Divergent effects of lure on multi-species camera-trap detections and quality of photos

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ABSTRACT

The use of attractants to increase detection of target species, such as carnivores, in camera trap studies must be tested for its effectiveness and be carefully planned, as it can lead to misleading comparisons among species. We analyzed a five-year multi-species camera trap dataset of lured and control stations in a protected area in the Amazon rainforest. We aimed to identify the lure effect on a wider range of species and assess whether its use is an efficient strategy to increase the number and the quality of carnivore records. From the 14 vertebrate species analyzed, we found that the use of lures had a negligible effect on nine species, and did not improve the number of records or the detection probability of the carnivores. On the other hand, lured stations attracted omnivores and scavengers (common opossum, black-and-white tegu, and turkey vulture) while had the opposite effect on potential prey species (Black-capped capuchin and Northern Amazon squirrel). We detected a stronger effect of the lure when considering the number of records (relative abundance models) than the probability of detection (occupancy models). The lure increased the proportion of high-quality photos, suitable for individual recognition of jaguars, but only for the first weeks, when the lure was fresh. Therefore, we suggest that the sardine and egg-based lures should be refreshed every two weeks to ensure greater effectiveness in the quality of photos for jaguar individualization. However, it is important to consider that lure renewing will imply a significant increase in field-related costs and it's likely to bias other species studies. Thus, we advise that lures should only be used if researchers are certain that the focus is only to increase carnivore data at the expense of using non-target species. Camera traps survey design must be carefully planned *a priori* and the cost-benefit of lure use and refreshment should be weighed in the study context.

KEY-WORDS: Amazon, attractant, carnivores, detection probability, Neotropics, survey design

INTRODUCTION

Monitoring wildlife and understanding ecological processes are imperative for conservation planning and require an adequate methodology for study goals (Hayward et al., 2015; Yoccoz et al., 2001). Uncertainties and bias resulting from methodological inconsistency might generate false inferences in the interpretation of the biological system (Burton et al., 2015). Camera traps (CTs) are a consolidated survey method for the study of medium and large-sized vertebrates (Burton et al., 2015; O'Connell et al., 2011) and, as the technology and knowledge advance, CTs use is accompanied by rigorous premises of sampling design and data analysis (Glover-Kapfer et al., 2019; Guillera-Arroita et al., 2010; Kays et al., 2020; Rovero et al., 2013; Shannon et al., 2014; Tobler et al., 2015). CTs collect data from multiple species, including those not targeted in the study (secondary data), which allows for posterior studies of community dynamics or interspecific relationships (Ahumada et al., 2011; Gompper et al., 2016). However, the number of records and the detection probability of a species varies due to sampling design and factors related to species traits and behavior due to sampling design and factors related to species traits and behavior (Srbek-Araujo & Chiarello, 2013; Wearn & Glover-Kapfer, 2017). These factors must be accounted for to allow cross-species and cross-study comparisons (Kays et al., 2020; Steenweg et al., 2017).

Attractants are used to increase the CTs records of species with low capture rates, such as carnivores (Mills et al., 2019; Schlexer, 2008). In the Neotropics, the most varied set of baits and lures are used in studies targeting carnivores (Duarte et al., 2018). Increasing the number of records and probability of detection improves the precision of estimates that require a large amount of data, for example, occupancy and abundance estimates (Braczkowski et al., 2016; Gerber et al., 2012). Attractants are also used to optimize the individual recognition of animals naturally marked, by inducing better animal positioning in addition to increasing the number of

66 photos – as the animal spends more time in front of the cameras (Du Preez et al., 2014; Fidino et
67 al., 2020; Rocha et al., 2016).

68 Attractant effectiveness remains a current topic of discussion (Avrin et al., 2021;
69 Buyaskas et al., 2020; Fidino et al., 2020; Holinda et al., 2020; Iannarilli et al., 2021; Rendall et
70 al., 2021), as it varies according to the target species, the substance used, the study area and other
71 design and habitat specifications, thus resulting in virtually infinite combinations and limited
72 generalizations. Several studies show an effective increase in detecting target species, usually
73 carnivores (Avrin et al., 2021; Du Preez et al., 2014; Holinda et al., 2020; Mills et al., 2019).
74 However, the use of attractants is not always warranted. For example, Braczkowski et al. (2016)
75 found that lures did not improve the recapture rates nor the precision of leopard population
76 estimates. As attractant effects are highly variable across species, there are also implications for
77 camera trap surveys for multiple species. Species responding differently to attractants might
78 undermine comparisons of spatial and temporal patterns because detection probabilities differ
79 among species (MacKenzie et al., 2017). For instance, the use of carnivore attractants can
80 negatively affect prey species (Rocha et al., 2016), although not always the case (Holinda et al.,
81 2020). Therefore, it is essential to determine the attractant effect on a wider range of species
82 before relying on CTs secondary data. In general, studies that evaluated the attractants
83 effectiveness in CTs surveys have been conducted mainly in temperate regions and
84 investigations in the Neotropics are still scarce (Espartosa et al., 2011; Ribeiro & Bianchi, 2019;
85 Rocha et al., 2016; Sebastián-González et al., 2020).

86 Using a multi-year multi-species dataset, we evaluated the attractant effect on species
87 CTs detections in a protected area in the Amazon to determine whether it is an efficient strategy
88 to increase the number and the quality of carnivores' records. We also aimed to reveal its effect

on a wider range of species. As our attractant was inaccessible for consumption (non-reward attractant), we considered it as a scent lure rather than a bait (Schlexer F. V., 2008). Employing two analytical frameworks often used in CT studies, we focus on three questions: (a) Does the lure influence the number of records of carnivores and other species? (b) How does the lure influence the species detection probability? (c) Does the lure enhance the quality of the photos regarding spotted cats' identification? We expected carnivores and opportunistic omnivores to be more attracted, whereas potential prey species would avoid lured stations. Following the same pattern, we hypothesized that the lure would increase the probability of detection of carnivores and reduce that of non-carnivores. We expected this effect to be stronger in the first weeks of sampling and to decrease as the lure aged and lost its attractiveness. Finally, we expected a higher proportion of high-quality photos in lured stations (spotted cats would be better positioned in front of the cameras).

