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Do available products to mask human scent influence camera trap survey results?

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Camera traps (i.e. remotely, motion or heat triggered cameras) can be used to examine a variety of ecological factors ranging from the activity patterns (Oliveira-Santos et al. 2008, Harmsen et al. 2010) to habitat selection (Fedriani et al. 2000, Kelly and Holub 2008) of wildlife. Camera traps are also used to estimate abundance, density and the distribution of secretive or rare species (Karanth and Nichols 1998, Trolle and Kéry 2003, Larrucea et al. 2007). Camera traps may be preferable to traditional mammal trapping techniques for various reasons, such as greater effectiveness for cryptic species (Sanderson and Trolle 2005, De Bondi et al. 2010) and high detection rates (Silveira et al. 2003, Gompper et al. 2006, Balme et al. 2009).

Despite their widespread use, there are still questions regarding appropriate protocols for the use of camera traps (Rowcliffe et al. 2011, Hamel et al. 2013; reviewed by Rovero et al. 2013). For example, little effort has been placed on assessing how disturbance associated with researcher presence at cameras during maintenance (i.e. checking batteries and memory cards) influences capture rates. Past studies have noted that animals can learn to avoid camera locations or are generally wary of camera traps, which may be due to either camera flash or disturbance associated with researcher activity (Cutler and Swann 1999, Sequin et al. 2003, Lyra-Jorge et al. 2008). Even minimal researcher disturbance may result in deposition of scent that may alarm wary species and result in avoidance of the area. Despite the need for further research on this topic, there has been no attempt to rigorously examine the role of human scent, or the masking of human scent, on camera trap effectiveness.

Our goal was to ascertain if the number of wildlife detections differ when human scent is masked versus unmasked while researchers perform regular camera maintenance. We hypothesized that wildlife capture rates would differ based on the presence of researcher scent, and we predicted captures would be higher on cameras where human scent was masked. We also believed that if no treatment effect was observed, two possible conclusions could be made: 1) the target species in the study region does not alter behavior due to human scent at camera trap stations and/or 2) employing available scent-masking products does not improve capture rates during camera trap surveys. The results of this study have potentially broad implications for the utility of this increasingly common survey technique.

Methods

Research was conducted at two sites in the Piedmont region of North Carolina, USA. We selected sites based on their similar habitat characteristics, remote location, and limited human traffic. The first site, referred to as the 'Haw River' site, is 16.2 ha of privately owned land in Alamance County, North Carolina. The property borders the Haw River and is predominantly alluvial forest habitat as described by Spira (2011). This rural locality is mainly exurban with minor components of agriculture nearby. The second site, referred to as the 'Rocky River' site, is located in Chatham County, North Carolina. The 12.9-ha study site is bordered by the Rocky River, and is comprised of oak–hickory forest (Spira 2011). This locality has been mostly uninhabited with only scattered agriculture close by. During the course of our study, human activity was documented once at the Haw River site (hiker) and twice at the Rocky River site (one hiker, one hunter). The Haw River site was surveyed outside of the recreational hunting season, and such activities are generally not permitted on this property. However, it is known that adjacent property owners hunt regularly. At the Rocky River site, hunting was also not permitted. On one occasion hunters were seen onsite, and on other occasions, hunters were heard in the surrounding area.

To test our hypothesis, we deployed eight camera traps at each site in total. We randomly applied one of two treatments, 'scent unmasked' or 'scent masked', to each of the eight cameras at each site, which resulted in four replicates of each treatment per site. Camera traps were placed semi-randomly within each study site, using randomly generated initial locations from a geographic information system

(GIS). We chose the nearest appropriate location within 15 m of the predetermined random locations, e.g. along a game trail, for camera deployment to ensure the highest chance of detection (Moen and Lindquist 2006, Rowcliffe et al. 2008, Brown and Gehrt 2009, O'Connell et al. 2011). We locked cameras in steel boxes and affixed them to trees at 23–27 cm above ground level to better capture both small and large animals (Kelly 2008). Cameras were oriented north to avoid issues associated with receiving direct sunlight (Brown and Gehrt 2009). We attempted to space cameras in order to reduce possible interaction between treatments. Given the limited size of our study sites, cameras were located at least 75–150 m from their nearest neighbor.

