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Using Camera Traps to Evaluate Predator Urine Avoidance by Nuisance Wildlife at a Rural Site in Central Missouri, U.S.A.

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ABSTRACT: Predator urine is sold commercially and marketed as a deterrent for nuisance wildlife. Previous studies have shown mixed support for this application. We assessed the potential application of coyote urine as a mesocarnivore deterrent at the Ozark Research Field Station in south-central Missouri. The field station is a 4-ha residential university property bordered by state conservation land and national forests. In Fall of 2019, bait stations were deployed at eight sites at the field station. A bait station consisted of one game camera and one bait pile (protein). Each bait station was deployed for 21 consecutive nights (eight sites × 21 nights = 168 trap nights). From days 7-14, coyote urine was deployed at all bait stations. Bait piles were weighed and refilled daily. Camera traps were assessed for battery charge and card storage daily. Bait removal, diversity, species composition, occurrence, activity, and abundance were compared among treatments. Raccoons were the most abundant and active species at all bait stations, and Virginia opossum was the second most abundant. Raccoon occurrence and bait removal decreased during urine treatment; however, raccoon abundance and activity did not change. Bait removal was highest during and post-urine treatment. Our study concludes that coyote urine has limited effects as a raccoon deterrent at our study site.

KEY WORDS: behavior, *Canis latrans*, coyote urine, foraging, human-wildlife conflict, mesocarnivore, Missouri Ozarks, *Procyon lotor,* raccoon, rural-wildland interface, vertebrate pest

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INTRODUCTION

As human population and global land use increase (Seto et al. 2011, Ortman 2015), wildlife habitat concurrently decreases (Martinuzzi et al. 2015). The search for new habitat and resources results in unanticipated human and wildlife interactions (Brooks et al. 2020) and increased risk to both wildlife and human livelihoods ("human wildlife conflict") (Acharya et al. 2017, Ascensão et al. 2019). The most commonly reported human wildlife conflicts result from crop damage (Hinton et al. 2017), animal exposure-related health risks (Veeramani et al. 1996, Pieracci et al. 2019), and nuisance wildlife in and around structures (Douglass et al. 2003). One strategy to mitigate human wildlife conflicts is the use of non-lethal deterrents. Several companies (e.g., Maine Outdoor Solutions, Deer Busters) manufacture and market products designed to exclude wildlife through visual (flagging on fences, per Zarco-González and Monroy-Vilchis 2014), olfactory (predator urine, per Stryjek et al. 2018), or auditory (playback of machinery, per Wijayagunawardane et al. 2016) deterrents. One such deterrent is predator urine, which is marketed to exclude nuisance mesocarnivores.

Predator urine has been examined as a tool for nuisance animal deterrence in a handful of other studies. Severud and colleagues examined the North American beaver (*Castor canadensis)* responses to predator urine on common foraging trails (Severud et al. 2011). They found that beavers shifted their visits away from trails that were inoculated with predator urine. Studies of potential predator urine avoidance by deer (Belant et al. 1998) and small mammals (Orrock and Danielson 2009) have found limited to no effect of urine on species behavior patterns. The sulfur in urine may serve as the primary compound responsible for deterrence due to its volatility and odiferous nature (Nolte et al. 1994).

Mesocarnivore-human conflicts, the focus of our study, present several unique risks, including disease transmission to humans (Ma et al. 2018) and domestic animals (Lopes et al. 2016), damage to and destruction of property (VerCauteren et al. 2010), and nuisance noise and interactions (Hill et al. 2007). Common mesocarnivores in the Ozark Mountains include *Procyon lotor* (raccoon), *Didelphis virginiana* (opossum), and *Mephitis mephitis* (striped skunk). Many of these species are generalists that have acclimated to and thrive in human settlements (Johnson 1970). In particular, raccoons have adapted to human settlement by occupying human homes in attics and feeding on refuse and garbage. They also carry unique risk as vectors of viruses (Roberts et al. 2009) directly to humans and through the deposition of feces in areas that domestic animals frequent. Heddergott et al (2017) found the protozoan parasite *Toxoplasma gondii* in raccoons located in central Europe; *T. gondii* has been linked to neuropsychiatric symptoms in humans (Wong et al. 2013). Other diseases such as raccoon roundworm (*Baylisascaris procyonis*) have been documented in the United States. Cases of raccoon roundworm have spread outside their historic range in the past decade (JAMA 2016).