MATERIALS AND METHODS

Study area

The study was conducted in Central Amazon, Brazil, in the Mamirauá Sustainable Development Reserve (1˚49' to 3˚09' S, 64˚45' to 67˚23' W). The Mamirauá Reserve is a 1.124.000 ha area of *várzea* floodplain forest (a rainforest wetland seasonally flooded) located at the confluence of the Amazon and Japurá rivers (Figure 1). Seasonality is defined according to the flooding cycle, with a flooded season (between May and July) and a dry season (between November and January) (Ramalho et al., 2009). The *várzea* forest is completely flooded by the Amazon River and its tributaries in the flooded season (IDSM, 2014). The forest is isolated by the large rivers and is

practically an island for species that cannot cross torrent waters. The land isolation and the flood-pulses act as filters, allowing only species adapted to the flooded habitat to thrive (Alvarenga et al., 2018). The regional climate is tropical humid, with a mean annual temperature of 29.5 °C and a mean annual precipitation of 2373 mm (Ayres, 1993).

Data collection

Camera trap deployment was conducted annually from 2015 to 2019 mainly in the dry season (see Table S1 for survey details). CT deployment was divided into major and minor grid sets, the major grid consisted of an array of 50 CTs stations with mean distance of 1.6 km between stations (grid area = 215 km², Figure 1). Minor grids with up to 41 additional stations were deployed annually in different locations within the major grid from 2015 to 2018 (mean distance between stations = 0.5 km, Figure 1). We used the same protocol in major and minor grid sets. In each CT station, two camera traps (Reconyx PC800 Hyperfire) were deployed facing each other, at 30 cm above the ground, fixed on trees distant 4–5 meters. The location of CTs stations were set in a stratified-random design, thus trails and other features were sampled in the proportion that they occured in the area. We only removed thin vegetation in front of the cameras. CTs were set to work 24 h and take 10 photos per trigger, without delay between triggers. Each year, we randomly-selected half of the stations of major and minor grids to receive a lure (Table S2) consisting of a mixture of sardine (125 g) and two eggs inside a vented container fixed on the ground central to the cameras. Sardine-based attractants are commonly used to study carnivores (Avrin et al., 2021; Duarte et al., 2018; Rocha et al., 2016; Sebastián-González et al., 2020). As we aimed to evaluate the duration of attractiveness, the lure was not replaced during sampling. The survey's sampling period was divided into two blocks, with half

of the CTs stations operating simultaneously, totaling 98 ± 14 sampling days per year, whereas CT stations were active for 45 ± 7 days, on average (Table S1).

Data analysis

We analyzed data from vertebrate species recorded every year and with at least 100 records in total, to assure model convergence (Table S3). We considered as independent records the records of a species at a CT station with more than 30 min interval. We assessed the effect of lure use and the interaction of lure and sampling occasion, as a measure of lure decay and consequent attractiveness reduction, on (1) the number of records (relative abundance models) and (2) the detectability for each species (occupancy/detection models), and on (3) the quality of camera trap photos for individual recognition of the naturally marked carnivores recorded (*Panthera onca* and *Leopardus wiedii*). The lure treatment was a binomial variable indicating 1 for lured stations in that sampling year or 0 otherwise. We divided the sampling period into 7-day occasions, starting from the first day the station was active. As most stations were not functional for more than 56 days, we restricted our analysis up to eight complete occasions (occasions with less than seven days were removed). To measure lure decay, we ordered the occasions from one to eight to create a variable representing the time since the lure was installed.

To model relative abundance data, we fitted a negative binomial generalized linear mixed model (GLMM) for each species (Bolker et al. 2009). The models consisted of the number of records per 7-day occasion as the response variable, with lure use and the interaction term for lure and lure decay as fixed effects (predictor variables). We included the year of survey and the CT station as random effects to account for the data nested structure. We assessed model coefficients' and p-value and ran an Analysis of Deviance (Type II Wald chi-square test) to

evaluate the importance of the fixed variables to the model. We removed the interaction term from the turkey vulture's *Cathartes aura* (herein vulture) model due to convergence issues. We did not include habitat-related variables in the model since our random design and paired treatment (lured vs. unlured) comprised a commensurate number of stations per treatment and habitat type, proportional to each habitat occurrence in the landscape (Table S4). GLMM residuals were inspected to assess model fit.

We also assessed the effect of lure use and lure decay on species' detection probability retrieved from occupancy models (MacKenzie et al., 2002). This framework uses species detection (1) or non-detection (0) by occasions – which are repeated samples of the same site, then allowing the model to accomodate imperfect detection (when the species is present but not recorded). We generated a matrix of detection or non-detection for each species, also restricted to eight occasions per season (i.e., year of the survey). Occasions began from the first day the station was active and were ordered to represent the lure decay over time. We included the number of days sampled in each occasion as a covariate to account for the difference in sampling effort between the final occasions. For this analysis, only stations from the major grid sampled all years were included (N = 46). We fitted dynamic occupancy models for each species assuming latent occupancy and dynamic states, as we were only interested in the lure effect on species detection probability (MacKenzie et al., 2003, MacKenzie et al., 2017). We evaluated the adequacy of models using goodness-of-fit tests based on Pearson's chi-square with 1000 boot-strapped samples (MacKenzie & Bailey, 2004). We compared our *a priori* hypotheses model to reduced models by AIC values and relative weights (Burnham & Anderson, 2002). For models with lack-of-fit, we adjusted estimated SEs multiplying it by the overdispersion parameter ($\hat{c}$) square-root and used QAIC for model selection when possible (MacKenzie & Bailey, 2004).