Cutler and Swann (1999) suggested that traditional white flash cameras may influence mammal activity. Although it is unclear if cameras with 'no glow' infrared flash offer significant benefits (reviewed by Rovero et al. 2013), we used a 'no glow' camera to minimize potential confounding effects. Cameras were set to take five pictures when their passive infrared detectors were triggered (trigger speed: 0.3 s). Camera sensitivity was set to high with no recovery time between triggers. Once cameras were placed, they remained in the same location during the duration of the study.

Experimental treatments

Prior to treatment application, cameras were deployed for one month without researcher disturbance. This was done to limit the impacts of scent deposition during camera installation. Pictures obtained in this baseline period were not directly comparable to data collected during treatment application period. Thus, pictures of wildlife from the baseline period were excluded from analyses, although patterns detected between pre- and post-treatment were used to make suggestions for future experimental design. Once treatment application began, we visited cameras for maintenance every two weeks (hereafter referred to as sampling period). Camera maintenance occurred over two subsequent days. All cameras in the scent unmasked treatment were visited on day one, while all cameras in the scent masked treatment were visited on day two. We used a GPS to map routes to each camera so that a maximum possible distance (100–150 m) was maintained from adjacent cameras in the opposite treatment.

For cameras in the unmasked treatment, normal fieldwork clothes were worn to mimic how a typical researcher might visit a camera location. For cameras in the scent masked treatment, we used a suite of commercially available scent-masking products shown to minimize or eliminate human-scent output (e.g. Pickering v. A.L.S. Enterprises 2012). We chose common commercial brands because we were interested in investigating the effectiveness of readily available items that researchers may employ. Scent-masking clothes include carbon fabric layers that reportedly bind to odor molecules, adsorbing them and preventing their release. Clothing consisted of scent-controlling boots, pants, socks, shirts, jacket, head-wear and gloves. In between site visits, these items were stored in a scent-obscuring bag that contained leaves and twigs from the respective study sites to further help mask unusual odors that may persist on clothing.

The outfit was washed every six weeks with an odor-eliminating detergent, following manufacturer's guidelines. Additionally, prior to maintenance of scent-masked cameras, researchers bathed with shampoo, conditioner, and soap meant to obscure scent, and they applied scent-masking deodorant. A set of non-specialized clothing was washed in detergent to act as a 'transition outfit' during travel to the research site. Once on-site, the specialized outfit was carried to the edge of the study area and then adorned. Before entering the study area, the researcher lightly misted the outfit with a spray to further ensure that any incidental scent accidentally transferred to the outfit was eliminated. Before handling cameras, scent blocking spray was re-applied to the outside of the gloves to remove any incidental scent from accidental contact with researcher skin or hair. After each camera was handled, a fine mist of scent-blocking spray was applied to the camera's security enclosure. Upon leaving the site, the researcher changed back into the transition outfit and the scent-obscuring clothes were appropriately stored. The products include proprietary formulas, so no information is available on their active ingredients. From the company website, these products rely on converting odor molecules, oxidation, bonding of molecules, and neutralization of odor (<www.hunterspec.com/products/all/all/Scent-A-Way>; accessed 3/25/2014). While the efficacy of such scent-masking products is hotly debated, product testing has shown scent-masking clothes can adsorb up to 99% of produced odors (Pickering v. A.L.S. Enterprises 2012).

Data analysis

Many complications can arise when analyzing camera trap images, such as multiple individuals captured in a single image, a long image series taken of a single individual, or false trigger events (Royle et al. 2009). The variable of interest during this study was the number of wildlife detections during each sampling period (capture rate). Therefore, if multiple animals were captured in a single image, they were each counted as separate detection events. In addition, if an animal spent extended amounts of time in front of the camera (based on time stamp), dozens of images would only count as one detection event. Likewise, if an animal left the field of view and returned from the same side it originally departed within two minutes, we did not consider it a new detection event. Therefore, each sampling period generated a count of animal detections (hereafter referred to as 'captures'), which we statistically analyzed.

