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Exploring a Potential Bias in Detection of Mesopredators by Cameras

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Exploring a Potential Bias in Detection of Mesopredators by Cameras

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Abstract

Mesopredators, such as the raccoon (*Procyon locor*), Virginia opossum (*Didpelphis virginiana*), and striped skunk (*Mephitis mephitis*) play crucial ecological roles as predators, prey, and disease vectors across much of the United States. Because of their importance and the way that populations of these mesopredators can dramatically increase due to human-subsidized resources, it is imperative that studies attempting to quantify mesopredator community composition are accurate and unbiased. However, it has recently been suggested that not all mammals trigger motion-activated wildlife game cameras at the same rate and for some species detection probability may be biased. My goals for this thesis were to 1) conduct a field experiment to explore potential detection bias of motion-triggered game cameras in relation to common mesopredators and 2) understand how reported results in the game camera literature may be influenced by this potential bias. I did this through a two-step approach. First, I simultaneously deployed side by side infrared motion-triggered game cameras and time-lapse cameras to compare the detections of mammals acquired by each. If certain species fail to reliably trigger motion cameras, I predicted that those species would be missed by the game camera while at the same time they would be documented by the time-lapse camera that is set to take photographs at 5 second intervals with no motion-trigger. Next, I conducted a systematic review of published game camera literature and compared community composition of mesopredators as determined by three approaches: by nonbaited game cameras, by baited game cameras, or by traditional research methods (track plates, trapping, roadkill surveys, hair snares, etc). This comparative analysis explored the potential detection biased quantified in experiment 1 over a larger spatial scale and across additional species.

Analysis for experiment 1 yielded animal size as the only driving factor for motion detection probability, while there were no significant factors driving timelapse detection.

Conducting analysis on the literature for experiment 2 yielded modest results; out of the 9 mesopredators collected with each paper, only opossum and coyote were affected by capture method. The findings of this study suggest that smaller animals could require bait for infrared detection, while larger mesopredators are generally unaffected by detection method.

Introduction

Medium-sized mammalian predators, or mesopredators, play important and diverse roles within ecosystems. As the human footprint expands and we modify habitats and drive out larger alpha predators, mesopredators are often released from predation and can take advantage of human subsidized resources and their populations often proliferate (Fischer et al. 2012; Nishijima et al. 2014). Thus, their roles within wildlife communities are expanding and altering the functioning of wildlife communities and ecosystems (Magle et al. 2015). Common and widespread mesopredators, such as the raccoon (*Procyon lotor*), striped skunk (M*ephitis mephitis*), and the Virginia opossum (*Didelphis virginiana*) have displayed the ability to adapt to human development, and oftentimes live in high densities in suburban and urban areas (Roemer et al. 2009, Hirsch et al. 2013).

Urban mesopredators have traditionally been of interest to wildlife managers because they can lead to several types of conflict with people and our pets. Many of the common urban-adapted mesopredators are known to be prominent vectors of diseases and pathogens- such as rabies, chronic wasting disease, black plague, tuberculosis, anthrax, and canine distemper virus- that can affect people and our pets (Turner et al 2020). Additionally, these mesopredators can be important predators of avian nests and small mammals and exert elevated pressure on urban-adapted populations of these prey species (Guerra et al 2003; Roemer et al 2009; Hirsch 2013: Schmidt 2013;). Furthermore, these species often come into direct conflict with people and our pets through antagonistic interactions, destruction to human property, or by denning within our buildings where they are unwanted (Soulsbury and White 2019).

As urban and suburban development increases across North America, mesopredators must quickly adapt to increasingly dynamic environments. It is thus becoming more important to quantify the mesopredator community composition in and around urban or developed areas to explore fluctuations in community and population dynamics, and the crucial ecological role that mesopredators play (DeStefano and DeGraaf 2003). The primary method used to study the community composition of mesopredators is through the use motion-triggered game cameras (hereafter, game cameras) that capture photos when triggered by a combination of movement within the viewshed of the camera and detectable infrared heat produced by animals (Cove et al 2011; Urbanek et al. 2019). Due to their cost-effectiveness and ease of use, game camera studies have proliferated in the ecological science community, thus increasing the scope of our understanding of mesopredator communities (Wong and Kachel 2016; Burton et al 2015; Caravaggi et al 2017; Blount et al 2021). It is of utmost importance that these studies that serve to investigate these medium-sized mammal communities are nonbiased and present accurate data. However, it has been recently suggested that not all mammals trigger motion-detection cameras at the same rate (Urbanek et al 2019), and for some species, detection probability may be biased (Kays et al 2021).

