Assessing the Effectiveness of Attractants to Increase Detection Probabilities in Northeastern Mammals

Michael Buyaskas
ASSESSING THE EFFECTIVENESS OF ATTRACTANTS TO INCREASE
DETECTION PROBABILITIES IN NORTHEASTERN MAMMALS

by

Michael Buyaskas

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Advisory Committee:
Alessio Mortelliti, Assistant Professor of Wildlife Habitat Conservation, Advisor
RW Estela, Professor in Honors College
Bryn Evans, Graduate Research Assistant in Wildlife Fisheries and Conservation
Biology
Daniel Harrison, Professor of Wildlife Ecology
Walter Jakubas, Mammal Group Leader Department of Inland Fisheries and
Wildlife
ABSTRACT

A primary problem with camera trapping in wildlife occupancy studies is the failure to detect an animal when it is present at the site. My objective was to determine the optimal attractant setup for maximizing detection probabilities of northeast mammalian communities. I carried out an camera trapping project in northern Maine, USA from August to November 2018, and tested 3 distinct attractant setup. Sampling stations consisted of four camera units, and each sampling unit constituted either a treatment or a control: 1) bait + lure (treatment), 2) bait only (treatment), 3) lure only (treatment), and 4) camera only (control). Data analysis was conducted in program PRESENCE, using a single season, multi-method occupancy modeling framework. Results showed that the combination attractant of bait + lure was the most effective for maximizing detection probability of carnivores. Bait + lure also proved to be particularly effective for mustelid species, while ‘lure only’ was particularly effective for American black bear (*Ursus americanus*). Use of attractants was shown to have nearly no effect on detection probability of non-carnivore taxa.
DEDICATION

To my Aunt Sue, for providing the initial inspiration that has launched me into a career that has become more of a lifestyle. To the many people who have given value to the many amazing places I have been so lucky to visit, you have inspired and motivated me. Lastly, to my brothers in Alpha Tau Omega who turned into my mentors, I would still be a shy kid without the confidence you inspired in me. Love is your boys!
ACKNOWLEDGMENTS

There are many people, places and landscapes I have to thank for inspiring me to chase my dreams and reach this point. My advisor, Alessio, and my committee for putting their faith in my abilities to conduct a rigorous scientific study. Specifically, my committee member, Bryn Evans, for her constant assistance, upbeat personality and endless amount of questions answered. To my parents who afforded me the financial means to chase my dreams wherever they led me, and the patience to entertain my boundless imagination.
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INTRODUCTION

In the field of wildlife management, effective and reliable monitoring protocols are of the utmost importance. Recent advancements in monitoring technology have shifted away from invasive live-capture studies, towards less invasive methods (Burton et al. 2015). Camera trapping, a tool that has long been used in wildlife management (Kucer and Barret 2011), has been at the forefront of this paradigm shift (O’Brien 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. 2016), particularly for cryptic or low-density species such as carnivores (Long et al. 2008, Foresman and Pearson 1998, Stokeld et al. 2015). Several studies 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 (Shannon et al. 2014, Stokeld et al. 2015), camera placement and orientation (Jacobs and Ausband 2018, Meek et al. 2016, Nichols et al. 2017, Swann et al. 2010).

Despite the increasing wealth of published knowledge on best use of camera traps, there are still several key knowledge gaps regarding their optimal use, such as the use and effectiveness 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 detection probability; thus, optimizing survey effort (Schlexer 2008), and facilitating species identification (Gil-Sánchez et al. 2011, Monterroso et al. 2011). 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 (Hunt et al. 2007; Schlexer 2008; Thorn et al. 2009). 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 (Stokeld et al. 2015, Du Preez et al. 2014), northern quoll (*Dasyurus hallucatus*) in Australia (Austin et al. 2017), and red fox (*Vulpes vulpes*) (Heggelin et al. 2014), among others. Only a few studies, however, have investigated the effectiveness of attractants for improving the detection of an entire carnivore guild; Paul et al. 2011 studied non-carnivore small mammals in Australia, and carnivore guilds were studied by Ferreras et al. 2017, Ferreras et al. 2018, and Ferreria-Rodriguez et al. 2019 in the Iberian Peninsula and southern Europe, and by Satterfield et al. 2017 in southern Africa.