Finally, we evaluated the quality of CTs photos of the two spotted cats (jaguar and margay) between lured and unlured stations regarding their suitability for individual identification (e.g. Figure S1). First, we randomly selected 100 CTs records of each cat species (50 from lured and 50 from unlured stations) and, for each record, we selected the sequences of photos taken by one of the camera traps of the CT station that encompassed that record. Records of melanic jaguars or multiple individuals, and flash blinded photos were discarded. We then (1) classified the first 10 photos of each sequence as of high, medium, or low-quality, following a standardized protocol (Supplementary Information 2). Three experienced researchers classified the photos, after reaching more than 85% of agreement on training tests. The final classifications were checked together to avoid inconsistency. To assess whether lure increases the permanence of animals in front of the camera, we also evaluated the proportion of photos in which the animal appeared in the camera field of view. For that, we (2) divided the number of photos with the animal by the total number of photos of the sequence ("proportion of felid photos"), using the same 100 randomly-selected records of each spotted cat. We performed two GLM models with binomial distribution for each cat species to test the effect of lure use and lure decay in the (1) proportion of high-quality photos (relative to low and medium quality photos) and (2) proportion of felid photos. For this analysis, we selected only the records until the 7th occasion due to the low number of jaguar and margay records in the last occasions.

All analyses were performed in R (R Core Team, 2021). GLMM and GLM models were run using the packages 'glmmTMB' and 'lme4' (Bates et al., 2015; Brooks et al., 2017) and models' fitness were assessed using the 'DHARMa' package (Hartig, 2020). Detection and effort matrixes were built using the R-package 'camtrapR' (Niedballa et al., 2016). Multi-season occupancy models were fitted using the colext function from R-package 'unmarked' (Fiske &

Chandler, 2011) and 'AICcmodavg' (Mazerolle & Mazerolle, 2017) to model selection and goodness-of-fit tests.

RESULTS

We obtained 7942 independent records with an effective sampling effort of 17092 trapping days. Lured stations produced 4263 records in 8765 trapping days, with an average of 853 records per year whereas unlured stations produced 2378 records in 8327 trapping days, being 476 records per year on average (Table 1). Fourteen species accounted for 94% of the records. The common opossum *Didelphis marsupialis* (herein opossum) was the most recorded species (N = 3338), followed by the black-capped capuchin *Sapajus macrocephalus* (herein capuchin, N = 524). The Northern Amazon squirrel *Hadrosciurus* sp. (herein squirrel) and the green ibis *Mesembrinibis cayennensis* were recorded 108 and 106 times, respectively (Table S3). The number of records per occasion ranged from 0 to 36 but was usually 0 or 1 (mean = 0.19, SD = 0.85).

Number of records

The use of lure influenced the number of records (relative abundance data) of five of the 14 species evaluated. Three of them (opossum, vulture, and black-and-white tegu *Tupinambis teguixin* – herein tegu) were most recorded in lured stations. In contrast, two species (capuchin and squirrel) were recorded less frequently in lured stations (Table 1, Figure 2a). The lure was a significant variable in models of Brazilian porcupine *Coendou prehensilis* ($x^2 = 9.051$, $p = 0.002$) and black squirrel monkey *Saimiri vanzolinii* ($x^2 = 8.167$, $p = 0.004$). However, the effect was imprecise, as the confidence intervals overlapped zero (Figure 2a). The attraction effect of the lure was stronger when compared to the avoidance effect. In lured stations, the number of records decreased significantly over the occasions for vulture, opossum, tegu and porcupine

while increased for squirrel (Table 2). The interaction of lure and lure decay was a significant term in the models of these species ($p < 0.05$), but only marginal for the squirrel ($p = 0.057$). None of the carnivore records were strongly related to the use of lure (Table 2, Figure 2a).

Detection probability

Overall, detection probability estimates were congruent with the GLMM results concerning to lure use, although the estimates from the models were less precise (Figure 2b). In line with GLMM results, opossum's and tegu's detection probabilities were higher in lured stations and decreased over the occasions as the lure decayed (Figure 3). The lure had a negative effect on squirrel detection probability. However, the goodness-of-fit tests indicated overdispersion (Table 3), and confidence intervals overlapped zero after SEs correction. Vulture, porcupine, margay, and curassow's models presented high overdispersion, and poor model fit, so we did not proceed with the model selection for these species. The models with the interaction term between 'lure use' and 'lure decay' were not always the best models to adjust the detection probability of the target species. Nevertheless, lure use was within the top-ranked model selection for capuchin, black squirrel monkey, and grey-cowled wood-rail (Table S5). In the models without 'lure decay', the detection probabilities of the capuchin and the black squirrel monkey were lower in lured compared to unlured stations while the wood-rail estimates showed the opposite response, i.e., was higher in lured stations.