The ability of game cameras to detect the presence of an animal requires both motion and changing temperature, which could lead to game camera effectiveness being influenced by a number of intrinsic animal factors as well as the environment. For example, the density of an animal’s pelage and its ability to trap body heat is likely a major factor in whether they trigger game cameras or not. Species with particularly dense pelage such as skunks or raccoons may be less likely to trigger cameras than those with more sparse pelage such as Virginia opossum

(Urbanek et al 2019; Tseng et al 2022; Mazur-Milecka 2016). Additionally, body size likely contributes to whether or not individuals trigger cameras such that larger-bodied species will be more likely to be detected than smaller-bodied species. Animals may also be more likely to trigger cameras during cold ambient temperatures when the difference between body temperature and air temperature is greatest (Rovero et al 2013). Numerous other factors related to the environment or species behavioral responses to bait likely factor into the effectiveness of cameras for detecting them (Lesmeister et al 2015; Larrucea et al 2010).

If game cameras do have an inherent bias where particular species are better detected than others, there may be a bias in the scientific record and our understanding of mammalian mesopredators communities. The goals of my thesis are to explore the potential detection bias of game cameras through two approaches: 1) explore possible detection bias of motion-triggered game cameras via a field study and 2) evaluate the influence of this potential bias within the reported results of the game camera literature. My specific objectives with experiment 1 are to explore species-specific detection bias by simultaneously deploying traditional motion-triggered game cameras and time-lapse cameras, which take photographs at set intervals irrespective of motion or heat. Furthermore, this experiment is designed to allow me to understand the factors (e.g., body size, group size, time of year, time of day) that influence the effectiveness of motion-triggered cameras. If certain species fail to reliably trigger motion-activated cameras, I predict that those species will be missed by the game camera while at the same time they will be documented by the time-lapse camera.

My second objective is to use published literature to search for potential species-specific motion-triggered game camera biases. If such a bias exists, much of our understanding of mesopredators communities could be erroneous and I would be able to suggest to future researchers methods to account for this bias. The specific objective of my second experiment is to conduct a systematic review of published game camera literature to identify all studies of North American mesopredators communities that used one of three study approaches: motion-triggered game cameras, motion-triggered game cameras with a bait or lure, or traditional survey techniques (through a combination of box traps, road-mortality surveys, hair snares, pitfall traps, and foot or track plates). I will then statistically compare the composition of each species within the mesopredators community as determined by each of the three study approaches. This comparative analysis explores the potential detection biased quantified in experiment 1 over a larger spatial scale and across additional species. I expect this analysis to support the assumption that the use of bait and/or lure in camera-trap studies will result in higher detection probability of mesopredators as it results in animals spending more time in front of cameras and make erratic movements which will have a higher chance of setting off the motion-trigger.

Materials and Methods: Experiment 1

Experiment 1: Detection Differences Between Timelapse and Game Cameras

To explore potential detection probability biases of game cameras, I conducted a series of field trials where I deployed paired motion-triggered game cameras (MT cameras) with timelapse cameras (TL cameras). I deployed these camera arrays starting in June 2022 and continuing through early November 2022. I ceased trials at the beginning of November because low night temperatures reduced mesopredator activity (Haswell et al 2020). Each trial consisted of one infrared MT camera (Browning Strike Force XD) and one TL camera (Reconyx Microfire) aimed in the same direction on one camera mount (Figure 1; Figure 2; Figure 3). Both cameras were programmed to turn on at 9:30 PM and operate until 5:30 AM to target times when mesopredators were most likely to be active (Garvey et al 2015). I set the time-lapse camera to take photographs at 5 second intervals with no motion trigger. I deployed cameras in the backyards of volunteers located in Northwest Arkansas as well as Northeastern Michigan.

Figure 1. Trial site MT and TL camera setup.

Figure 2. Trial site camera setup, front view.

Figure 3. Configuration of TL camera (top) and MT camera (bottom).

I conducted each trial (periods during which both cameras were on and programmed to collect photograph) for approximately 1-2 weeks before changing the location of the camera array. After the completion of each trial, I manually reviewed all photographs taken and identified each species detected. I recorded which of the cameras detected each individual, calculated time of night the detection occurred, estimated the duration of the detection, and counted the number of individuals present in each detection. Each time an animal was detected by either camera, I considered this a “detection event.” For each detection event, I identified which camera successfully detected the animal, and calculated the amount of time the detected animal spent in front of the camera.