There is a need for greater understanding of optimal game camera usage in surveys of cryptic and elusive species (Paul et al. 2011), specifically with regard to attractant usage for maximizing detection probability, as there has previously been a lack of protocol standardization over a multi-species and community level (Carreras-Duro et al. 2016, Ferreras et al. 2017, Gompper et al. 2006). In particular, there have been few assessments of optimal attractants for an entire mammalian community, of both carnivores and non-carnivores (see Fonju 2011 for an attempt). Additionally, the combination of bait + lure at the same site as an attractant has not been assessed before (but see Jordan and Lobb-Rabe 1996), therefore the relative efficiency of these two attractants in combination is not well understood. My goal is to contribute in filling this knowledge gap.
My research aim is to determine the attractant combination for a guild of northeastern carnivores that maximizes their detection probability on a species-specific level, using beaver (*Castor canadensis*) as bait and skunk (*Mephitis mephitis*) essence as lure. Specifically, I aim to simultaneously compare all of the following methods to each other: 1.) bait + lure, 2.) only bait, 3.) only lure and 4.) only control. Common carnivores and herbivores present in my study area include: American marten (*Martes americana*), fisher (*Pekania pennati*), Canada lynx (*Lynx canadensis*), bobcat (*Lynx rufus*), long (*Mustela frenata*) and short-tailed weasel (*Mustela erminea*), American black bear (*Ursus americanus*) and eastern coyote (*Canis latrans*), white-tailed deer (*Odocelious virgianus*), 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 (*Mephitis mephitis*). There have been past surveys of optimal attractants for urban carnivores (Andelet and Wooley 1996, Jordan and Lobb-Rabe 2015), and one study of limited scope on best attractants for a guild of local species in New Mexico (Fonju 2011). I believe that my study adds valuable information to the aforementioned literature, due to differences in the methodology of my attractant setup, scale of study, and inclusion of efficacy for one attractant used to survey both carnivore guilds and the surrounding non-carnivore taxa.

My work, in combination with appropriate modeling techniques, will help inform the best methodology for maximizing detection probability in camera trapping surveys of northeast mammals, specifically carnivores, and limit the effects of imperfect detection, thus resulting in more efficient data collection efforts. Furthermore, my results are useful
to managers throughout much of North America and Europe, where species similar to those studied in this project are found (Monterroso et al. 2016, Torretta et al. 2017).
STUDY AREA

My study area in northern Maine occurs in the Acadian Forest zone, a transitional forest type between northern boreal and temperate deciduous forests (Seymour and Hunter 1992, McWilliams et al 2003). Surveys were broken up into three regions: the area immediately west of Chesuncook Lake (CL), the area immediately east and northeast of the Clayton Lakes (Round Pond – RP), and finally the Scientific Forestry Management Area (SFMA) of Baxter State Park and its surroundings (Fig. 1). The entire study area is heavily forested and under pressure from regular forestry harvest, typically shelterwood cuts, with the exception of the SFMA, which is overseen by Baxter State Park as an area of less intensive experimental harvest. These regions all have similar climate conditions, and the average temperature of the region for our fall study season is 12.8° C. 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 saccharinum* and *acer rubrum*).
METHODS

