Assessing the effectiveness of attractants to increase camera trap detections of North American mammals

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Abstract

Camera traps are a cost-effective tool for large-scale and long-term population monitoring of mammals. Either bait or lure is often used to attract animals in front of a camera; however, the relative efficiency of these two attractants, or their combination, is not well understood. Our objective was to determine the optimal attractant setup for maximizing detection probabilities of mammals in the northeast USA. We conducted a camera trapping project in northern Maine, USA, from August to November 2018, and tested three distinct attractant treatments against a control. Sampling stations were a minimum of 5 km apart, and consisted of four camera units spaced 100 m apart, and paired with one of the four setups: (1) bait plus lure (treatment), (2) bait (treatment), (3) lure (treatment), and (4) camera only (control). Detection data on 11 species of mammals were collected from 41 stations and analyzed through multi-method occupancy models. We totaled 4280 photo-trap-nights and captured 37,781 images. Results showed that the combination of bait plus lure was the most effective for increasing detection probability of carnivores. Specifically, bait plus lure proved to be particularly effective for mustelid species, while lure was particularly effective for American black bear (*Ursus americanus*). While attractant usage was shown to be ineffective for increasing detection probability of non-carnivores, it also did not decrease effectiveness. Based on our results, we recommend the simultaneous use of both bait and lure as attractants when conducting camera trapping work on mammals. The combination of bait and lure appears to maximize detection of carnivore species, while simultaneously having minimal effects on the detection of other taxa.

Keywords Bait · Camera trap · Carnivores · Detection probability · Lure · Mustelids · Occupancy models

Introduction

Cost-effective and reliable monitoring protocols are of the utmost importance in the field of wildlife research and conservation. Recent advancements in field monitoring technology have shifted away from invasive live-capture studies, towards less-invasive methods (Burton et al. 2015; Mortelliti and Boitani 2008a). Camera trapping, a tool that has long been used to monitor mammals, has been at the forefront of this paradigm shift (O'Connell et al. 2011; Rovero et al. 2013; Rowcliffe and Carbone 2008). Camera traps are now recognized as a cost-effective tool for large-scale and long-term population monitoring (Steenweg et al. 2017), particularly for cryptic or low-density species such as carnivores (Foresman and Pearson 1998; Long et al. 2008; Stokeld et al. 2015). Several studies have evaluated the effectiveness of this method, through comparison with other detection techniques such as track plates (Williams et al. 2009) and snow tracking (Clare et al. 2017), as well as research focused on optimizing sample size (Evans et al. 2019; Shannon et al. 2014; Stokeld et al. 2015) and camera placement and orientation (Jacobs and Ausband 2018; Meek et al. 2016a, b; Nichols et al. 2017; Swann et al. 2004).

Despite the increasing wealth of published knowledge on the best use of camera traps, there are still several knowledge gaps regarding their optimal use, such as the effectiveness and consequences of different attractant types (Burton et al. 2015; Steenweg et al. 2017). An attractant is defined as a substance that attracts a species of interest and helps to increase its detection, thus optimizing survey effort (Long

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et al. 2008), and facilitating species identification (Monterroso et al. 2011). When employed, typical attractants used in carnivore studies are baits and lures (Schlexer 2008): baits attract an animal via smell or taste, typically in the form of a food item (Zielinski and Kucera 1995); lures attract animals through vision, smell or hearing (Harrison 1997). The work of Austin et al. (2017) shows that when used effectively, these attractants can reduce sampling effort and survey cost, especially in surveys of elusive and cryptic mammals like carnivores (Long et al. 2008; Thorn et al. 2009). We note that unintended consequences can arise from use of attractants, such as increased inter- and intraspecific contact and risk of disease transmission (Mills et al. 2019), among other concerns. Much work has been done investigating attractant usage for single species such as brown hyena (*Hyaena brunnea*) in Botswana (Thorn et al. 2009), felids in Australia and South Africa (Du Preez et al. 2014; Stokeld et al. 2015), northern quoll (*Dasyurus hallucatus*) in Australia (Austin et al. 2017), and red fox (*Vulpes vulpes*) in Europe (Hegglin et al. 2005), among others. Only a few studies, however, have investigated the effectiveness of attractants for improving the detection of multiple species within a community. Examples of multi-species studies include Paull et al. (2011), studying non-carnivore small mammals in Australia, and studies of carnivores in the Iberian Peninsula, southern Europe and southern Africa (Ferreira-Rodríguez and Pombal 2019; Ferreras et al. 2017, 2018; Satterfield et al. 2017).