Data Analysis: Experiment 1

To explore the effectiveness of each camera type, I scored each wildlife detection as one of three outcomes: detected by MT, detected by TL, or detected by both methods. I then analyzed the detection probability of MT cameras separately from TL cameras. Starting with MT cameras, I scored each detection as a binomial response (detected by MT or not). I analyzed these data using a binomial generalized linear mixed model with detection (yes or no) as the response variable. I used location as a random effect to account for unmeasured variation between locations at which repeated experiments were performed. I used number of individuals present, animal size (a categorical variable for medium or small), time in front of camera, month, and hour of day as fixed factors in the analysis. Animal size was determined based on species with raccoons, opossum, domestic cats (*Felis catus*), and foxes (*Vulpes vulpes*) defined as medium size while mice (*Mus musculus*) and eastern cottontail (*Sylvilagus floridanus*) were considered small sized. Time in front of camera was calculated by assessing the start and end times of detection for each animal detected both on time lapse and motion detection cameras and calculating the difference between the two.

Materials and Methods: Experiment 2

Experiment 2: Literature Review of Species-Specific Bias Based on Study Method

In order to explore if 3 different study methods lead to potential biases in our understanding of mesopredator community composition, I searched the North American game camera literature using primarily Google Scholar as a search engine and collected all published literature that used game cameras or traditional methods to quantify the community composition of mesopredators. In order to be included in my study, each paper needed to report the location, season, habitat, number of trap nights, height of the camera (if applicable), number (or proportion) of animals detected, and method of detection (game camera (baited or nonbaited) or alternative method). I initially extracted the exact type of traditional method of trapping from papers without game cameras, but I later simplified all traditional studies to “non-camera” for analysis purposes. I extracted data from studies using bait and studies without bait for this experiment, so both types of studies were included. We did not analyze the effect of different types of bait in detection probability, only the effect of the presence of bait.

Data Analysis: Experiment 2

After all data were extracted, I used generalized linear models to assess if the mean community composition proportion of each of the 9 common mesopredators (striped skunk, opossum, raccoon, coyote, bobcat, cat, dog, red fox, and grey fox) varied between the three research methods (MT, MT with a lure, and non-camera trapping). I conducted separate analyses for each species. My response variable was the proportion of the mesopredator community comprised of the focal species and my predictor variable was the study design: motion-trigger cameras without bait, motion trigger with bait, or non-camera study methods. Non-camera study methods included common medium-sized animal trapping techniques such as Tomahawk traps, track-plates, footholds, box traps, and roadkill. Each of these methods (except roadkill surveys) utilizes bait (urine, cat food, apples, etc.) and functions to trap medium sized animals without inflicting harm on the animal. These methods may have biases in which species are most effectively sampled but should provide a good reference group by which we compare how MT cameras are biased. Larger mesopredators such as coyotes, bobcats, dogs, red fox and grey fox were analyzed using the same analytical approach except only two groups were compared as many of the non-camera study approaches were inappropriate for animals of this size.

Results

Experiment 1

I conducted trials from late July to the beginning of November, for a total of 74 days and 148 trap nights. These were conducted primarily residential backyards in Fayetteville, Arkansas, which is located in a mostly suburban landscape, save for the college campus nearby. Experiments were also conducted in Northeastern Michigan in residential backyards located near the town of East Tawas. There were in total 322 detections by the TL camera, and 272 MT camera detections.

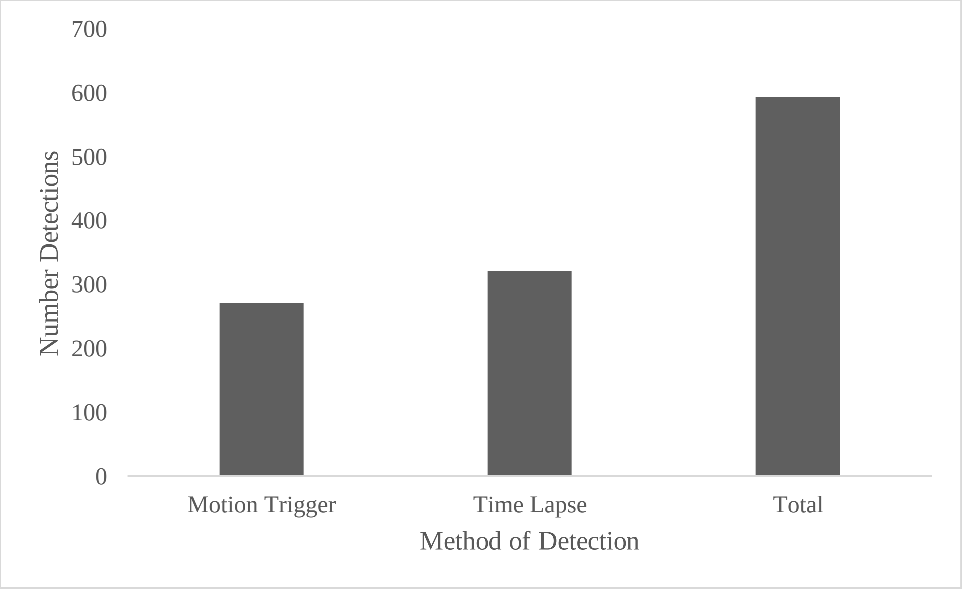

Figure 4. Total number of camera detections (detections that successfully photographed the animal) for motion-trigger camera, time lapse camera, and both combined, using data gathered over the entire approximately 5 month experimental period collected in experimental trials conducted in AR and MI.