Photo quality

For both cat species, the number of high-quality photos and of felid photos were highly variable within sequences from lured and unlured stations (Figure S2), with no clear patterns. We found similar values between the two treatments (lured and unlured stations) considering all the

records. For example, jaguar had 144 high-quality photos out of 370 photos available (38.9%) in lured stations, and 123 high-quality photos from 332 available (37.0%) in unlured stations. A similar pattern was found for the number of felid photos, in both lured and unlured stations 74% of the photos had the jaguars in the image. However, the lure effect emerged when accounting for the lure decay factor. Considering only the sequences from records up to the 2nd occasion, the median of high-quality photos in lured stations was higher than in unlured stations for jaguars (Figure S3). In that scenario, jaguars had a higher proportion of high-quality photos (45.4%) and felid photos (76.7%) in lured stations than in unlured stations (31.5% high-quality photos and 68.3% felid photos). The jaguar's GLM binomial model corroborated this pattern, indicating that the proportion of high-quality photos and the proportion of felid photos were positively related to lure use and that lure effect decreased significantly over the time ($p < 0.001$; $r^2 < 0.16$. Table 4, Figure 4). In fact, 103 out of the 144 high-quality photos of jaguars were taken up to the 4th occasion. Margays however, showed no marked response to the presence of lure (Table S6) as lure use did not increase the proportion of high-quality photos or the felid photos in the species records. For that spotted cat, the proportion of felid photos in lured stations decreased over time, but there was no significant effect of lure use alone (Table 4).

DISCUSSION

We analyzed a five-year multi-species camera trap dataset with a robust treatment-control design consisting of randomly selected lured and control (unlured) stations in the Brazilian Amazon floodplains. To our knowledge, this is the largest quasi-experimental research on this topic in the Neotropics. Our findings suggest that the use of lure did not increase the number of records or the detection probability of carnivores in our study area. However, it increased the recording of opportunistic species such as opossum, vulture and tegu, while decreased for the

268 squirrel and two primates. The attractant had a variable effect across species, but it was
269 negligible for nine of the 14 vertebrates studied. We found a stronger effect of the lure when
270 considering the number of records than the detection probability. The lure increased the
271 proportion of photos suitable for individual recognition of jaguars, but only for the first two
272 weeks when the lure was fresh, suggesting it should be refreshed to enhance the proportion of
273 high-quality photos for the entire sampling period.

274 All species that showed attraction to lure had generalist or scavenger diets. The only
275 mammal among them was the opossum, a marsupial well-known to be attracted by baits
276 (Espartosa et al., 2011; Fidino et al., 2020; Gompper et al., 2006; Rocha et al., 2016). Opossum
277 records in lured stations were almost three times higher than in unlured stations in our study.
278 Nevertheless, the number of opossum records in unlured stations was already high, implying that
279 use of lure is expendable for detecting the species and is even detrimental, as it increases data
280 processing time. The other species most strongly attracted by the lure was the tegu, a large
281 terrestrial lizard with a diet plasticity that includes carrion (Kiefer & Sazima, 2002). Since the
282 lure mimics the scent of rotting carcasses, its great attraction to scavengers is not surprising. As
283 expected, the vulture was greatly attracted to lure, presenting 99% of records in lured stations,
284 which reflects its scent-guided scavenging behavior (Grigg et al., 2017). The effect of lure for
285 these three species decreased over time. Changes in detection probability over time, due to
286 attractant decay, have also been observed for small carnivores from Africa (Mills et al., 2019)
287 and North America (Avrin et al., 2021). Attractants of organic matter degrade faster than
288 synthetic ones (Avrin et al., 2021), especially in warmer environments where the climate favors
289 the decomposition process (Moseby et al., 2004). Our results endorse that lure decay is fast under
290 the Amazon environmental conditions, and lure attractiveness is reduced by the second week. In

North America, sardine lures lost efficacy on the 18th sampling day and authors suggested refreshment every two weeks (Avrin et al., 2021). This implies that 'time' must also be considered to correctly account for the variation in detectability due to the attractant effect, unless it was constantly refreshed. Lure replacement at short intervals could yield stronger effects on species' detection, but at extra costs that may be unfeasible in some circumstances, aside from potentially increasing human interference at sites or repel other species. These aspects must be considered according to study's goals, target species and available resources.

Our results concur with previous research in an adjacent Amazon reserve (Amanã SDR), where carnivore's prey species avoided CTs stations lured with the same attractant we used (Rocha et al., 2016). Although vertebrate communities of Amanã and Mamirauá reserves differs (Alvarenga et al., 2018), we also found a tendency of lure's negative effect on four species that are potential carnivore preys in the Mamirauá reserve (squirrel, porcupine, and the two primates). This behavior could be related to the association of putrefied smell of the lure to the presence of a predator. Primates are one of the items in the jaguar's diet in Mamirauá (Ramalho, 2012), and squirrels are described as part of margay's diet (Oliveira, 1998). In a similar methodological study Fidino et al. (2020) found that gray squirrels (*Sciurus carolinensis*) and fox squirrels (*S. niger*) took longer to be detected and were detected less often in lured sites in forest fragments of a metropolitan area in the USA. We assume the avoidance found for those arboreal and semi-arboreal species in our study were due to individuals refraining at least from descending to the ground at lured sites.

Contrary to our hypothesis, the lure was ineffective for increasing the detection of jaguars and margays, the carnivores most present in our study area. Regardless of studies that have shown that certain types of lures or baits increase the detection of carnivores (Buyaskas et al.,

2020; Du Preez et al., 2014; Holinda et al., 2020; Iannarilli et al., 2021), feline species locate their prey primarily by sight and hearing, being more responsive to visual than to scent stimuli (Kitchener, 1991). The olfactory stimulus may be insufficient to increase the records of felids, especially in a highly productive environment where prey is abundant (Braczkowski et al., 2016; Rocha et al., 2016), which is the case of the Mamirauá Reserve. Alternative attractants should be evaluated under rainforest conditions to increase carnivore detection in this environment.