Raccoons are generalists whose primary diet consists of plant and animal matter, including seasonal fruits, crayfish or opportunistic injured animals (Schwartz and Schwartz, 2001). Raccoons are primarily nocturnal but will travel during dawn and dusk (Greenwood 1982). Their breeding season usually lasts from mid-late winter until the beginning of summer (Fritzell et al. 1985). Litters are usually born in April or May, with an average of 3-4 young. Young stay with their mothers up until the spring after birth (Hamilton 1936). Raccoons do not hibernate during cold times in the winter but will stay in dens during harsher weather. They also use these dens to avoid predators and protect their young. Coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) are two of the most common predators of raccoons (Kamler and Gipson 2004).

This study examined the efficacy of predator urine as a passive deterrent for raccoons and other mesocarnivores at a rural site. We predicted that coyote urine would deter raccoons from food resources and would increase the abundance and activity of predators at these resources.

METHODS

Field Site

This project was conducted at the Ozark Research Field Station, a rural biological field station owned by Missouri University of Science and Technology, located in southern Phelps County, MO. The 4-ha field station is surrounded by the state-managed Bohigian Conservation Area (Missouri Department of Conservation) and the federally managed Mark Twain National Forest (USDA Forest Service). The Ozark Research Field Station property is comprised of ponds (30%), wetland (30%), pasture (20%), and shrubland habitats (10%). Local and regional forests are dominated by oak (*Quercus* spp.), hickory (*Carya),* and short-leaf pine (*Pinus echinata*). The wetlands are dominated by mixed grasses and early successional tree species (e.g., *Salix, Celtis, Cornus*). Human-wildlife conflicts at the site include raccoon latrining on porches, rodent and bat entry into structures, beaver-mediated flooding, and aquatic rodent burrowing into dams. The field station attempts to use non-lethal and passive deterrents to control these conflicts, when possible. Primary concerns of field station leadership include non-target effects, destruction of monitored populations, and loss of ecosystem function. Concern about the potential transmission of *B. procyonis* at latrine sites and potential loss of local diversity at latrines (Weinstein et al. 2018) led to the initiation of this study (Page et al. 1998).

Field Methods: Bait Selection

To determine which food resources would most effectively recruit raccoons, we examined the consumption of two bait types from 3 September to 13 September 2019. We selected known food sources that had comprised large portions of raccoon diets in previous studies: corn (Hamilton 1940, Rivest and Bergeron 1981) and cat food (McCleery et al. 2005). Baits were deployed at eight stations located at least 25 m apart across the field station in two separate pans (Figure 1). Each pan was initially filled with 1,000 g. Half (n = 4) of sites were treated with 500 g of sugar beet powder (Wildgame Innovations, New Roads, LA), and half of the sites were treated with a 2 kg salt block (VitaRack; Figure 1) to encourage detection of the baits. Salt block and sugar beet treatments were only conducted on Day 1 of the study. Cat food and corn baits were refilled to 1,000 g daily. Bait removal was measured using a portable scale.

We monitored bait sites with Herter's 12MP cameras with a 3-burst sequence. Each camera was mounted on a 1m t-post, using a t-post camera mount (T-Post Trail Camera Holders; HME Products, Grand Prairie, TX). The camera was oriented down 10 degrees from horizontal to view the bait, which was placed 1 m away. All sites were measured daily for loss of bait and camera cards were collected. We refilled baits and checked cameras between 900 h to 1500 h to limit potential disruption of crepuscular species.