There is a need for greater understanding of optimal game camera usage in surveys of cryptic and elusive species (Paull et al. 2011), specifically for the use of attractants for maximizing detection probability, as there is a lack of protocol standardization at multi-species and community levels (Carreras-Duro et al. 2016; Ferreras et al. 2017; Gommper et al. 2006). In particular, there have been few assessments of optimal attractants for an entire mammalian guild including both carnivores and non-carnivores (see Fonju 2011 for an example). Additionally, the combination of bait and lure at the same site as an attractant has received limited attention (but see Jordan and Lobb-Rabe 2015); therefore, the relative efficiency of these two attractants used in combination is not well understood.

Our objective was to contribute in filling this knowledge gap and determine the attractant combination that maximizes detections of mammals in Maine, using American beaver (*Castor canadensis*) as bait and striped skunk (*Mephitis mephitis*) essence as lure. Specifically, we aimed to simultaneously compare all of the following methods to each other: (1) bait plus lure, (2) bait, (3) lure and (4) no bait and no lure (control). There have been past assessments of optimal attractants for urban carnivores (Andelt and Woolley 1996; Jordan and Lobb-Rabe 2015), and one study on attractants for a guild of local species in New Mexico (Fonju 2011). We believe that our study adds valuable information because of our methodology, scale of study, and investigation of efficacy for one attractant used to survey both carnivore and non-carnivore taxa. Our results may be useful to managers throughout much of North America and Europe, where species similar to those studied in our project are found (Monterroso et al. 2016; Mortelliti and Boitani 2008b; Torretta et al. 2017).

Materials and methods

Study area

Our study area in northern Maine, USA, is located in the Acadian Forest zone, a transitional forest type between northern boreal and temperate deciduous forests (Huff and McWilliams 2016; Seymour and Hunter 1992). Surveys were conducted in three study areas: the area immediately west of Chesuncook Lake (CL 46°01′48.03″N, 69°33′33.09″W), the area immediately east and northeast of the Clayton Lakes (Round Pond [RP] 46°40′19.01″N, 69°13′37.53″W), and finally the Scientific Forestry Management Area (SFMA 46°10′05.53″N, 69°02′45.48″W) of Baxter State Park and its surroundings (Fig. 1). The entire study area is forested and commercially harvested for timber products, typically via shelterwood cuts, with the exception of the SFMA, which is overseen by Baxter State Park as an area of less-intensive experimental harvest practices. These regions all have similar climate conditions, and the average temperature of the region for our fall study season is 12.8 °C, with a mean annual precipitation of 112 cm (NOAA 2010). The dominant tree species are conifers, mainly consisting of spruces (*Picea spp.*), eastern white pine (*Pinus strobus*) and balsam fir (*Abies balsamea*); while, the hardwood stands are an assortment of green, white and black ash (*Fraxinus pennsylvanica, fraxinus americana, fraxinus negro)*, birches (*Betula spp.*), American beech (*Fagus grandifolia)*, and silver and red maple (*Acer saccarinum* and *acer rubrum)*.

Medium- to large-sized mammals that occur in our study area include: American marten (*Martes americana*), fisher (*Pekania pennati*), Canada lynx (*Lynx canadensis*), bobcat *(Lynx rufus)*, long- and short-tailed weasel (*Mustela frenata and M. erminea*), American black bear, eastern coyote (*Canis latrans*), red fox, white-tailed deer (*Odocoileus virginianus*), snowshoe hare (*Lepus americanus*), American red squirrel (*Tamiasciurus hudsonicus*), northern flying squirrel (*Glaucomys sabrinus*), moose (*Alces alces*), raccoon (*Procyon lotor*), North American porcupine (*Erethizon dorsatum*) and striped skunk.