Despite not increasing jaguar detections, the use of attractant may induce behavioral responses, such as slowing the pace or staying longer in the camera's field of view. This improved photo quality for jaguar individualization and yielded more photos of the animal that triggered the camera, at least in the first two 7-day occasions. Increasing the quality and the number of photos is important for accurate identification, especially for population studies that rely on capture-recapture analysis of marked animals (Karanth & Nichols, 1998; Silver et al., 2004). Nevertheless, researchers must consider the cost-effectiveness of using and renewing lures to obtain a 20% increase in the proportion of high-quality photos. In some cases, one high-quality photo by record is enough to identify an individual jaguar (Rocha et al., 2016). Cat species may even be attracted and interact with devices unrelated to prey stimuli, as camera traps themselves (Meek et al., 2016; Meek et al., 2014; Read et al., 2015). In our study, some records from unlured stations had a high proportion of high-quality photos. This might be explained by the behavior of inspecting and playing with the equipment, which increases the time the animal spends in front of the opposite CT and the likelihood of high-quality photos (see the video in Supplementary Information). That behavior was not observed for the margay, a small felid with a more evasive behavior.

We found similar trends in species responses using two different approaches, relative abundance data and occupancy models. The use of indices that do not explicitly account for imperfect detection, such as the number of records and relative abundance have been contested because the assumption of perfect detection (i.e. the species is detected if present) is unrealistic in the nature (Bailey et al., 2004; Mackenzie et al., 2002). Thus, these metrics could confound animal abundance/presence with detection/non-detection (Guillera-Arroita et al., 2014; Sollmann et al., 2013). As the response to lures differs between species, comparisons between studies or across species may therefore be biased if this effect on detection probability is not accounted for (MacKenzie et al., 2017; Tyre et al., 2003). Although there is a direct link between a species' number of records and its detectability, these two metrics are not the same and the differences we found reinforce this. While the lure affected the number of records of five species, we only found a strong effect in the detection probability of two species. The vulture, the capuchin monkey, and the squirrel showed a strong response to lure with the relative abundance modeling, but presented a weak response when using the occupancy approach. Among the reasons for these divergences, a likely explanation could relate to how the data is structured: to model the detection probability, records count is contracted into 1/0 at each 7-day occasion, which attenuates the effect size of the lure. In the vulture's case, a species strongly associated with the lure and rarely detected in unlured stations, the unbalanced data was probably the cause of the large SE's, which precluded the detection modeling from providing precise estimates (Banks-Leite et al., 2014; Welsh et al., 2013).

CONCLUSIONS

Here we demonstrate that the use of lure was ineffective in improving the detection of carnivores and had divergent effects in the vertebrate community. The use of attractants in CTs

studies must be carefully planned *a priori*, as species tend to respond differently to its presence – some demonstrate avoidance, others are attracted and, in some cases, species are neutral – which could lead to misleading comparisons among species or assemblages (Anile & Devillard, 2016). Hence, using lures can hamper the use of camera-trap data to estimate the relative abundance of carnivores' prey. Also, estimating species abundance from lured stations can lead stakeholders to draw erroneous conclusions about the conservation status of a given area. Furthermore, the use of attractants will not necessarily lead to increased detection of carnivores, as already shown in the literature (Braczkowski et al., 2016; Fidino et al., 2020; Mills et al., 2019; Rocha et al., 2016; Stokeld et al., 2015) and corroborated by this study. In the specific case of jaguars in the Amazon floodplains, we suggest that when using sardine and egg-based lures, they should be renewed every two weeks to ensure more CT photos of higher quality for individual recognition. If researchers decide to follow this path, though, it's important to consider the expressive increase of costs, time and efforts. In our case, field-related costs would double as well as the time and effort spent in the field. In addition, with the lure renewing, the number of records of non-target species would drastically increase – vultures would triplicate; tegus would duplicate and opossums would increase by half – which, in turn, would increase the time and effort spent organizing the data. With that in mind, we recommend the use of lures to situations where the target species is extremely rare and the lure use would significantly increase the records and improve photos quality.

379 **Table 1** Mean and standard deviation (SD) of the number of records per year and capture rate
380 (CR = total records/total trapping effort ×100) of the 14 species recorded in lured and unlured
381 stations from 2015 to 2019 in the Mamirauá Sustainable Development Reserve. Total trapping
382 efforts in lured and unlured stations were 8765 and 8327 trapping days, respectively

		Unlured		**Lured**	
Common name	**Species name**	**Mean ± SD**	**CR**	**Mean ± SD**	**CR**
Mammals					
Common Opossum	*Didelphis marsupialis*	162 ± 129	9.72	506 ± 319	28.85
Black-capped Capuchin	*Sapajus macrocephalus*	59 ± 24	3.52	46 ± 25	2.64
Black Squirrel Monkey	*Saimiri vanzolinii*	44 ± 11	2.64	31 ± 9	1.77
Brazilian Porcupine	*Coendou prehensilis*	37 ± 20	2.23	28 ± 5	1.61
Margay	*Leopardus wiedii*	18 ± 5	1.07	20 ± 2	1.13
Jaguar	*Panthera onca*	15 ± 6	0.88	16 ± 10	0.89
South American Coati	*Nasua nasua*	13 ± 3	0.80	13 ± 6	0.73
Northern Amazon Squirrel	*Hadrosciurus* sp.	14 ± 7	0.85	7 ± 4	0.42
Birds					

Razor-billed Curassow	*Pauxi tuberosa*	36 ± 18	2.14	40 ± 16	2.30
Grey-cowled Wood-rail	*Aramides cajaneus*	32 ± 20	1.92	35 ± 20	2.02
Turkey Vulture	*Cathartes aura*	0.4 ± 0.5	0.02	28 ± 17	1.59
Wattled Curassow	*Crax globulosa*	21 ± 4	1.26	24 ± 17	1.35
Green Ibis	*Mesembrinibis cayennensis*	8 ± 3	0.48	13 ± 10	0.75
Reptiles					
Black-and-white Tegu	*Tupinambis teguixin*	17 ± 16	1.02	45 ± 33	2.59
Total		**476 ± 230**	**28.56**	**853 ± 362**	**48.64**