Variable	**F**	***P***
No. of Individuals	$F_{1,318} = 1.245$	2.65
Estimated time in front of camera	$F_{1,318} = 0.312$	0.577

Month	$F_{4,318} = 1.135$	0.34
Hour	$F_{8,318} = 1.363$	0.212
Animal size	$F_{1,318} = 26.326$	<0.001

Table 1: Results from a generalized linear mixed model analysis evaluating the effects of number of individuals detected, time spent in front of camera, month of year, hour of day, and animal size (medium or small) on the ability of motion-triggered game cameras to detect them based on field trials conducted in Arkansas and Michigan, USA.

I found that animal size had a significant effect on the ability of MT cameras to detect a species ($F_{1,318} = 26.326$, $P < 0.001$) with larger animals more likely to be detected than smaller animals ($\beta = -2.283$, 95% CI -3.905, -1.740). Number of individuals, estimated time in front of camera, month, and hour did not have any significance in successful motion detection (Table 1).

I found that month of year was the only variable that had a significant effect on the ability of TL cameras to detect animals ($F_{4,318} = 3.152$, $P = -0.015$), with timelapse cameras performing better in November than in all other months except October (Table 2; Table 3). No other variables including number of individuals, estimated time in front of camera, hour, or animal size had a significant effect on the ability of TL cameras to detect animals. The TL camera in general was more likely to capture animals than the MT (Figure 4). Figures 5 and 6 display the distinction between detection success in MT camera and TL camera in each species; these show the higher success rate of capture in the TL camera versus the MT camera. (Figure 5; Figure 6).

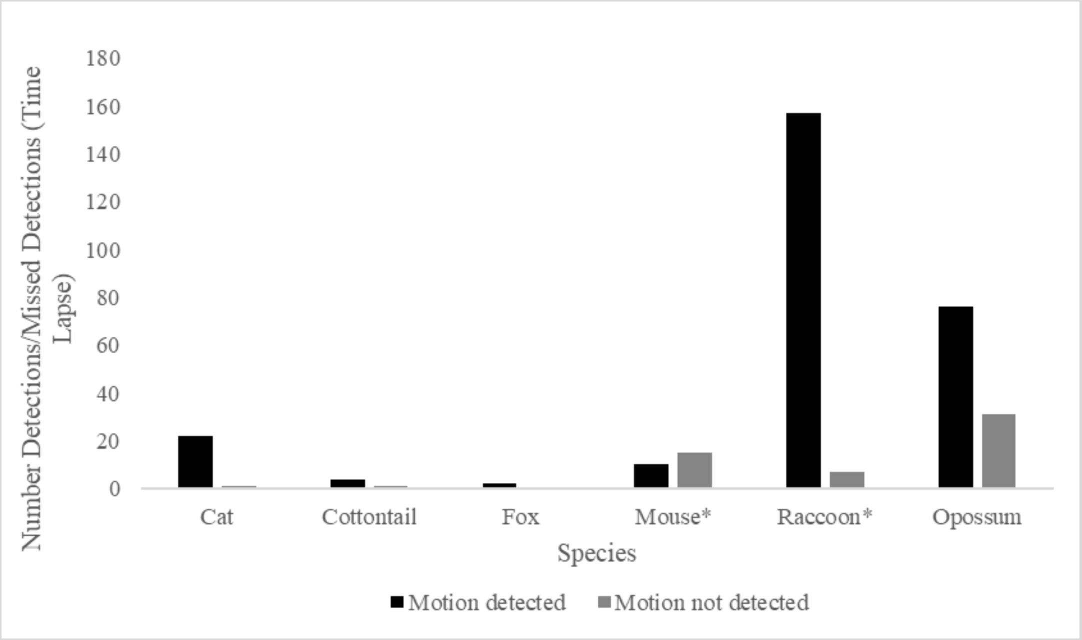

Figure 5. Number of mesopredator detections that were either detected by a motion-triggered game camera or missed by a motion-triggered game camera (but detected by a timelapse camera) using data collected during field trials in AR and MI.