Field methods

Camera trap surveys were conducted by deploying *stations* (sensu Nichols et al. 2008), a minimum of 5 km apart,

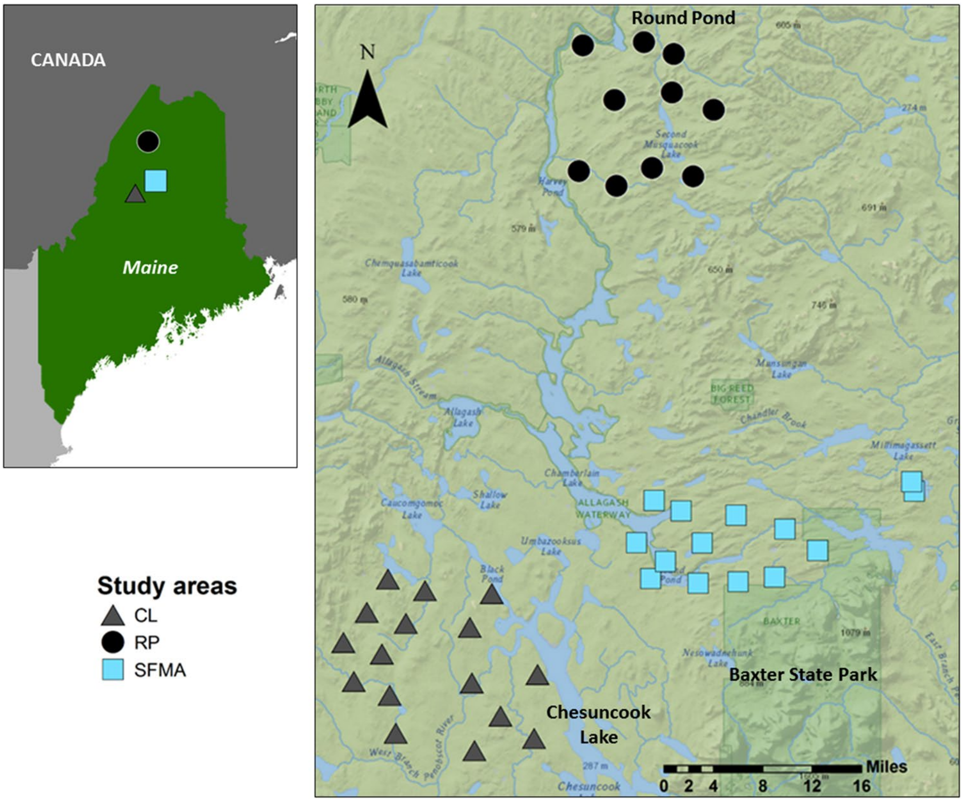

Fig. 1 Three study areas assessed using squares of four cameras in north and central Maine, USA. 16 squares were deployed in the Chesuncook Lake (CL) area during August–September 2018, 15 squares were deployed in the Scientific Forestry Management Area (SFMA) of Baxter State Park/ Scraggly Lake state lands in September–October 2018, and 10 squares were deployed in the Round Pound (RP) region in October–November 2018

each comprised of four *sampling devices* placed in a square configuration, 100 m on each side. Each sampling device included one Bushnell Trophy Cam Essential 2 passive infrared (PIR) trail camera (Overland Park, Kansas, USA), and one of the four attractant treatment types: (1) bait plus lure (treatment), (2) bait only (treatment), (3) lure only (treatment) and (4) camera only (control). Bait was American beaver carcasses, cut to standard size ($\bar{x} = 0.22$ kg) and wired to a tree approximately 2 m in front of the camera at an average height of 30 cm above the ground (Evans et al. 2019). The lure was a Vaseline-based scent lure designed to attract furbearers (skunk essence and Vaseline based, Kenduskeag, Maine, USA) applied to a tree in front of the camera at head height, and again at bait level. The stations were deployed using randomized target locations, and the sampling devices were set by selecting trees with minimal vegetation between them. Placement of four treatments within the square was systematically randomized in relation to each other and the road access point, to ensure there was no bias.