Field Methods: Mesocarnivore Deterrence

We deployed eight monitored bait sites at the field station from 28 September to 19 October 2019. We monitored bait sites with the same cameras, and settings used in the bait selection study. Baits were placed in aluminum disposable baking pans filled with 2,000 g of cat food (Master Paws®, Menards, Eau Claire, WI). Cat food was selected because of its high rate of consumption during the bait selection experiment (see Results: Bait Selection). Sugar beet powder (Wildgame Innovations; 140g) was deployed on Day 1 of the trial as an attractant and refreshed on Day 8 and Day 15. Bait pans were anchored to the ground using garden staples to prevent movement out of the camera frame. Stations were established in daylight hours between 900 h-1500 h to avoid disturbance of crepuscular activity. Bait stations were deployed for 21 consecutive nights. From Nights 1-7 (pre-urine) and 15-21 (post-urine), bait stations were untreated. From Nights 8-14 (urine treatment), a cotton-wicked scent tag soaked in 15 mL of coyote urine (PredatorPee®, Maine Outdoor Solutions LLC, Hermon, ME) was attached to the t-post. Scent tags were refreshed every 48 hours, unless rainfall occurred in which case the tag was refreshed at the next bait check.

Bait stations were checked, and bait was weighed to the nearest gram daily during daylight hours using a portable scale. Spillage around and near the pan was returned to the pan for weighing. Baits were refilled to 2,000 g after weighing. Camera battery life, settings, and SD card storage were checked daily.

Temperature (°C) was logged on-site during bait weighing using a portable weather station. Rainfall was recorded using the local USGS rain gauge (USGS 2019). Rainfall data was used to estimate potential bait weight deviations associated with water absorption by the cat food. In the laboratory, we tested three different bait masses (10 g, 50 g, 100 g) wetted to depths that corresponded with rainfall totals observed during the experiment (1 cm, 2 cm, 3 cm, 4 cm). Each combination of mass and rainfall depth was replicated three times (n = 36 total wetting trials) and left to soak for 24 hours. The following day, any standing water was poured out of the pan and the saturated bait was weighed to provide estimates to account for overestimates of remaining bait weight in field trials.

Data Analysis

Game camera photos were analyzed using Colorado Parks and Wildlife Photo Warehouse (Newkirk 2016). Each photo was tagged with metadata including species occurrence and abundance in each individual photo. For the bait selection study, we analyzed the effect of salt block and sugar beet presence using a two-way ANOVA examining sites and treatments. We regressed bait removal against total number of photos containing detectable animals and calculated R^2 values.

For the mesocarnivore deterrence study, total number of photos, species composition, raccoon activity (number of photos containing any raccoons per night), raccoon abundance (represented as the maximum number of individuals of the same species in a single photo per night), rainfall presence, bait mass loss, and Shannon diversity were compared among treatments (bait types, pre-urine, urine treatment, and post-urine) using one-way analyses of variance (ANOVA, alpha = 0.05). Student multiple comparisons tests were used to examine significant differences among treatments. We individually regressed raccoon activity against temperature and Shannon diversity and calculated R^2 values. We also regressed bait removal and total number of photos captured and calculated R^2 values. We calculated total species composition across all sites and dates and calculated relative abundance of all species with at least three individual photos by dividing the total number of photos containing a species by the total number of photos that detected animals. Data were analyzed and visualized using JMP statistical software (SAS 2019) and Microsoft Office Excel.

RESULTS

Bait Study

Over the ten-night bait trial, we collected a total of 58,749 photos. The mean nightly bait loss of corn baits was 295.8 g (SE = 46.8). The mean nightly bait loss of cat food was 888.3 g (SE = 71.8). Our analysis showed no effect of site ($p = 0.81$), so site was removed from all further models and analyses. The presence of a salt block did not significantly influence cat food ($p = 0.063$, df = 87) or corn ($p = 0.063$, df = 87) bait removal. The presence of sugar beet powder significantly increased bait removal for corn ($p < 0.0001$, df = 87) and cat food ($p = 0.0002$, df = 87). As the number of photos captured per night increased, cat food mass loss increased ($R^2 = 0.15$, $p = 0.0007$) and corn mass loss also increased ($R^2 = 0.12$, $p = 0.0002$).