383

Table 2 GLMM coefficients and standard error (SE) of fixed effect variables 'lure use' and 'lure decay' on the number of records per 7-day occasions for the 14 species recorded in the Mamirauá Sustainable Development Reserve from 2015 to 2019. The asterisks indicate model significance

Species	**Lure use**	**SE**	**Lure decay**	**SE**
Turkey Vulture[a]	4.842 ***	1.011	-1.444 ***	0.151
Black-and-white Tegu	2.318 ***	0.304	-0.312 ***	0.045
Common Opossum	2.041 ***	0.127	-0.210***	0.017
Grey-cowled Wood-rail	0.480	0.348	-0.001	0.053
Margay	0.234	0.340	-0.013	0.056
South American Coati	0.262	0.405	-0.021	0.067
Green Ibis	0.083	0.666	0.138	0.100
Wattled Curassow	-0.096	0.418	0.107	0.067
Brazilian Porcupine	-0.116	0.302	-0.150 **	0.056
Razor-billed Curassow	-0.189	0.263	0.056	0.042
Jaguar	-0.223	0.386	0.026	0.064
Black Squirrel Monkey	-0.447	0.260	0.026	0.046
Black-capped Capuchin	-0.482 *	0.208	0.038	0.035
Northern Amazon Squirrel	-1.399 **	0.511	0.194 *	0.085

[a]Turkey Vulture's model did not include the interaction term 'lure' and 'lure decay' due to model convergence problems. * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$

389 **Table 3** Occupancy model estimates of detection probability (p) and standard error (SE) for the
390 covariates 'lure use' and 'lure decay' for the species recorded in the Mamirauá Sustainable
391 Development Reserve. The Goodness of Fit tests results are included (ĉ > 1 and p-value < 0.05
392 indicates lack of fit). The asterisks indicate model significance

Species	**Lure use**	**SE**	**Lure decay**	**SE**	**Goodness of Fit (ĉ)**
Turkey Vulture	11.347	1161.498	5.268	781.959	36.000***
Black-and-white Tegu	2.724***	0.511	-0.456***	0.113	0.990
Common Opossum	1.734***	0.261	-0.200***	0.056	0.960
South American Coati	0.573	0.523	-0.180	0.116	0.510
Grey-cowled Wood-rail	0.507	0.484	0.022	0.105	0.690
Brazilian Porcupine	0.412	1.197	-0.125	0.267	6.730***
Jaguar	0.241	0.464	-0.093	0.106	1.310
Margay	0.108	1.429	-0.008	0.327	12.860**
Wattled Curassow	-0.015	2.503	-0.032	0.526	24.590***
Razor-billed Curassow	-0.091	2.662	-0.011	0.577	48.500***
Black-capped Capuchin	-0.475	0.424	0.060	0.093	1.700
Black Squirrel Monkey	-0.510	0.371	0.000	0.083	1.290
Green Ibis	-0.624	0.771	0.012	0.164	1.340
Northern Amazon Squirrel	-1.832	1.180	0.168	0.237	2.700*

393 * = p<0.05; ** = p<0.01; *** = p<0.001

394 **Table 4** GLM coefficients and standard error (SE) of fixed effect variables 'lure use' and 'lure
395 decay' on the proportion of high-quality photos and the proportion of felid photos of jaguar and
396 margay in Mamirauá Sustainable Development Reserve. The asterisks indicate model significance

Metric	Species	Fixed effects	Estimate	SE
Proportion of high-quality photos	**Jaguar**	Lure	0.841***	0.286
		Lure decay	-0.177***	0.054
	Margay	Lure	-0.012	0.311
		Lure decay	0.053	0.067
Proportion of felid photos	**Jaguar**	Lure	0.755***	0.198
		Lure decay	-0.125***	0.038
	Margay	Lure	0.151	0.255
		Lure decay	-0.173***	0.052