Field Methods

Camera traps were deployed using randomized target locations across northern and central Maine. All camera sampling units consisted of one Bushnell Trophy Cam Essential 2 passive infrared (PIR) trail camera (Overland Park, Kansas, USA). Four cameras were deployed in each station (sensu Nichols et al 2008) with a minimum distance of 5km between stations. Each camera constituted a sampling device, and these were arranged in a square orientation and spaced 100 meters apart (Fig 2). Each sampling device constituted either a treatment or a control: 1) bait + lure (treatment), 2) bait only (treatment), 3) lure only (treatment) and 4) camera only (control) (Fig. 2). Placement of treatments in the square was systematically randomized in reference to each other and the road access point, to ensure there was no bias. The lure was a Vaseline based scent lure designed to attract furbearers (skunk essence and Vaseline based, Kenduskeag, Maine, USA) applied to the tree at head height, and again at bait level. Bait was beaver (Castor canadensis) carcasses, cut to standard size ($\bar{X} = 0.298 \pm 0.05$) and wired to a tree 2.1 meters in front of the camera (Evans et al (In Press) at a height of 31cm above the ground.

Cameras were placed low to the ground, with an average height from lens to ground of 34 cm, in an effort to maximize small mammal detections (Swann et al 2010) and avoid false triggers associated with tree movement and background foliage movement, both of which increase with greater height of camera placement (Meek et al 2016). The camera unit nearest the road access point was always placed at a distance of
50 meters from the road for consistency of road condition effect, which was a categorical covariate assessed in analysis. 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 (*In press*) methodology. 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 two (Moruzzi et al 2002) or three weeks (Jones and Raphael 1993).

**Analytical Methods**

I created detection histories for each sampling unit by tagging images with **Recoynx MapView Professional™** software (Holmen, WI, USA). Resulting data files were exported into Microsoft Office Excel for formatting. These detection histories were then exported into program PRESENCE (Version 12.25, Hines 2006), in which I fitted single season multi-method models (Nichols et al. 2008) for each of the eleven target species. Models were ranked based on the Akaike Information Criteria (AICc) score, corrected for small sample size (Hurvich & Tassi 1989). The key parameters estimated by the multi-method occupancy models (Nichols et al 2008) are $\psi$ (occupancy probability of whole array), $\theta$ (probability of presence at the immediate sample unit conditional on occupancy of the array) and $p$ (detection probability).

The first step in my modeling process was a comparison of models with method (i.e., effect of attractant method accounted for) versus no attractant method. Step two in my modeling process accounted for the effects of additional individual covariates affecting detection probability (Table 1). Covariates included were: 1) *Effectiveness*, to
account for trap shyness and effectiveness of attractants over time at each device 
(Foresman and Pearson 1998, Gompper et al 2006), 2) Road condition to gauge the effect
of development and proximity of human infrastructure on detection probability of
carnivores (Kowalski et al. 2015, Rich et al. 2016, Siren et al. 2017) and was defined on a
scale of 0 – 5 (Table 1) based upon maintenance and use level. “0” represents roads that
were completely abandoned or unnavigable by truck, and “5” represents well maintained
roads used frequently for recreation and logging activity. I also included a variable for
study area (Area) to account for any underlying variation between our study areas
(Chesuncook Lake, CL, Scientific Forestry Management Area, SFMA, and Round Pond, 
RP).

In the third and final step of my modeling process, covariates shown to be ranked
within 2 ΔAIC were included in additive models and retained for final inference, in
congruence with Burnham et al. 2011. Top models from the detection process were
selected and retained for each species (Table 1). When more than one model was highly
competitive, I used model averaging to compute estimates by averaging across all models
within 2 ΔAIC.
RESULTS

I deployed 41 stations of four cameras each for three to four weeks (mean 24.9 days, range 20-28) from 29 August to 4 November, 2018. I recorded 4,280 total trap-nights of data and captured 37,781 PIR-triggered 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 (29), fisher (26), eastern coyote (24), American black bear (22), moose (22), and white-tailed deer (20).