Cameras were placed low to the ground, with an average height from lens to ground of 34 cm, in an effort to maximize detections of smaller species (Swann et al. 2004) and avoid false triggers associated with the movement of trees and background foliage, both of which increase with greater height of camera placement (Meek et al. 2016a, b). The camera unit nearest the road access point was always placed at a distance of 50 m from the road for consistency of road condition effect, which was a categorical covariate assessed in analyses. Cameras were programed to take a single image for every PIR trigger event, and to record time-lapse images at 03:00 and 15:00 to capture weather events impacting performance, in accordance with Evans et al. (2019). Camera sensor sensitivity was set to medium. On average, cameras were deployed for 24.9 days (range 20–28), exceeding the recommended deployment time for carnivore surveys of 2 (Moruzzi et al. 2002) or 3 weeks (Jones and Raphael 1993).

Analytical methods

We created detection histories for each sampling unit by tagging images with Recoynx MapView Professional™ software (Holmen, WI, USA). Species detection histories were created in the form of 0 (not detected) and 1 (species detected) for all images within a 24-h period at a given camera unit. This was done in accordance with previous camera trap studies of similar size (Mills et al. 2019; Shannon et al. 2014), which also used 24-h detection periods. A 24-h time period also helps to avoid bias of any nocturnal or diurnal animals in detection results. A minimum of 10 stations with detections was required for a species to be included in our analysis. Detection history data were exported into program PRESENCE (Version 12.25), in which we fitted single season multi-method occupancy models (Nichols et al. 2008) for the eleven target species meeting our detection criteria (observed at more than 10 sites). The key parameters estimated by the multi-method occupancy models (Nichols et al. 2008) are *psi* (occupancy probability of the whole station, that is the probability that a member of the target species occupies a home range and uses the landscape surrounding the survey station), *theta* (probability of presence at the immediate sampling device conditional on occupancy of the array) and *p* (probability of detection given that both the overall area is occupied and the species is in the immediate area of the survey devices). We emphasize that this model allows for dependence between the different methods (i.e., between the four cameras, or sampling devices, spaced 100 m apart) (Nichols et al. 2008). Models were ranked based on the Akaike Information Criteria score, corrected for small sample size (AICc).

The *first step* in our modeling process was to compare the relative fit of models, which allowed detection to vary between treatments with models holding all treatments constant. *Step two* in our modeling process accounted for the effects of additional individual covariates affecting detection probability (Table 1). Covariates included were: (1) Time since deployment (TSD), as the count of days since first deployed to account for trap shyness (Foresman and Pearson 1998; Gommper et al. 2006). (2) Road condition (RC) to gauge the effect of development and proximity to human infrastructure on detection probability (Kowalski et al. 2015; Rich et al. 2016; Sirén et al. 2017) and that was defined on a scale of 0–5 (Table 1) based upon maintenance and use level. "0" represented well-maintained roads used for recreation and logging activity, with posted speed limits of 40 mph or greater, and "5" represented roads that were completely abandoned or undriveable by 4 × 4 vehicle. (3) We also included a variable for study area (Area) to account for any underlying variation between our study areas (e.g., deployment period).

In the *third step* of our modeling process, covariates included in models within 2 ΔAIC of the top ranking model were included in additive models (Burnham and Anderson 2002). Inference was conducted through model averaging including all models within 2 ΔAIC (Table 1).

Results

We deployed 41 stations of four cameras each from 29 August to 4 November, 2018. We totaled a survey effort of 4280 total trap-nights and captured 37,781 images. Of all species, American red squirrel was detected on at least one camera in the greatest number of stations (41), followed by ruffed grouse (40), northern flying squirrel (38), snowshoe hare (37), short-tailed weasel (37), American marten (28), fisher (26), eastern coyote (24), American black bear (22), moose (22), and white-tailed deer (20). The two resident felid species, Canada lynx and bobcat, had insufficient detections for inclusion in our analysis, at 6 stations for the former and 0 for the latter.