Mesocarnivore Deterrence

We collected a total of 149,236 photos (86,662 containing detectable animals) over the 21-day study. Of these, 77,527 (90%) were of raccoons, 4,701 (5%) were of opossums, and the remaining 4,434 were comprised of 16 additional species (Table 1). A total of 15 photos of potential raccoon predators were recorded during this study. Given their low occurrence and proportion of total photos (0.0002%), we did not statistically analyze these.

During this trial, total numbers of photos captured did not vary among pre-, urine-, and post-treatment sites (df = 167, $F = 1.15$, $p = 0.3203$). Shannon diversity metrics were not significantly different among treatments (df = 167, $F = 1.48$, $p = 0.2299$). Overall bait removal was lowest pre-urine treatment, increased during treatment, and remained elevated post-treatment (Figure 2, df = 167, $F = 4.42$, $p = 0.0135$). Bait removal correlated positively with the number of photos captured per night (Figure 3; df = 167, $R^2 = 0.11$, $p < 0.0001$).

Abundance of raccoons (maximum number of raccoons in a single photo per night; df = 20, $F = 0.09$, $p = 0.7662$) and mean number of raccoon photos per night (df = 167, $F = 0.34$, $p = 0.56$) were unchanged across all treatments. Raccoon occurrence (presence) did not show a decrease, during urine treatment (Figure 4; df = 167, $F = 27.72$, $p = 0.0681$). Bait removal increased as mean number of raccoons increased (Figure 5, $R^2 = 0.13$, $p < 0.0001$). As mean number of raccoons per photo increased Shannon diversity increased (Figure 6; $R^2 = 0.07$, $p = 0.0006$). Warmer temperatures correlated with more raccoon photos per night (Figure 7; $R^2 = 0.03$, $p = 0.03$), but rainfall (categorical, presence/absence) had no effect on raccoon activity.

Table 1. Animal species detected with camera traps during this study. Relative abundances are reported as proportions. Only species with at least five individual photos were analyzed.

Species	Photos	Relative Abundance
Procyon lotor	77,527	0.895
Didelphis virginiana	4,701	0.054
Neotoma spp.	2,091	0.024
Aix sponsa	753	0.009
Corvus brachyrhynchos	433	0.005
Sylvagius floridanius	423	0.005
Canis lupus familiaris	358	0.004
Cyanocitta cristata	159	0.002
Peromyscus spp.	93	0.001
Sciurus carolinensis	60	0.001
Dasypus novemcintus	15	< 0.001
Lynx rufus	15	< 0.001
Sayornis phoebe	15	< 0.001
Marmota monax	6	< 0.001
Strix varia	4	< 0.001
Thryothorus ludovicianus	3	< 0.001
Tamias striatus	3	< 0.001
Sciurus niger	3	< 0.001

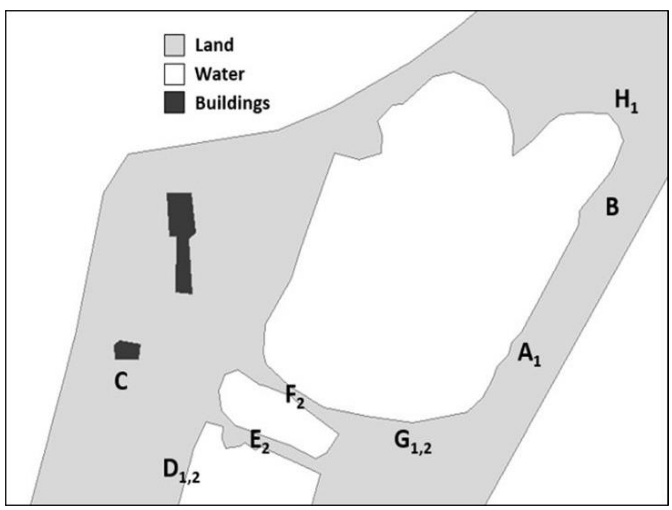

Figure 1. When testing bait preference, all bait sites (A-E) received 2,000 grams of corn and 2,000 grams of cat food. Salt blocks (1) and sweet beet powder (2) were placed at sites on Day 1 of the trial and not removed or refilled.