We compared captures between treatments with a general estimating equation (GEE) analysis ($\alpha = 0.05$). GEEs are a 'semi-parametric' extension of the generalized linear model (GLM) and allow for analysis of repeated measures in a similar fashion to a repeated-measures analysis of variance (ANOVA). However, GEEs are particularly robust to data that break assumptions of normality and independence (Nelder and Wedderburn 1972, Ballinger 2004). Furthermore, GEEs are highly appropriate for analysis of count data due to their quasi-likelihood method of estimation (Zeger et al. 1988, Ballinger 2004). Because wildlife are not uniformly distributed across a landscape, captures were highly associated with camera location, so we selected an exchangeable correlation structure to account for this.

Standard error was calculated with a model-based estimator which performs better for data with few subjects and many repeated measures (Hardin and Hilbe 2002). The model selected for analysis was Poisson-loglinear (Gardner et al. 1995, O'Connell et al. 2011).

Considering many mammal species exhibit seasonal variation in activity, we included survey period as another explanatory variable. For all species analyzed we assessed the likelihood of our models (treatment only, survey period only, both treatment and survey period) with quasi-Aikake's information criterion (QIC; Pan 2001). All statistical analyses were conducted with SPSS 20.

Results

Camera traps were active at the Haw River site from early February to mid-July 2011, with each camera simultaneously in operation for 158 trap-nights. In July 2011, three cameras were stolen from this property, and research at the site immediately ceased. The study resumed at the Rocky River site and ran from September 2011 to the beginning of March 2012, with each camera simultaneously in operation for 210 trap-nights.

We obtained 2085 and 3358 mammal captures at the Haw River and Rocky River site respectively. Between both sites, 11 mammal species were observed (Table 1). The most frequently captured species at both sites were white-tailed deer *Odocoileus virginianus*, eastern gray squirrel *Sciurus carolinensis* and raccoon *Procyon lotor* (Table 1). Several species were omitted from statistical analyses due to low capture rates (Table 1), including the eastern cottontail rabbit *Sylvilagus floridanus* at the Rocky River site.

Table 1. The total number of mammal captures recorded by all cameras at the Haw River site (Alamance County, NC) and the Rocky River Site (Chatham County, NC). 'Unidentifiable mammal' are species unable to be determined from the quality of photographs. *Omitted from analysis due to low captures.

	Haw River Site	Rocky River Site
Coyote* *Canis latrans*	59	9
North American beaver* *Castor canadensis*	0	3
Virginia opossum *Didelphis virginiana*	134	251
River otter* *Lontra canadensis*	2	0
Bobcat* *Lynx rufus*	3	1
Striped skunk* *Mephitis mephitis*	0	2
White-tailed deer *Odocoileus virginianus*	632	971
Common raccoon *Procyon lotor*	425	668
Eastern gray squirrel *Sciurus carolinensis*	459	1428
Eastern cottontail rabbit *Sylvilagus floridanus*	334	16
Gray fox* *Urocyon cinereoargenteus*	3	5
Unidentifiable mammal*	34	4

Our analyses revealed that treatment is a likely factor explaining differences in white-tailed deer captures at the Haw River site only ($p = 0.013$; QIC = 0.376.8; mean scent masked captures/survey period = 5.23 ± 0.63 SE; 95% CI = 4.1–6.6; mean unmasked captures/survey period = 3.38 ± 0.49 SE; 95% CI = 2.5–4.5; Fig. 1). Although not formally compared, captures of white-tailed deer at the Haw River differed between baseline and treatment period. For example, we obtained fewer deer captures by cameras that would receive the scent-masked treatment (4.75 ± 2.1 SE) than captures by cameras that would receive the unmasked treatment (16.75 ± 15.5 SE) during the baseline period (Fig. 1). Similar 'switch' patterns were seen for raccoon and eastern cottontail at the Haw site, and opossum at the Rocky site. For the other species at both sites, survey period (seasonality) was a stronger predictor of captures (Table 2, 3). However, when examining the treatment effects for species at both sites, there are general trends that imply scent (or scent masking products) cannot be ruled out as affecting mammal activity at camera locations (Table 4). Even though the use of scent-masking products did not significantly affect model selection for other species, we include the confidence intervals of the scent effect sizes to give a sense of the strength of our results, as recommended by Steidl et al. (1997) and Johnson (2002).