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

For all carnivores, camera sites with one of the attractant methods had higher detection probability estimates than those of control sites (Figure 3a). Detection probability increase was greatest for mustelid species, with an average eight fold increase between ‘control only’ sites and bait + lure sites; the increase in detection probability ranged from a nearly six fold increase ($P_{control} = 0.082 \pm 0.028$ to $P_{bait+lure} = 0.482 \pm 0.070$) for American marten to a 15 fold increase ($P_{control} = 0.048 \pm 0.068$ to $P_{bait+lure} = 0.263 \pm 0.080$) for fisher, compared with smaller increases for non-mustelid carnivores (less than two fold increases). The difference in detection probability for camera sites with attractant methods versus control sites is within a three percent change for non-carnivores, except for American red squirrel, which experienced a 16% decline in
detection probability at bait + lure sites, and ruffed grouse, which experienced a 18% and 9% decline for bait + lure and lure only (Figure 3a,3b). For carnivores, bait only and lure only were consistently more effective than control (except for American black bear), but not as effective as bait + lure, which is the most effective overall carnivore community attractant. An effective attractant for maximizing detection probability of non-carnivore communities was not identified.

Of my four tested covariates, Study Area and Method were most frequently included in top ranked models, at eight out of eleven models for the former and seven for the later (Table 1, Table 1). These variables were followed by effectiveness, at seven of eleven models, for most frequently included variable (Table 1, Table 1). All species experiencing effects from effectiveness exhibited decreasing detection probability with each passing trap night. ‘Road condition’ was found to be of importance for American black bear and white-tailed deer detection (Table 1, Table 1). Both American black bear and white-tailed deer 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 former, and road condition – 0, p = 0.138 to road condition – 5, p = 0.238 for the latter.
DISCUSSION

My findings indicate that the use of attractants in camera trapping surveys of mammalian carnivore communities effectively maximizes detection probability, but attractants are not effective for other non-carnivore taxa. A combination of bait + 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; mustelids 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. For the entire carnivore community, control sites were extremely ineffective at detecting animals, while control sites were equally effective as attractant sites for detection of non-carnivore taxa.

A in depth analysis shows the combination of bait + lure as an attractant is particularly effective for all mustelid species, especially American marten and fisher, and slightly less effective than bait only for short-tailed weasel. Compared to mustelids, the use of my 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 + lure and bait only (p = 0.1 for both) and only increases by p = 0.06. American black bear had sizeable increases in detection probability, but the use of lure only was more effective, while bait only was less effective than control. In comparison, use of bait + lure was not
effective for any non-carnivore taxa, but also did not cause any large 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, the Stone marten (*Martes foina*) (Ferreras et al. 2018). The use of meat baits alone, however, specifically beaver meat, is shown to be ineffective for American black bear, resulting in a lower detection probability than control sites (Figure 3). It should be noted that my field sampling was conducted at the height of Maine’s bear hunting season, where bears are hunted over bait stations of 55-gallon drums filled with a wide variety of bait that is a much stronger attractant than the small pieces of meat we used. Additionally, the work of Gompper et al. 2006 has shown the eastern coyote in particular is wary of human scent at bait stations and often has a low probability of detection. This makes sense for my detections and the seemingly wary behavior of many coyotes at my camera sites, characterized by cautious approaches and shorter duration of stay than other species. It should also be noted that many studies have successfully identified attractants that effectively increase detection probability for many non-carnivore taxa: peanut butter and rolled oats for small mammals in Australia (Paul et al. 2011) and salt licks for white-tailed deer in Texas (Koerth and Kroll 2000).

