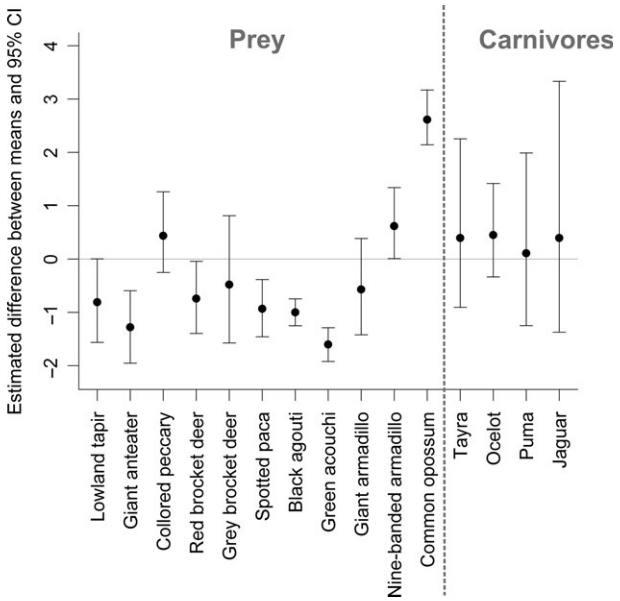

Figure 3 Estimated difference between means of records of carnivores and prey species at baited and unbaited camera-trap stations and 95% confidence intervals (CI). The null hypothesis, which assumes that the bait has no effect on the mean number of records, could not be rejected for those species for which the CI includes zero. Species for which the CI is below zero had significantly higher number of records at unbaited camera-trap stations compared to baited stations, suggesting avoidance of the bait. Species for which the CI is above zero are apparently attracted by the bait.

1994) and the giant anteater is an insectivore specialist (Redford, 1985). It is very likely that the protein-rich bait used in this study does not represent a food source for those herbivore prey species. Moreover, herbivores have been effectively repelled by the use of the Big Game Repellent® (Walters, 1981; Swihart & Conover, 1990; Mason *et al.*, 1999; Brown *et al.*, 2000), which is based on putrescent egg solids, similar to our bait. It may be that the scent of rotting sardine and egg mimic the scent of rotting carcasses, possible signaling a nearby predator and resulting in avoidance behavior by the prey species. Other kinds of protein-rich baits and lures made by macerated carnivore glands, urine or synthetic pheromone-like chemicals may also have similar effects on prey detection rates as they may also indicate predator presence (Stoddart, 1980; Nolte *et al.*, 1994; Apfelbach *et al.*, 2005). Our results highlight risks of using carnivore baits in surveys where the prey species data are also of interest.

The common opossum was strongly attracted by the sardine and egg bait. This species had the highest difference between means of number of records at baited and unbaited camera-trap stations. The common opossum is an omnivore and opportunistic forager. However, the species was more attracted by fresher baits. The fresh sardine and egg bait appears suitable for studies aiming to detect common opossums, as individuals investigated the baits for up to 3 h.

Camera-trap studies that identify naturally marked individuals need suitable records to minimize identification uncertainty, which results in fewer new target animals recorded and fewer recaptures, and consequently less-robust population-parameter estimation (Maffei *et al.*, 2011). Difficulty in identification often results from photos that show the target animal from a distance or only part of its body (usually face or tail shots). This can be caused either by chance or due to the slow trigger system of the camera employed. Even when the animal is well positioned, photos may be blurry, unfocused or overexposed. These usually result from animals passing quickly in front of the camera, heavy rain or mist, malfunction or wrong set up of camera traps. The use of bait has the potential to reduce many such problems by inducing the target animal to stop in front of the camera for longer.

In this study, the baited stations had a higher number of suitable photos for individual identification than unbaited stations. However, the likelihood of obtaining at least one suitable photo of one or both sides of the target animal was not related to the use of bait. Therefore, the potential of the bait used in this study to improve individual identification was slight.

Balme, Hunter & Robinson (2014) identified other possible complications associated with the use of bait, such as violation of the assumption of geographic closure in closed capture–recapture sampling, increased mortality by inflating inter- and intraspecific carnivore interactions and negative consequences to species conservation caused by habituation of carnivores to bait. The use of baits may also result in biased population parameters. For example, Allen *et al.* (1996) argued that territorial dingoes in Australia apparently exhibited neophobia to stations with baits inside their territories. As a consequence, detection may be biased toward transient individuals and capture probabilities are not equal for all segments of the population.

Sampling protocols should be chosen based on research objectives and method applicability (Foresman & Pearson, 1998). Although the use of bait is a widespread recommendation to increase carnivore capture rates in camera-trap surveys, the fresh mix of sardine and egg bait was not effective in this study. We highlight the need to consider such recommendations with caution, since they may reduce the capture rates of some prey species. This might lead to misunderstanding of the availability of prey, which is one of the main factors believed to influence carnivore distributions, occupancy and densities (Rabinowitz & Nottingham, 1986; Karanth *et al.*, 2004; Mohamad *et al.*, 2015). Researchers intending to collect carnivore and prey data from the same survey should be particularly aware of the constraints and limitations of using a single bait type for various species.

In this study, we only tested the effect of the mix of fresh sardine and egg bait. We stress that other types of baits and lures may not have the same effect. Therefore, we recommend future multispecies studies to run pilot studies to test for complications caused by the use of bait before employing it. Camera-trap studies of felids often produce surveys of many medium- and large-sized mammals as a by-product (Tobler *et al.*, 2008). However, the use of baits may bias or reduce the efficiency of such supplementary studies. This highlights the problem of studying multispecies assemblages using a single survey technique. The more the technique is optimized for a single species, the less likely it is to be capable of describing general patterns of species abundance in the assemblage.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. Data files.