For all carnivore species, models including method were top ranked; whereas, the null model was top ranked for four of the six non-carnivore species (Table 1). For non-carnivores, only ruffed grouse and American red squirrel showed an effect of method in the top model set (Table 1).

For all carnivores, camera sites with one of the attractant methods had higher detection probability estimates than control sites (Fig. 2a). Detection probability increase was greatest for mustelid species; as an example, the probability

Table 1 Top-ranked occupancy models for eleven species surveyed with trail cameras in Maine, USA

Species	Model	ΔAICc	Wgt
Martes americana	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{TSD})$	0	0.78
Mustela erminea	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area} + \text{TSD})$	0	1
Pekania pennati	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area})$	0	0.59
Canis latrans	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area})$	0	0.62
Ursus americanus	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{RC} + \text{Area} + \text{TSD})$	0	0.55
Odocoileus virginianus	$\Psi(.)$, $\Theta(.)$, $p(.)$	0	0.46
	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{RC} + \text{TSD})$	0.82	0.31
Alces alces	$\Psi(.)$, $\Theta(.)$, $p(. + \text{Area})$	0	0.92
Lepus americanus	$\Psi(.)$, $\Theta(.)$, $p(. + \text{Area} + \text{TSD})$	0	1
Glaucomys sabrinus	$\Psi(.)$, $\Theta(.)$, $p(. + \text{TSD})$	0	0.98
Tamiasciurus hudsonicus	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area} + \text{TSD})$	0	0.80
Bonasa umbellus	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area})$	0	0.72
	$\Psi(.)$, $\Theta(.)$, $p(\text{Method} + \text{Area} + \text{TSD})$	1.84	0.29

Only top ranking models within 2 ΔAICc (Akaike's information criterion corrected for small sample size) are shown