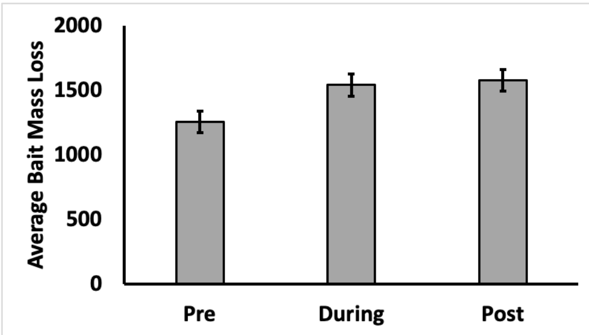

Figure 2. Average mass loss (Y; grams) across treatments (X). DF = 167, F = 4.4227, P < 0.0135. Bars not connected by letters are significantly different. Error bars represent standard error.

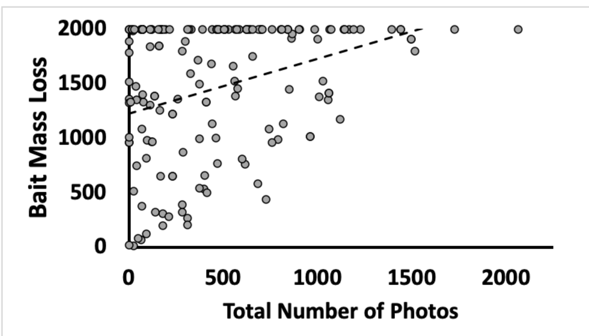

Figure 3. Bait mass loss (Y) increased as total number of photos increased (X). R^2 = 0.11, P < 0.0001.

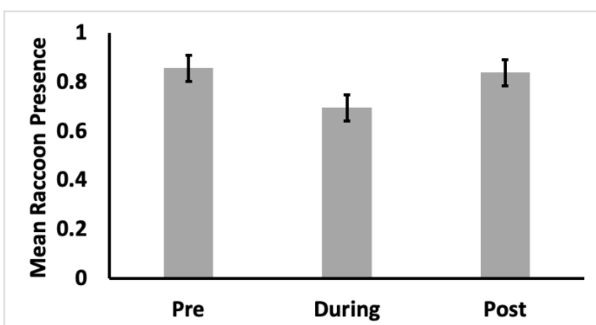

Figure 4. Mean number of raccoons per photo (Y) is lowest during urine treatment and not significantly different pre- and post-treatment (X). DF = 167, F = 3.09, P = 0.048. Bars not connected by letters are significantly different. Error bars represent standard error.

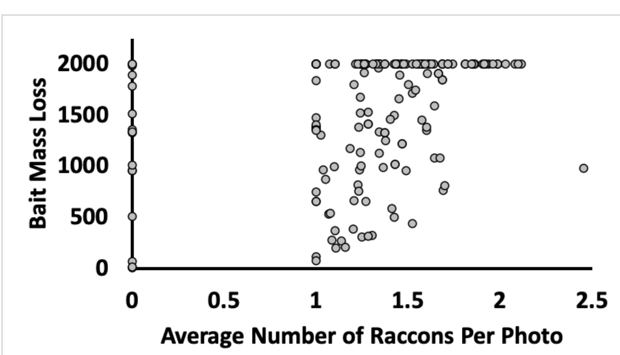

Figure 5. As mean number of raccoons per photo (Y) goes up, bait mass loss increases (X). R^2 = 0.07, P < 0.0001.

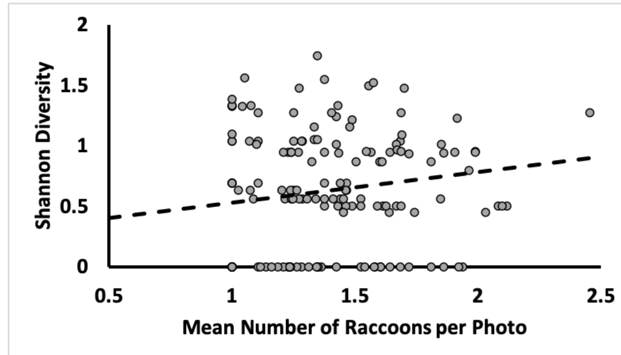

Figure 6. Shannon diversity (X) increases as mean number of raccoons increases (Y). R^2 = P = 0.0006.