I demonstrate that employing the use of attractants at remote camera sites, in the occupancy modeling framework, can be a cost-effective way of increasing detection probability. I observed detection probability increases within my sampled carnivore guild sufficient to enable a decrease in length of deployment period by up to half (Mackenzie and Royal 2005) and greatly increase accuracy of estimates (Mackenzie and Royal 2005). This allows more rapid turnover of cameras, enabling greater total
sampling effort (Burton et al. 2015). These changes are due to increased length of animal stay at camera sites, and a reduction in failed identifications, resultant of attractant use (Gil-Sánchez et al. 2011; Monterroso et al. 2011, Karanth and Nichols 1998), coupled with greater initial incentive to visit the camera site, in the form of bait. Attractants, however, were shown to have minimal effect on the non-carnivore members of my community and were unable to help provide an effective community level solution to the problem discussed in Austin et al. 2017, which is a lack of empirically supported attractant options for non-carnivore mammalian communities, a problem that still warrants further research. It should also be noted that many unbaited camera surveys are plagued by low detection probabilities (Du Preez et al. 2014). Baited camera surveys, such as mine, are a cost-effective solution when able to attain bait donations for free (Du Preez et al. 2014), but incur much greater costs without the same luxury of access to a continuous supply of free bait, which constitutes a majority of studies (Balme et al. 2014). I contend that while this is a very important point, the degree of cost incurred depends upon bait usage; Du preez et al. 2014 set out whole impala legs, which could become extremely costly. I used small pieces of beaver meat in suet cages, 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 non-reward bait, which is essentially a scent lure as opposed to a first visitation bait (Gerber et al. 2012; Braczkowski et al. 2016).

I built upon the work of previous attractant studies, mainly taking place in the Iberian Peninsula. In a fairly young area of limited research, a great amount about optimal sampling for mesocarnivore guilds remains unknown (Satterfield et al. 2017). With the first assessment not occurring until 2011 (Monterrose et al. 2011), and many studies have
been unable to identify a specific attractant that effectively samples mesocarnivores across the entire guild. My results have suggested a clear and empirically supported option for an effective mesocarnivore guild attractant, in the combination of beaver meat and skunk essence lure. I was also able to fill a knowledge gap for the eastern US, where there has been a previous lack of robust investigation on attractant selection on the carnivore guild level. Fonju 2011 conducted work in New Mexico that investigated the use of optimal attractant usage; however, he did not include any bait attractant in his study design, and I show that this is an important facet to consider in optimizing attractant usage for study of mesocarnivore guilds. It is my recommendation that future studies on optimal attractant usage consider seasonality in their study design, and its possible effects on detection probability, resultant to differences in food availability, hyperphagia, dispersal, hibernation, competitive exclusion and other things known to change carnivore food preference (Ditmer et al. 2015, Prigioni et al. 2008).

I observed different responses among species for two of my site characteristics (road condition and study area) included in my models. Road condition only had an effect on American black bear and white-tailed deer, which both experienced increased detection probabilities as level of road use increased. My results do not entirely corroborate past research conducted in Europe, of Mata et al. 2017 and Moriarty et al. 2011, that has shown negative effects of road proximity on carnivore presence and behavior. Both the stone marten, a sympatric species to American marten, and the weasel have been shown to use roads as territory boundaries in Europe (Mata et al. 2017). Many canids are also known to regularly mark and travel the boundaries of their territory (Gese and Ruff 1996, Hutchings and White 2000) which would lead me to expect increased eastern coyote
presence along more major roads, however this was not observed. Effectiveness was the only site characteristic to be constant for all seven species for which it had an effect on. For all species the effect resulted in a very small decreased 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. I was unable to establish what this point is, but I was able to show the aforementioned negative trend that will eventually lead to such a point.

Seven species had an effect of study area present in their top model (Table 1). Among the seven species, the highest detection probability occurred most frequently in the SFMA (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. Even though table one shows a majority of species selecting for the SFMA, nearly all of the detection probability estimates for non-carnivores were almost equivalent to the detection probability estimates produced for the CL area (within six percent), while the guild wide carnivore detection probability estimates were noticeably increased in the CL study area.