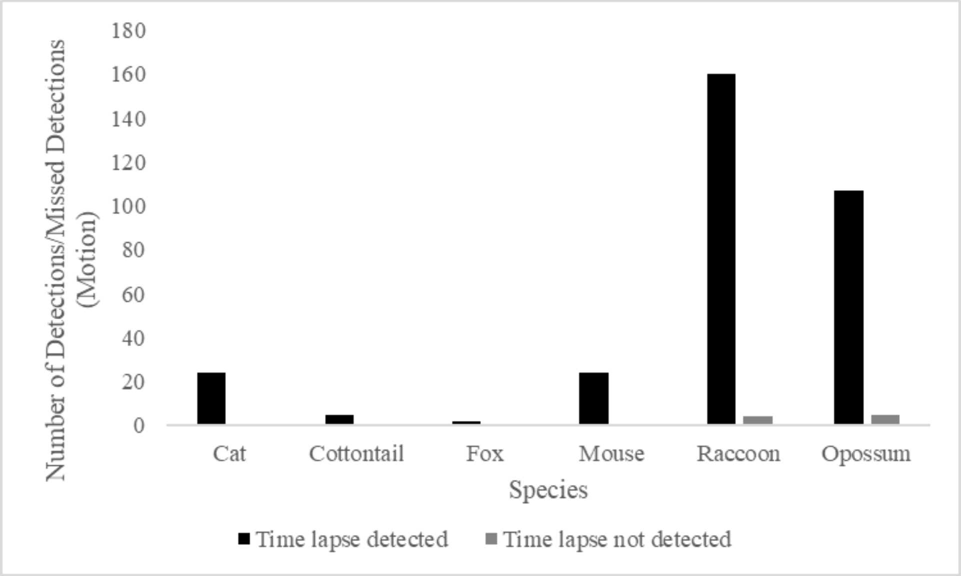

Figure 6. Disparity between photos in which there was successful capture in time lapse detection vs. no detection (determined using data collected from opposing motion-trigger camera) for each species using data collected during field trials in AR and MI.

Variable	**F**	***P***
# Individuals	$F_{1,318}=0.870$	0.352
Estimated time in front of camera	$F_{1,318}=0.013$	0.911
Month	$F_{4,318}=3.152$	0.015
Hour	$F_{8,318}=0.104$	0.999
Animal size	$F_{1,318}=0.050$	0.824

Table 2: Fixed effects extracted from a generalized mixed model for time lapse detection analysis using data recovered from time lapse trials conducted in Arkansas and Michigan, US.

Table 2 displays the results of the generalized mixed linear model for time-lapse camera detections. Month was the only significant variable with a p value of 0.015. No other tested variables held significance in a successful capture of the time lapse camera.

Model Term	**Coefficient**	***P***
# Individuals	0.54	0.352
Estimated time in front of camera	0	0.911
Month=7	-2.981	0.002
Month=8	-2.852	0.002
Month=9	-2.867	0.005
Month=10	-2.76	0.162
Month=11	0^b	
Hour=0	-0.006	0.996
Hour=1	0.001	1
Hour=2	-0.019	0.989
Hour=3	0.369	0.765
Hour=4	-0.482	0.74
Hour=5	0.045	0.982
Hour=21	0.584	0.633
Hour=22	-0.028	0.98
Hour=23	0^b	
Animal size=medium	0.231	0.824
Animal size=small	0^b	

Table 3. Fixed coefficient results for time lapse analysis of field experiment data collected in Arkansas and Michigan to assess relevant factors in detection success of time lapse camera.

Experiment 2

I extracted data from 206 literature studies that used non-baited game cameras to study wildlife, 14 studies that used baited game cameras, and 13 studies that used a combination of traditional non-camera methods that ranged from box traps (1), to hare snares (1), roadkill (1), live traps (10), scent-stations/track plates (4), and pitfall traps (2). Many traditional studies employed more than one non-camera method for trapping.