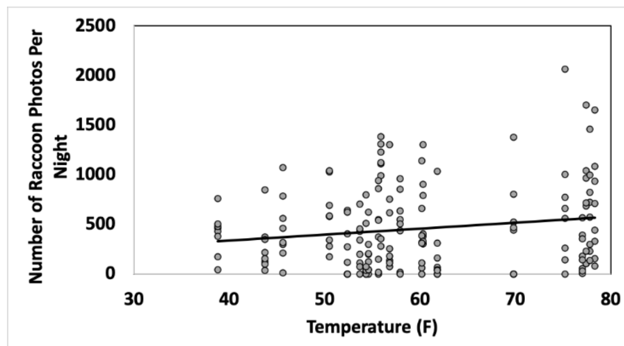

Figure 7. With temperature increase (Y), the number of raccoon photos increase (X). R^2 = 0.03, P= 0.0299.

DISCUSSION

Overall, we found limited support for the use of coyote urine as a raccoon deterrent and no support for coyote urine as a predator recruitment tool. We found that coyote urine decreased occurrence of raccoons and decreased bait removal (resource consumption); however, raccoon abundance and activity remained high when raccoons were present. Raccoon activity also increased diversity of other animals at the baits. Despite this, predator recruitment to baits and urine was extremely low and not statistically analyzed due to insufficient sample sizes.

The seasonal timing and specific location of this study may have contributed to the high abundance and activity level of raccoons at these sites (Parsons et al. 2013). Habitat and seasonality can be defining factors in raccoon diet (Rulison et al. 2012). Our study was completed during autumn when plant matter availability was rapidly declining at the site, which may explain the high activity levels, despite a predator sign. Further, protein consumption correlates with earlier breeding capacity and the potential for second litters in raccoons (Bissonnette and Csech 1938), suggesting that protein sources should be highly desirable food sources, particularly prior to breeding season.

Raccoons are most abundant on forest edges and near streams in Missouri (Dijak and Thompson 2000). Additionally, the presence of ponds and permanent water sources at the study site may have recruited female raccoons in higher numbers (Gehrt and Fritzell 1998), though we did not specifically analyze sex ratios.

Despite previous reports of predation and the use of coyotes and raccoons as models of mesopredator release (e.g., Rogers and Caro 1998), coyote predation of raccoons may actually be very low, resulting in no reason for raccoons to change foraging behaviors when detecting coyotes. Raccoons are adept climbers and may be able to easily avoid coyotes even when they are in proximity to one another (Stuewer 1943). Coyotes may be most consequential to raccoons as interference competitors; Gehrt and Prange (2007) also found no effect of coyote urine as a raccoon deterrent.

As raccoons adapt to human environments, natural resource managers need to consider the implications of their interactions and presence. Passive avoidance techniques such as predator urine, may work at sites with low raccoon densities, but in urban sites where raccoon populations are higher (Prange et al. 2003), other techniques or combinations of techniques may be required. Alternative techniques such as eviction fluid, noise devices, and visual tools may produce more successful deterrence (Bomford and O'Brien 1990, Mason 1998, Vantassel et al. 2013) in these environments. Future work should examine predator urine avoidance in other rural settings, urban settings, and among potential predator types, urine brands and concentrations. For example, while raccoons are common in urban settings, human infrastructure might lead to fewer encounters with predators; thus, predator urines may influence movement patterns more markedly than this study produced (Prange et al. 2004). Future studies should also continue to examine predator use of sympatric cues, as our results contradict other published reports which found increases in coyotes in sites treated with coyote urine (Windberg 1996, Shivik et al. 2011). Finally, rural environments create unique challenges for wildlife that are distinct from "natural" undisturbed environments and urban environments that should be evaluated and examined, as these challenges inform management strategies and deterrence efforts.

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