Wgt—Akaike model weight, *TSD*—time since deployment, *RC*—road condition

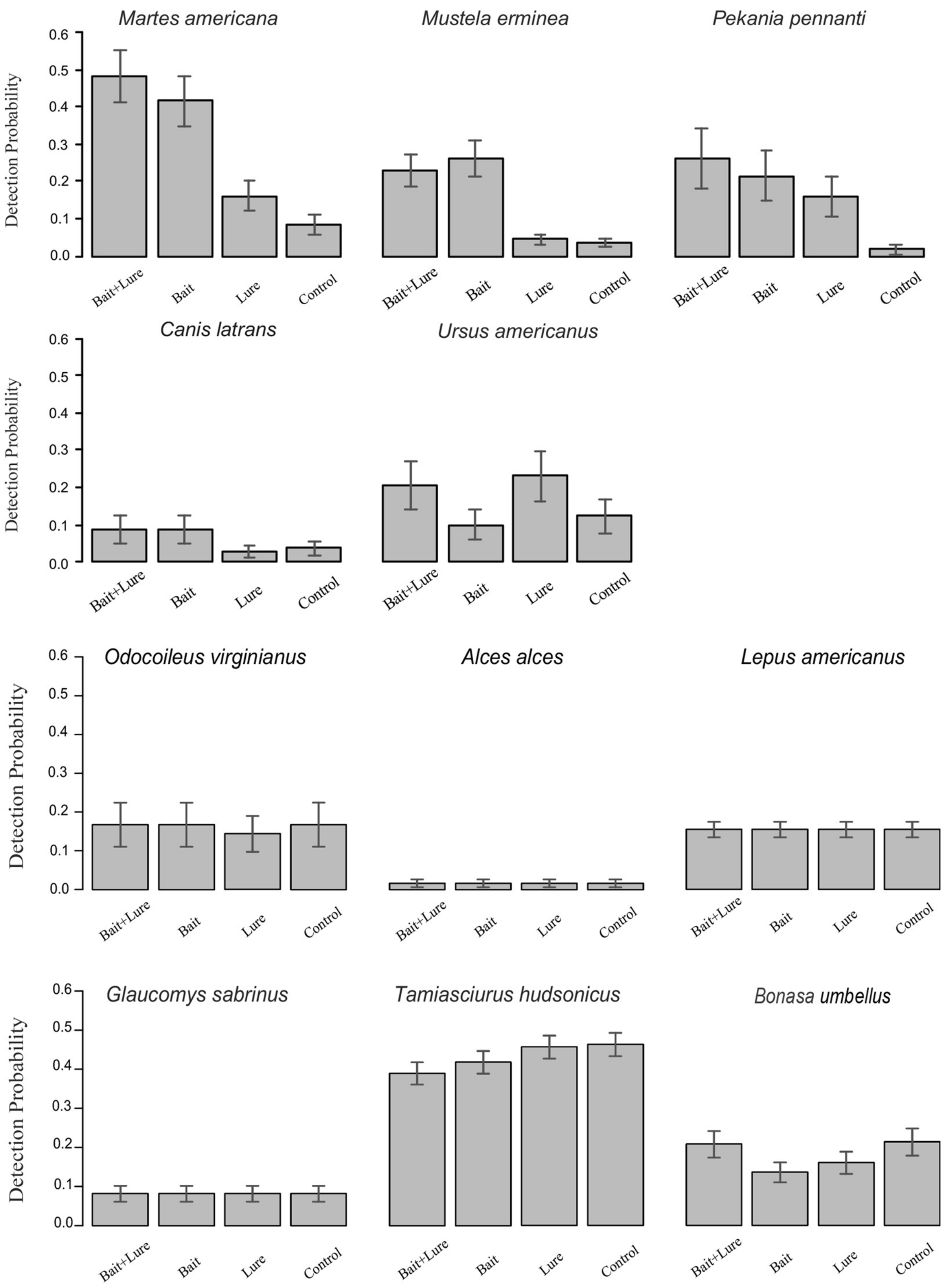

Fig. 2 Model-averaged predicted detection probabilities and standard errors for five carnivore (**a**) and six non-carnivore (**b**) species native to Maine, USA. When derived from models including the study area parameter, results are shown for Chesuncook Lake (CL). When detection probability was a function of road condition, results are displayed for condition level "2" defined as a road that is of average maintenance, and when the variable "Time since deployment' was included in top ranking models results for day 1 are displayed

of detection of American marten was very low without bait and lure ($P_{\text{control}} = 0.082 \pm 0.028$) but it increased to a much higher value with bait and lure ($P_{\text{bait+lure}} = 0.482 \pm 0.070$). For carnivores, bait only and lure only were consistently more effective than the control (except for American black bear), but not as effective as bait plus lure, which we found to be the most effective overall carnivore community attractant.

For non-carnivore species, the difference in detection probability for camera sites with attractant methods versus control sites was minimal (within a three percent change), with the exception of the American red squirrel, which experienced a 16% decline in detection probability at bait plus lure sites, and ruffed grouse, which experienced a 18% and 9% decline for bait plus lure and lure only (Fig. 2b). No consistent influence from attractant usage, positive or negative, was observed for non-carnivores.

Of our four tested covariates, study area was included in the top model set for eight out of eleven species; whereas, time since deployment (TSD) was included in the top model set for seven out of eleven species (Table 2). All species with TSD in top models experienced a decreasing detection probability with each passing trap night. Road condition (RC) was found to influence the detection of the American black bear and the white-tailed deer (Table 2). Both species showed an increase in detection probability with a decrease in level of road usage; road condition—0, $p = 0.156$ to road condition—5, $p = 0.404$ for the American black bear, and road condition—0, $p = 0.138$ to road condition—5, $p = 0.238$ for the white-tailed deer.