Discussion

Our hypothesis and prediction (i.e. that capture rates would differ and be higher at scent masked cameras) were only statistically supported for white-tailed deer at the Haw River site. Other species did not exhibit significant treatment responses, yet the treatment related effect sizes for most species indicate that scent-masking could have a more subtle effect than our study was able to detect (Table 4). Many had an average GEE slope parameter (Beta) that indicated higher captures at cameras where scent was masked. Thus, the impacts of human scent and scent-masking products on wildlife activity and survey effectiveness appear to be complex.

Our focal species are generally wary of human activity, with the exception of habituated individuals in more urban or suburban areas. Our inability to detect a difference based on treatment may seem unexpected for several of the species that we captured, which are often considered scent-motivated (e.g. raccoons). Yet, it is likely that scent motivation in these species relates to food rather than aversion to humans. It is not surprising that white-tailed deer showed a response based on treatment type. This species is hunted recreationally in North Carolina. Hunting pressures are known to cause changes in home range size, movement and activity patterns of white-tailed deer (Kilpatrick and Lima 1999). This may be the result of an anthropogenic 'landscape of fear' created by hunters. As reviewed by Laundré et al. (2010), it is beneficial for prey species to maintain a baseline level of fear of predation. Without such fear, prey species may undertake risky behavior that could lead to mortality. Much like the fear that elk *Cervus canadensis* feel due to the threat of predation by wolves *Canis lupus*, human hunters may instill fear in various game species in the vicinity of our

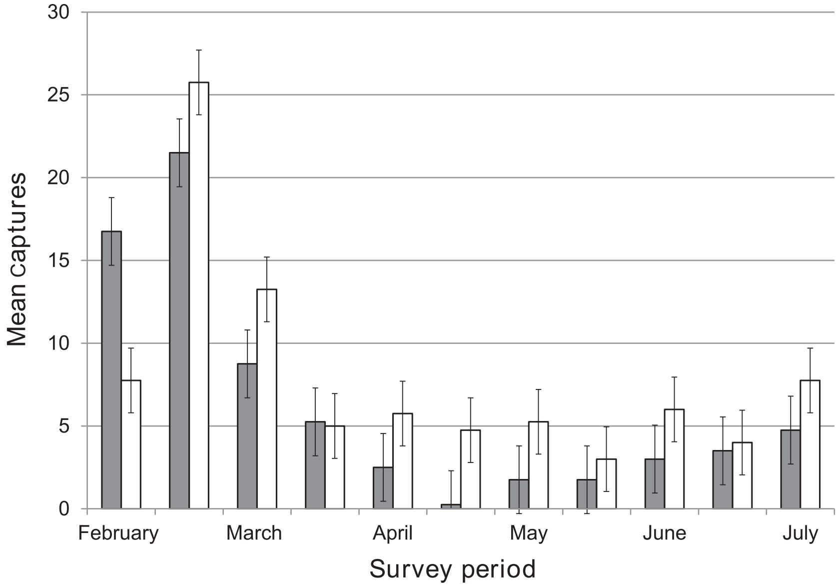

Figure 1. White-tailed deer captures among survey periods (±SE) at the Haw River site (Alamance County, NC). Grey represents cameras in the unmasked treatment, and white represents cameras in the scent-masked treatment. February is baseline data and was excluded from formal analyses.

study sites, such as white-tailed deer (Laundré et al. 2001, Ciuti et al. 2012). As a result, game species may associate human scent with increased risk of mortality in our study areas and shift activity away from camera locations where scent was unmasked.