I also would like to note that detection processes evidently vary by species. Had I observed the same number of Canada lynx in all study areas, as I did in the RP study area, I would have been able to include them in my analysis. This leads into discussion of potential factors affecting detection probability, within my study areas that were beyond the purview of sampling ability for this study. Factors such as prey availability,
forest stand structure, and time of year (there was a month and a half difference between start of CL and start of RP sampling) all warrant further investigation to determine their exact effects on detection probability. Hence, I endorse the use of *a priori* pilot studies when prior empirical study is lacking, to optimize survey effort and research efficiency.
MANAGEMENT IMPLICATIONS

My recommendation to researchers and managers is to use both a bait and lure as attractants at each camera site when conducting research with camera traps, which will effectively increase detections while simultaneously decreasing chances of collecting insufficient data and using resources inefficiently. I found bait + lure to be the most effective attractant, and bait only and lure only to be the second and third most effective attractants for increasing detection probability in carnivore guilds. ‘Bait only’ is an effective attractant for four of five carnivore species, and use of ‘lure only’ as an attractant is only effective for the American black bear. Additionally, my attractants were not effective for maximizing detection probabilities of non-carnivore taxa, but also did not cause any large decreases in detection probability either, and can be safely used for carnivores without negatively affecting sampling of these other taxa.

The type of attractant most effective for maximizing detection probability is likely to vary between regions and specific species. As such, a pilot study to determine what those attractants are should be conducted prior to the start of all camera trapping projects employing the use of attractants, unless prior empirically supported research on attractants for species of interest in the region is available. I 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. For similar species of other regions, primarily in North America and Europe, usage of my same attractants should garner similar results in
 optimizing detection probability. Further research is warranted to determine efficacy of use for these same attractants on carnivores within my own study area in different seasons, to account for potential seasonal effects such as prey availability, dispersal, hyperphagia, etc. In my research, there were differences in detection probability between study areas, and with time since attractant deployment. I recommend careful consideration and potential further study of forest stand composition and its effects on detection probability, as well as potentially rebaiting sites during study period.
APPENDIX

Table 1. Influence of camera array features on detection probabilities for eleven mammal and avian species native to northcentral Maine, USA, surveyed in fall of 2018. Road condition was defined on a scale of 0 – 5 based upon maintenance and use level; with “0” representing roads that were completely abandoned or unnavigable by truck, and “5” representing well maintained roads used frequently for recreation and logging activity. The three study areas were the Scientific Forestry Management Area of Baxter State Park (SFMA), Chesuncook Lake (CL), and Round Pond (RP).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Species</th>
<th>Impact</th>
</tr>
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<tbody>
<tr>
<td>Road Condition</td>
<td><em>Odocoileus virginianus</em></td>
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</tr>
<tr>
<td></td>
<td><em>Ursus americanus</em></td>
<td>+</td>
</tr>
<tr>
<td>Effectiveness</td>
<td><em>Glaucomys sabrinus</em></td>
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<tr>
<td></td>
<td><em>Lepus americanus</em></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Martes americana</em></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Mustela erminea</em></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Odocoileus virginianus</em></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Tamiasciurus hudsonicus</em></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Ursus americanus</em></td>
<td>-</td>
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<tr>
<td>Area</td>
<td><em>Alces alces</em></td>
<td>SFMA&gt;CL&gt;RP</td>
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<tr>
<td></td>
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<td>CL&gt;SFMA&gt;RP</td>
</tr>
<tr>
<td></td>
<td><em>Canis latrans</em></td>
<td>SFMA&gt;CL&gt;RP</td>
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<tr>
<td></td>
<td><em>Lepus americanus</em></td>
<td>RP&gt;SFMA&gt;CL</td>
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<td><em>Mustela erminea</em></td>
<td>RP&gt;SFMA&gt;CL</td>
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<td><em>Pekania pennati</em></td>
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<td><em>Tamiasciurus hudsonicus</em></td>
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<table>
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<th>Species</th>
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<th>WGT</th>
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<td>American marten (<em>Martes americana</em>)</td>
<td>$\psi()$, $\Theta()$, p(method+Latency)</td>
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<td>$\psi()$, $\Theta()$, p(m+Area)</td>
<td>0</td>
<td>0.616</td>
</tr>
<tr>
<td>American black bear (<em>Ursus americanus</em>)</td>
<td>$\psi()$, $\Theta()$, p(m+Road+Condition+Area+Latency)</td>
<td>0</td>
<td>0.553</td>
</tr>
<tr>
<td>White-tailed deer (<em>Odocoileus virginianus</em>)</td>
<td>$\psi()$, $\Theta()$, p( )</td>
<td>0</td>
<td>0.461</td>
</tr>
<tr>
<td></td>
<td>$\psi()$, $\Theta()$, p(m+Road+Condition+Latency)</td>
<td>0.82</td>
<td>0.306</td>
</tr>
<tr>
<td>Moose (<em>Alces alces</em>)</td>
<td>$\psi()$, $\Theta()$, p(+Area)</td>
<td>0</td>
<td>0.92</td>
</tr>
<tr>
<td>Snowshoe hare (<em>Lepus americanus</em>)</td>
<td>$\psi()$, $\Theta()$, p(+Latency+Area)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Northern flying squirrel (<em>Glaucomys sabrinus</em>)</td>
<td>$\psi()$, $\Theta()$, p(+Latency)</td>
<td>0</td>
<td>0.978</td>
</tr>
<tr>
<td>American red squirrel (<em>Tamiasciurus hudsonicus</em>)</td>
<td>$\psi()$, $\Theta()$, p(m+Area+Latency)</td>
<td>0</td>
<td>0.804</td>
</tr>
<tr>
<td>Ruffed grouse (<em>Bonasa umbellus</em>)</td>
<td>$\psi()$, $\Theta()$, p(m+Area)</td>
<td>0</td>
<td>0.715</td>
</tr>
<tr>
<td></td>
<td>$\psi()$, $\Theta()$, p(m+Area+Latency)</td>
<td>1.84</td>
<td>0.285</td>
</tr>
</tbody>
</table>