Discussion

Our findings indicate that the use of attractants in camera trapping surveys maximized the detection of carnivores; whereas, it was not effective for other taxa. A combination of bait and lure at the same site was identified as the most effective attractant for surveying northeastern carnivore communities. Use of bait only and lure only were the second and third most effective attractants in our carnivore community. Lure was notably more effective than bait for American black bear and bait was notably more effective than lure for mustelids, which also had a much greater chance of being detected with attractant use than other carnivores. While attractant usage was shown to be ineffective for increasing detection probability of non-carnivores, it also did not decrease effectiveness (i.e., control sites were equally effective as attractant sites for detection of non-carnivore taxa). It should also be noted that we were unable to record a sufficient number of station observations to draw any reportable

Table 2 Influence of camera array features on detection probabilities for eleven mammal and avian species native to northern Maine, USA, surveyed in fall of 2018

Variable	Species	Impact	SE
RC	*Odocoileus virginianus*	0.29	0.11
	Ursus americanus	1.45	0.12
TSD	*Glaucomys sabrinus*	−0.05	0.01
	Lepus americanus	−0.03	0.02
	Martes americana	−0.06	0.02
	Mustela erminea	−0.07	0.01
	Odocoileus virginianus	−0.06	0.02
	Tamiasciurus hudsonicus	−0.02	0.01
	Ursus americanus	−0.05	0.03
Area	*Alces alces*	SFMA(0.057) > CL(0.016) > RP(0.012)	0.01 > 0.00 > 0.00
	Bonasa umbellus	CL(0.209) > SFMA(0.102) > RP(0.086)	0.02 > 0.01 > 0.01
	Canis latrans	SFMA(0.134) > CL(0.089) > RP(0.059)	0.05 > 0.04 > 0.02
	Lepus americanus	RP(0.290) > SFMA(0.186) > CL(0.159)	0.03 > 0.02 > 0.02
	Mustela erminea	RP(0.552) > SFMA(0.339) > CL(0.243)	0.05 > 0.04 > 0.03
	Pekania pennati	SFMA(0.274) > CL(0.263) > RP(0.087)	0.07 > 0.08 > 0.04
	Tamiasciurus hudsonicus	SFMA(0.412) > CL(0.394) > RP(0.332)	0.03 > 0.02 > 0.02
	Ursus americanus	SFMA(0.202) > RP(0.184) > CL(0.164)	0.08 > 0.07 > 0.07

Road condition (RC) was defined on a scale of 0–5 based upon maintenance and use level; with “0” representing well-maintained roads used for recreation and logging activity, with posted speed limits of 40 mph or greater, and “5” representing roads that were completely abandoned or undriveable by 4 × 4 vehicle. The three study areas were the Scientific Forestry Management Area of Baxter State Park (SFMA), Chesuncook Lake (CL), and Round Pond (RP). Impact numbers represent the slope of the beta estimate for road condition and time since deployment, and the probability of detection for bait plus lure attractant for each study area conclusions for the two felid species known to inhabit our study area, Canada lynx and bobcat.

The combination of bait and lure as an attractant was particularly effective for all mustelid species, especially American marten and fisher, and slightly less effective than bait for short-tailed weasel (within confidence intervals, Fig. 2a). Compared to mustelids, the use of our attractants for eastern coyote and American black bear was less successful in maximizing detection probability, despite increases in detection probability for both species. For the eastern coyote, detection probability was the same for both bait plus lure and bait only ($p = 0.1$ for both). American black bear had sizeable increases in detection probability with the use of lure only and bait plus lure, while bait only was less effective than control. In comparison, use of bait plus lure was not more effective than control for non-carnivore taxa, but we note that it did not cause any decreases in detection probability, and thus was not detrimental either.

The use of meat baits as effective attractants for mustelids is consistent with previous findings on similar European species such as the stone marten (*Martes foina*) (Ferreras et al. 2018). The use of meat baits alone, however, was ineffective for American black bear, resulting in a similar detection probability to control sites (Fig. 2a). It should be noted that our field sampling was conducted at the height of Maine's bear hunting season, when bears are hunted over bait stations, with large piles consisting of a wide variety of bait that is a much stronger attractant than the small pieces of meat we used, so this may have influenced our results.

We found low probabilities of detection for the eastern coyote, which are in line with the work of Gommper et al. (2006), suggesting that the eastern coyote is wary of human scent at bait stations. Consideration of human presence at the monitoring site should be taken into account in study design. If the study design protocol requires frequent site visits for rebaiting, care must be taken to assure that the species of study is known to be resilient to effects of human presence; otherwise, such a protocol may not be suitable. In our research, suet cages were used to contain the beaver meat attractant, which greatly impeded the ability of animals to take the bait away from the camera site. This in effect turned the beaver meat into a scent-lure non-reward bait, as opposed to a first visitation bait (Braczkowski et al. 2016; Gerber et al. 2012). Similar solutions to the above should be employed to reduce the need for rebaiting visitations to the site and, thus, reduce human presence at sites.