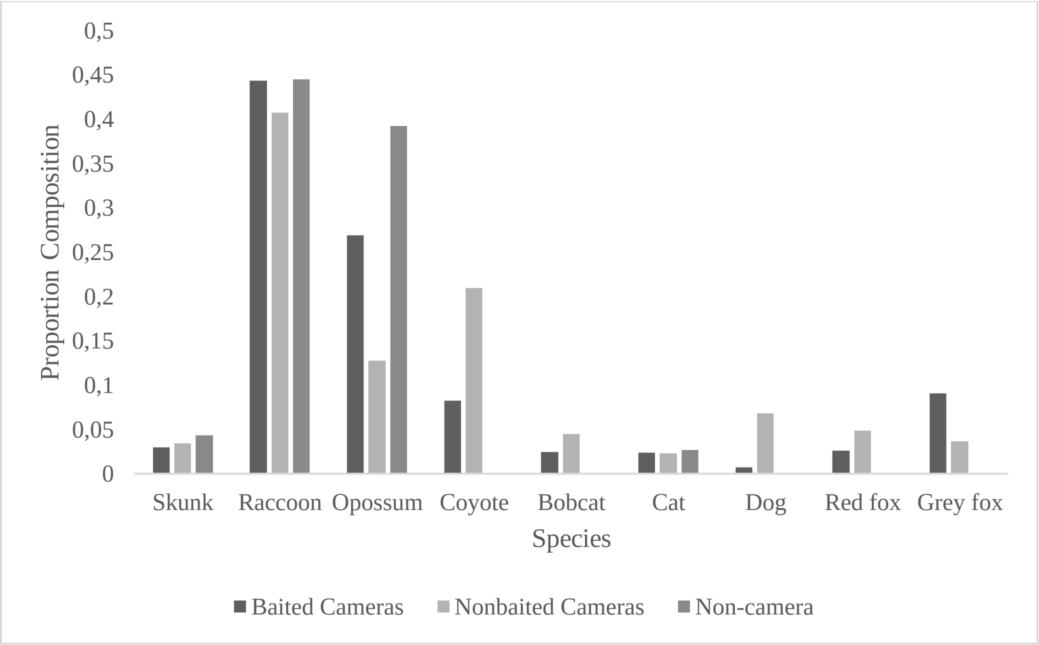

Figure 7: Comparison of species composition based on capture technique, including baited camera, nonbaited camera, and non-camera methods to assess the difference in the observed proportion of each species in each method.

We found no evidence that study design influenced the proportion of the mesopredator community comprised of striped skunks (Wald Chi-Square= 0.113, df=2, *P*= 0.945). Striped skunks generally comprised a small portion of the mesopredators community regardless of study design: 0.034 (95% CI: -0.020- 0.080) by nonbaited cameras; 0.030 (CI: 0.021- 0.047) by baited cameras and 0.043 (CI: -0.012- 0.097) by non-camera methods.

We found a significant effect of study design on the proportion of the mesopredator community comprised of opossum (Wald Chi-Square= 38.535, df= 2, *P* < 0.001). Opossum were determined to comprise a smaller average proportion of the mesopredator community if researchers used nonbaited or baited cameras compared to non-camera methods, constituting a proportion of 0.269 in baited studies, 0.128 in nonbaited studies, and 0.392 in noncamera studies. (β = -0.264, P < 0.001; β = -0.124, P = 0.051, respectively).

We found no significant effects of study design on raccoon community composition (Wald Chi-Square= 0.424, df= 2, *P*= 0.809). Raccoon comprised a notable amount of the mesopredator community averaging in 0.4436 (CI: 0.303 0.5842) of the community in baited studies, 0.4072 (CI: 0.3706 0.4439) in nonbaited studies, and 0.4436 (CI: 0.2918 0.5955) in non-camera studies. Similarly, no significance of study design was found between studies with cats (Wald Chi-Square= 0.041, df= 2, *P*= 0.980). Cats were a relatively rare part of the mesopredators community across studies averaging in 0.023 (CI: 0.015 0.031) of the community in non-baited studies, 0.024 (CI: -0.008 0.055) in baited studies, and 0.027 (CI: -0.008 0.061) in non-camera studies.

For the larger sized mesopredators (coyotes, bobcats, foxes and dogs) we removed non-camera studies and compared the proportion of community composition between only studies baited vs nonbaited camera studies because many of the non-camera techniques are unable to reliably capture animals of that size. We found a significant effect of study design on the proportion of mesopredator community comprised of coyote (Wald Chi-Square= 3.876, df= 1, *P*= 0.049). Coyote constituted 0.082 (CI: -0.041 0.205) of the baited studies and 0.210 (CI: 0.178 0.242) of the nonbaited studies. Studies using baited cameras showed that coyotes were a smaller proportion of the mesopredator community compared to studies using nonbaited cameras (B = -0.128, *P* = 0.049). Pairwise comparisons for baited versus nonbaited studies yielded a mean difference of -0.128 (CI: -0.255 -0.001; *P*= 0.049).