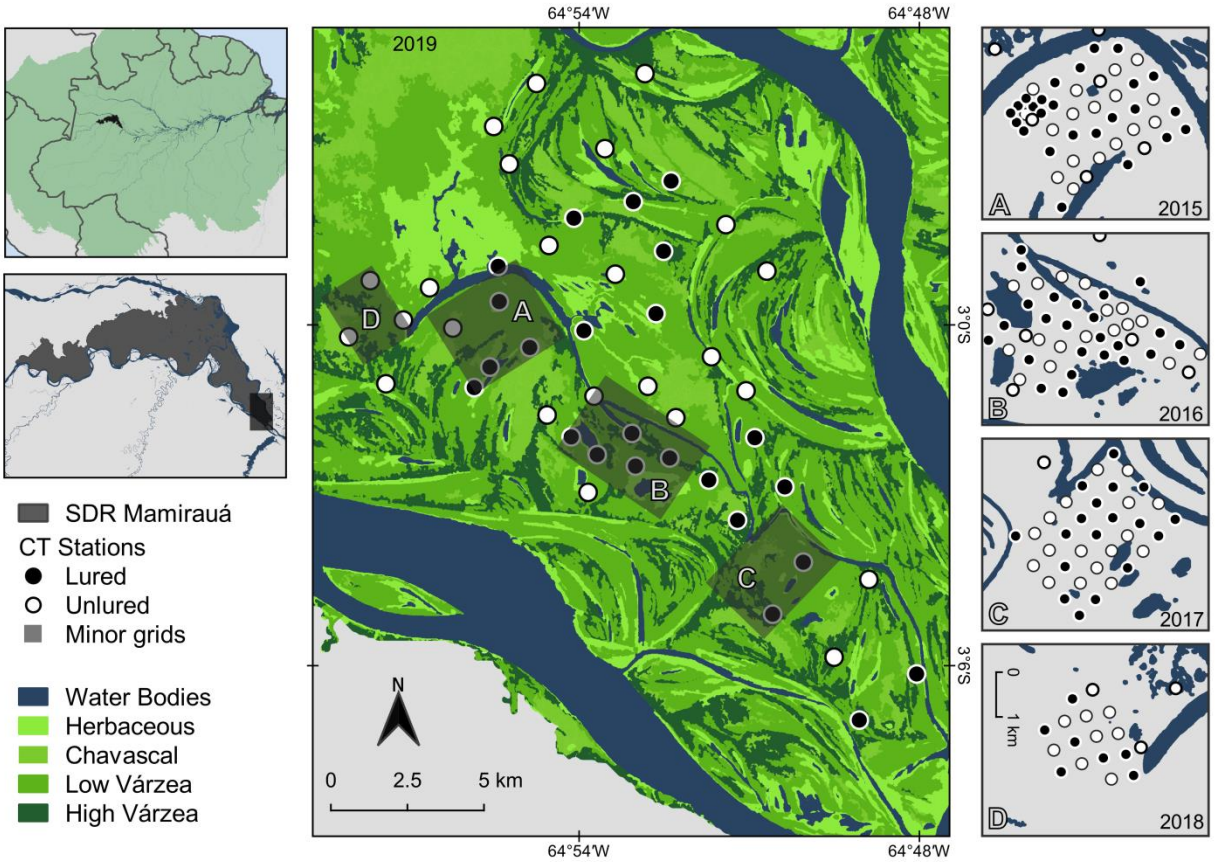
397 *= p<0.05; **=p<0.01; ***=p<0.001

Figure 1 The study area, located in Central Amazon, Brazil in the south portion of Mamirauá Sustainable Development Reserve. Circles represent camera trap stations within the study area, shaded areas represent the minor grid areas zoomed on the right. Black circles represent the randomly selected stations that received lure. The central map shows the configuration of the 2019 survey

Figure 2 Estimated difference (and confidence intervals) of (a) number of independent records per 7-day occasion and (b) probability of detection between lured and unlured camera trap stations, modeled for 14 vertebrates in Mamirauá Sustainable Development Reserve. Positive values of (a) GLMM coefficients or (b) estimated detection probability indicate higher number of records or detection probability in lured stations for the species, while negative values indicate higher number of records or detection probability in unlured stations. The lighter the blue color represents the species which the CI encompasses the zero, meaning that the difference between lured and unlured stations may be no different from zero. The Turkey Vulture's GLMM model did not include the interaction term between 'lure' and 'lure decay' due to model convergence problems and the estimated confidence intervals for the vulture's detection probability model were very large, so results are shown only in Table 4

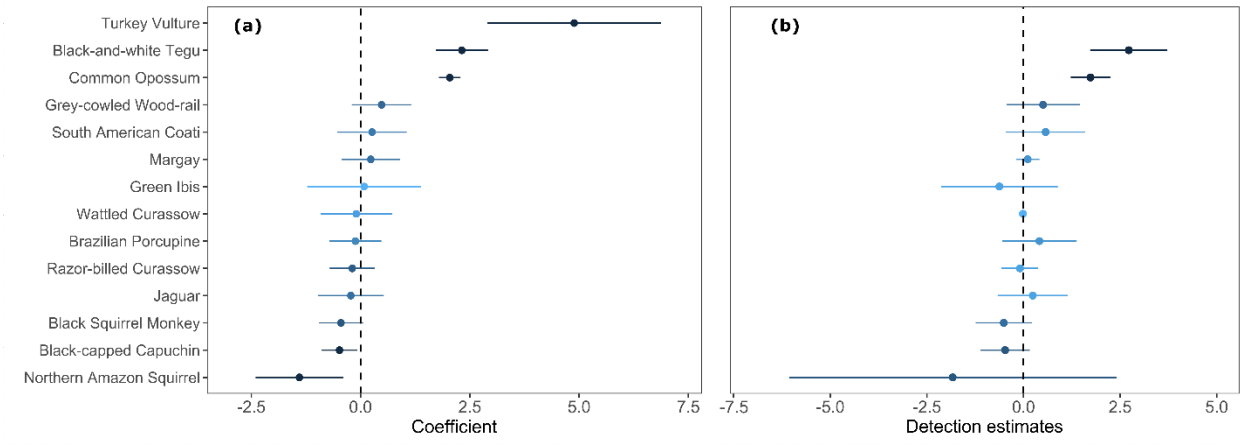
Figure 3 Detection probability estimates over the 7-day occasions (as lure decay) from lured and unlured CT stations for common opossum and black-and-white tegu. Predicted model estimates are relative to a complete sampling effort per occasion

Figure 4 Estimates of proportion of high-quality photos in the jaguar records between lured and unlured stations over 7-day occasions. $R^2 = 0.13$


64°54'W
64°48'W
2019
A
B
C
D
3°0'S
3°6'S
N
0
2.5
5 km
SDR Mamirauá
CT Stations
Lured
Unlured
Minor grids
Water Bodies
Herbaceous
Chavascal
Low Várzea
High Várzea
2015
2016
2017
2018
0
1 km