We recommend that future studies on optimal attractant usage consider seasonality in their study design, and its possible effects on detection probability. Indeed, any factor affecting food availability and habitat use should be considered as it may affect the results (Mortelliti and Boitani 2008b; Prigioni et al. 2008).

Additional factors affecting detections

We observed different responses among species for two of our additional explanatory covariates (road condition and study area) included in our models. Road condition had an effect on American black bear and white-tailed deer, with both species experiencing increased detection probabilities as level of road use decreased. Our results do not entirely corroborate past research that has shown negative effects of road proximity on carnivore presence (Mata et al. 2017; Moriarty et al. 2011). Both the stone marten (*Martes foina*) (a congeneric species to the American marten), and the weasel (*Mustela nivalis*) use roads as territory boundaries in Europe (Mata et al. 2017). Many canids regularly mark and travel the boundaries of their territory (Gese and Ruff 1997), which would lead us to expect increased eastern coyote presence along major roads; however, this was not observed.

Previous research of Mills et al. (2019) indicated potential for baited surveys to result in inter-specific competitive exclusion. While we did not see any evidence of predator–prey competitive exclusion in our research, we did observe clear differences in carnivore attractant preference. As previously mentioned, American black bear exhibited a much greater preference for lure than bait, and the opposite is true for mustelids. Incorporating the use of attractants that are effective to increase detection on a species-specific level while reducing likelihood of interspecific interactions, can potentially aid in preventing negative inter-specific interactions like aggression or parasite transmission. It should be noted that while we did not find evidence of competitive exclusion in our research, we were not able to analyze the effect of the two largest carnivores of this landscape and our forest and mammalian system of study is vastly different from that of Mills et al. (2019) research. Thus, future researchers should take great care to account for potential negative effects of inter-specific interaction in their specific area of study, as results may change accordingly.

Time since deployment had an effect on seven species. For all species, we found a very small decrease in detection probability (< 0.03) with each passing trap night, which is likely resultant to the decreasing appeal of bait as it decays (bait) and weakens (lure). Eventually, the continued deployment of these attractants will reach a point of diminishing return, where the increased length of deployment will be nullified by the decreased attractant effectiveness. Researchers and managers will need to account for a suite of factors when determining if the use of attractants is beneficial for their specific survey. Areas of greater heat and humidity may experience increased bait decay rates and, thus, decreased efficiency, similar to the results seen by Mills et al. (2019) where our protocols may be unsuitable.

Through our analyses, we found a potential effect of study area for eight species (Table 1). Among the eight species, the highest detection probability occurred most frequently in the SFMA area (5 species), while the lowest detection probability was most frequent in the RP area (5 species) (Table 1) and the CL area had the greatest average detection probability across all eleven species. Several factors may have determined these results, such as prey availability and forest stand structure. A further consideration is that seasonality may impact the detection of species, and, thus, the order of deployment (CL, then SFMA, then RP) may have contributed to differences between areas. More detailed investigation was beyond the scope of this study, but these results warrant further research to improve our mechanistic understanding of factors affecting detection probability.

Conclusions

Based on our results, we recommend the use of both bait and lure as attractants when conducting research or monitoring with camera traps. The combination of bait and lure would maximize detection of carnivore species, while simultaneously having minimal effects on the detection of other taxa.

The type of attractant most effective for maximizing detection probability is likely to vary between regions and species. As such, a pilot study to determine the most cost-effective attractants should be conducted prior to the start of the project, unless prior empirically supported research on attractants for species of interest in the region is available. We observed that the use of attractants resulted in near negligible effects on detection probabilities for all six non-carnivore species in our analysis. In other study designs and study areas, which may contain different non-carnivore species communities, attractant usage may be effective, warranting further research.

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