We found no significant effect of study design on presence of bobcats in literature (Wald Chi-Square= 0.875, df=1, *P*= 0.350). For all studies using bait, bobcats comprised 0.024 (CI: -0.018 0.067), while comprising 0.045 (CI: 0.034 0.056) in nonbaited studies. We similarly found no significance of study design for the proportion of dogs in the mesopredator community (Wald Chi-Square= 2.628, df=1, *P*= 0.105). For all baited studies, dogs comprised 0.007 (CI: -0.064 0.079) and 0.068 (CI: 0.050 0.087) of nonbaited studies. We found no significant effect of study design on the grey fox proportion (Wald Chi-Square= 2.950, df-1, *P*= 0.086). For all baited studies, grey fox comprised 0.091 (CI: 0.031 0.151) and 0.036 (CI: 0.021 0.052) of nonbaited studies. Lastly, we found no significance in effect of study design on the proportion of red fox in the mesopredator community (Wald Chi-Square= 0.508, df=1, *P*= 0.476). For all baited studies, red fox constituted 0.026 (CI: -0.035 0.087) and 0.049 (CI: 0.033 0.065) of studies without bait.

Discussion

Experiment 1: Motion-Trigger and Time Lapse

When comparing the performance of MT and TL cameras, I found that animal size made the biggest difference in the ability of MT cameras to detect species. This was driven by MT cameras performing well and having relatively few misses of raccoons and cats (Figure 5). MT cameras detected approximately 2/3 of opossum. The smallest animal I detected in my study was mouse (*Peromyscus sp.*) and MT cameras missed more mice than they detected (Figure 5). These results support the notion that the larger the animal, the more likely it will trigger the motion camera. Urbanek et al. (2019) tested the efficacy of Reconyx motion-trigger cameras for detecting a collection of wildlife species of varying size within several distinct field of view zones. The authors found that the infrared cameras were generally species dependent in that they favored larger animals; the motion detection missed 14-16% events of bears and other large mesopredators, while missing 92% and 80% of squirrel and rabbit detections, respectively. They also found that detection of the animal in more than one detection zone increased the detection probability. They suggested this could be due to the size or heat signature of the animal, both which suggest larger animals will more reliably trigger the camera. These results support the findings of the experiment conducted here; although only opossum and coyote had significant results, the detection disparity could likely be due to similar reasons found in their study (i.e., size disparity) (Urbanek et al. 2019). Other studies have found results that coincide with the heat signature hypothesis; for example, Lerone et al. (2019) found that infrared motion detector cameras less reliably detect otters leaving the water due to their lower heat signatures.

Hour of day had no significant effects on either time lapse or motion trigger detection. We had predicted that MT cameras would operate best at the latest hours of the night when the difference between air temperature and animal body temperature was great; however, this prediction was not supported. However, I did find that month of the year had a significant effect on the detection ability of TL cameras. I had not predicted that any of the factors other than “time in front of camera” would be significant for this method. It is unclear why animals were more likely to be detected by TL in November compared to July, August, or September. I believe this may be due to a small sample size (1 trial, 5 TL detections, 3 MT detections during the month of November), this was likely also a sampling error and will not be used to determine successful time-lapse detection.

Experiment 2: Literature Review

Practitioners using camera trap studies often debate whether to use a bait/lure or not. The presence of a bait (a consumable attractant) or a lure (nonconsumable attractant) can attract animals to the camera detection zone that would not otherwise have passed through and more importantly, may increase the amount of time that they spend in front of the camera thereby increasing detection probability of motion-triggered cameras. Urbanek et al (2019) describes the potential biased effect of bait in camera trap surveys, in which the use of bait or lure in studies exploring population estimates may be skewed due to altering the behavior of the animal. However, many studies encourage the use of both bait and lure in camera trap surveys; Buyaskas et al. (2020) found that while using only lure does not significantly increase number of detections, the usage of both bait and lure resulted in a higher number of carnivore detections, while having no effect on the detection probability of smaller prey. Contrastingly, Rocha et al. (2016) concluded that the use of bait has no effect in the capture rates of carnivores, but it potentially repelled the presence of smaller prey species, therefore decreasing smaller animal detection. In fact, there are two ongoing large-scale, long-term nationwide camera trap studies occurring right now (Kays et al 2022; Gallo et al 2022) and these studies have differing approaches with Snapshot USA using nonbaited cameras and the Urban Wildlife Information Network (UWIN) using fatty acid tablets as lures. Within my literature review, I found that nonbaited studies were far more common than studies using bait (Nonbaited = 206 vs Baited = 14). I evaluated the use vs nonuse of bait because I predicted that bait would result in animals spending more time in front of cameras and those animals making erratic movements to try and attain the bait, thus increasing the ability of MT cameras to detect them. However, the results of my analysis were modest.