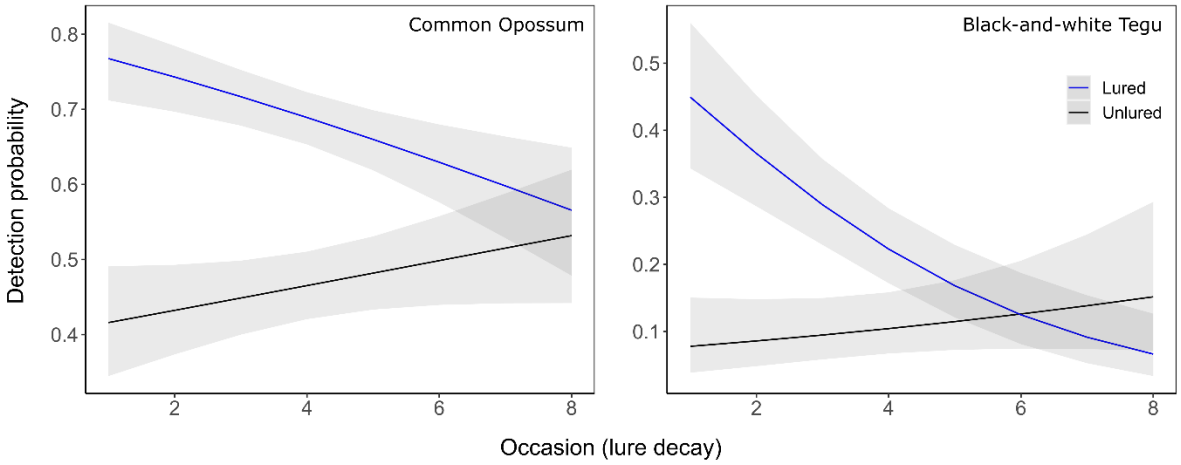
420

421


(a)
(b)
Turkey Vulture
Black-and-white Tegu
Common Opossum
Grey-cowled Wood-rail
South American Coati
Margay
Green Ibis
Wattled Curassow
Brazilian Porcupine
Razor-billed Curassow
Jaguar
Black Squirrel Monkey
Black-capped Capuchin
Northern Amazon Squirrel
-2.5
0.0
2.5
5.0
7.5
Coefficient
-7.5
-5.0
-2.5
0.0
2.5
5.0
Detection estimates

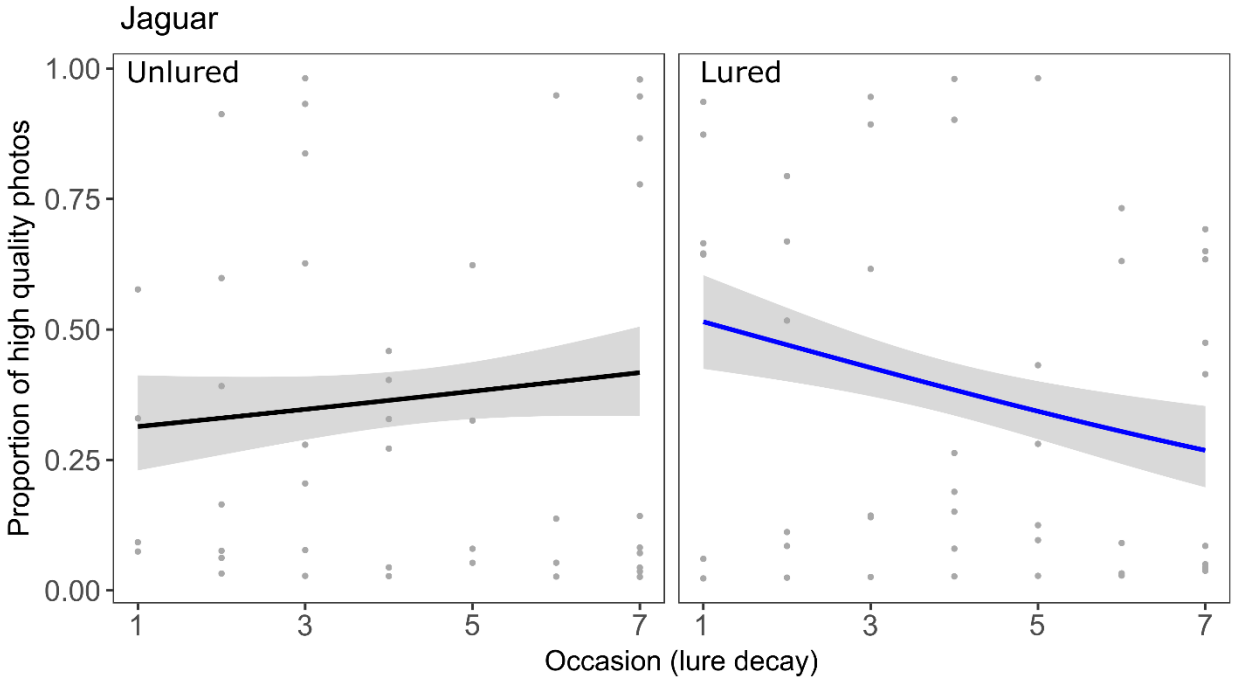
422

423


Common Opossum
Black-and-white Tegu
Lured
Unlured
Detection probability
Occasion (lure decay)
0.8
0.7
0.6
0.5
0.4
0.5
0.4
0.3
0.2
0.1
2
4
6
8

424

425


Jaguar
Unlured
Lured
Proportion of high quality photos
1.00
0.75
0.50
0.25
0.00
1
3
5
7
Occasion (lure decay)

426

427

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Authors' contributions

Conceptualization: DB, GCA, FBB, EER, DMG.

Methodology: DB, GCA, DMG, FBB, EER.

Formal analysis: DB, GCA, FBB.

Writing – original draft: DB.

Writing – review & editing: DB, GCA, FBB, DMG.

DISCLOSURE STATEMENTS

Conflicts of interest/Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Availability of data, code and material

The data that support the findings of this study are available on request from the authors or the Mamirauá Institute for Sustainable Development.

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