*Table 1.* Top-ranked occupancy models for eleven species surveyed with trail camera transects in Maine, USA. Only the top model and any models within ΔAIC < 2 are shown (using Akaike’s information criterion). WGT is the model weight, and par is number of parameters.
Figure 1. Three study areas surveyed 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 arrays were deployed in the Round Pound (RP) region in October-November 2018.
Figure 2. Square configuration of a trail camera station deployed in northern Maine in fall of 2018, where the numbering on the cameras (1-4) signifies their position within the square. Each station contains four treatment types (bait + lure, only bait, only lure, and control) randomized in orientation to each other, with one treatment at each camera.
Figure 3. Top model and model-averaged detection probabilities and standard errors for five carnivore (3A) and six non-carnivore (3B) species native to Maine, USA. All depicted detection probability estimates assume local and daily species availability. 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 effectiveness was included in top ranking models results for day 1 are displayed.
Figure 3. Top model and model-averaged detection probabilities and standard errors for five carnivore (3A) and six non-carnivore (3B) species native to Maine, USA. All depicted detection probability estimates assume local and daily species availability. 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 effectiveness was included in top ranking models results for day 1 are displayed.
LITERATURE CITED


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AUTHOR’S BIOGRAPHY

Originally from Clifton Park, New York, and a graduate of Christian Brothers Academy in Colonie, NY, Michael is a Wildlife Ecology major. At the University of Maine, he is member of the Beta Upsilon chapter of the Alpha Tau Omega fraternity. Previously, he served on the ATO executive board for two years as House Manager, was the Vice President of Club Track, and Vice President of Academics for the InterFraternity Council. Over the years, he has developed a strong passion for outdoor activities such as rock climbing, hiking, backpacking and canoeing. He has a deep-seated love for running, dating back to his high school days of cross country and track. Michael has also found a fervent love of travel while in university, having visited 39 states and 8 countries during his time at college. He has held positions in his field across the United States and will be leaving The University of Maine to start a position in the state of Washington. He hopes to continue the pursuit of his passions with a permanent move to the West Coast in pursuit of a graduate degree in carnivore ecology.