If the presence of a bait or a lure increases the detection probability of particular species, one could expect that those species would constitute a larger proportion of the mesopredators community in studies using bait compared to those not using bait. However, I found that most species- including skunk, raccoon, bobcat, cat, dog, and grey and red fox- were not determined to constitute a different proportion of the wildlife community if investigators used bait or not. I only found two species where the results significantly differed between methods, and they differed in contrasting ways. First, I found that opossum constituted a smaller proportion of the mesopredators community if researchers used either baited or nonbaited MT cameras when compared to non-camera methods (Figure 7). There were 8 nonbaited (total N= 206) studies in the literature in which opossum comprised more than 50% of the studied mesopredator community, compared to 3 non-camera (total N= 12) studies that had over 50% opossum. No studies using bait (N= 14) had over 50% opossum in their results. The studies employing noncamera methods that resulted in a high proportion of opossum used Tomahawk traps and scent stations. However, one of the Tomahawk trap studies did not use bait. As there were no other observable differences in study method to account for the higher proportion of opossum compared to other non-camera and camera studies, this could be due to a number of factors. Fidino et al. (2020) explored the use of lure in motion-trigger camera trap detection for a wide range of animal sizes, and found that opossum detection increased with the presence of an olfactory carnivore lure; however, other studies have reported no effect of lure on the presence of opossum (Erb 2012). These contrasting results suggest other factors at play that affect the appearance of the opossum, such as location, predator/prey density, or perhaps season of the year. Primathilake (2018) conducted baited camera trap trials in Oklahoma, USA, and found high detection probability of opossum, skunk, and raccoon during the winter; this result could be accounted for by the higher abundance of food sources during the summer than the winter seasons, which could encourage the opossum to explore alternative options for food during the winter.

In contrast to opossum, I found that coyote were most likely to be detected by nonbaited cameras (Figure 7). In studies using nonbaited cameras, coyotes were determined to comprise 0.210% of the mesopredators community compared to 0.082% of baited studies. Since the purpose of bait within baited studies is to prolong the time of the animal in front of the camera (or drawing the animal into the trap in traditional methods) in order to ensure the capture of the animal, these results show the necessity of bait in studies capturing smaller mesopredators (Williams et al 2011). Larger mesopredators, like coyote, constituted a larger portion of the animals captured on camera without bait, meaning no extra time in front of the motion-trigger camera was needed to capture the animal. We hypothesize the reason for this is the larger body mass and surface area that emits body heat, as compared to smaller animals that emit less heat in front of infrared cameras. Although the majority of small mesopredators had no significant results, the parameter estimates displayed the same trend of non-camera having the most success and non-baited being the least successful. Another potential reason to account for the lower coyote presence in baited studies could be avoidance behavior; there are many efforts to reduce coyote predation on sheep using conditioned taste aversion; mutton bait laced with LiCl attracts coyote which then eat the bait and become sick, and subsequently associate sheep with sickness which would deter further predation- though this method has not been proven effective (Burns 1983). Allsop et al (2017) explores the subject of bait resistance and describes sublethal poisoning and behavioral (innate or learned) aspects of the species as the main factors that influence bait avoidance.

Conclusion

This experiment displays significant and applicable information pertinent to mesopredator detection in motion trigger game cameras. First, my findings from the field experiment indicate that smaller species are less likely to trigger motion-triggered cameras and our conclusions about community composition may be biased against these small-bodied species. This could be important for practitioners because small-bodied carnivores such as ferrets, weasels, swift fox, and spotted skunks are some of the rarest and fastest declining mammals in North America (Jachowski and Edelman 2021) and an inability of cameras to detect these species can hinder our understanding of their distribution, abundance, and habitat needs. One solution would be for practitioners to use timelapse cameras, although this creates a significant burden of photographic review; my study alone generated approximately 20,000 photos per trial (~2 weeks) from timelapse. Another solution would be to increase detectability by the use of bait/lure in front of cameras to increase the time animals spend there. However, my review of the literature found only minor differences in the results of community composition of baited vs nonbaited cameras. While coyote were better censused with nonbaited cameras, opossum were best studied using non-camera methods. Our findings suggest that common smaller species such as mice, rats, cottontails, and cats- as well as the rare and declining weasels and allies– could require bait near the motion-trigger camera in order to reliably set off the infrared motion trigger. Moreover, larger mesopredators such as coyote and bobcat do not require bait to set off the motion trigger, likely due to their larger size and higher body heat index, or conditioned avoidance behavior to bait. We believe that the findings of this study have potential to impact future studies involving mesopredator community composition, and that future authors of such papers should consider possible errors and bias associated with motion-triggered infrared game cameras.

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