We found evidence to support this notion by descriptively comparing the capture rates of white-tailed deer during the baseline period to the treatment period. For example, during the baseline period at the Haw site we had more white-tailed deer detections at cameras that would be scent unmasked versus scent masked (February; Fig. 1). Once treatment application began, human scent may have sufficiently altered activity levels at unmasked camera locations. For species other than white-tailed deer, weaker scent effects may be due to lower hunting pressures or to an inconsistent response to human scent. The 'landscape of fear' concept requires that animals identify human activity as a threat. Low hunting pressure may reduce the perceived threat, resulting in a weaker response to human scent.

While white-tailed deer showed a treatment effect at the Haw River site, this trend was not detected at the Rocky River site. There was more documented human activity at the Rocky River site, and given the presence of hunters nearby on several occasions, it is possible that undocumented trespassing could have confounded treatments in certain survey periods. Additionally, it is possible that potential differences in the density of white-tailed deer per site, subtle variation in habitat composition at each site, differences in the surrounding landscape matrix, or the time of year during which each survey occurred precluded any treatment effect at the Rocky River site. This last factor may play the biggest role. The rate of human scent deposition and the duration of scent retention in the area surrounding camera traps is likely to be higher in the hotter months of the spring and summer in North Carolina. The autumn and winter months in which surveys took place at the Rocky River site would be when researcher odor output, due to sweating, would be at a minimum. Additionally, during the months of study at the

Table 2. GEE results from the Haw River site (Alamance County, NC) within a QIC model selection framework. The p-values for the models' factors are included.

Species	Treatment and Survey period	Treatment	Survey period
White-tailed deer	QIC = 376.8 Treatment p = 0.013 Survey period p = 0.000	QIC = 404.8 p = 0.001	QIC = 388 p = 0.000
Eastern gray squirrel	QIC = 369.8 Treatment p = 0.452 Survey period p = 0.000	QIC = 456.7 p = 0.079	QIC = 344 p = 0.000
Eastern cottontail rabbit	QIC = 398.2 Treatment p = 0.000 Survey period p = 0.000	QIC = 566.3 p = 0.001	QIC = 395.1 p = 0.000
Raccoon	QIC = 412.3 Treatment p = 0.562 Survey period p = 0.000	QIC = 581.6 p = 0.749	QIC = 347.5 p = 0.000
Opossum	QIC = 132.7 Treatment p = 0.228 Survey period p = 0.001	QIC = 132.7 p = 0.231	QIC = 130.7 p = 0.001

Table 3. GEE results from the Rocky River site (Chatham County, NC) within a QIC model selection framework. The p-values for the models' factors are included.

Species	Treatment and Survey period	Treatment	Survey period
White-tailed deer	QIC = 664 Treatment p = 0.006 Survey period p = 0.000	QIC = 1038.9 p = 0.000	QIC = 636.7 p = 0.000
Eastern gray squirrel	QIC = 1284.9 Treatment p = 0.000 Survey period p = 0.000	QIC = 1480 p = 0.000	QIC = 1004.1 p = 0.000
Raccoon	QIC = 960.1 Treatment p = 0.033 Survey period p = 0.000	QIC = 965.8 p = 0.664	QIC = 846.8 p = 0.000
Opossum	QIC = 540.6 Treatment p = 0.325 Survey period p = 0.001	QIC = 549.2 p = 0.815	QIC = 477.9 p = 0.002

Haw River site, a regional drought occurred, whereas precipitation levels were higher during research at the Rocky River site. Scent is harder to track during frequent precipitation, and environmental conditions play a large role in scent detection and persistence (Regnier and Goodwin 1977) as seen in search-dog studies (Shivik 2002). Thus, the likelihood that researcher scent deters wildlife from a given area may be higher in warmer, drier seasons.

Several past camera trap studies have commented on the need for research to assess the influence of human activity and scent on camera trap effectiveness (Cutler and Swann 1999, Lyra-Jorge et al. 2008, Rowcliffe et al. 2008). While there have been camera trap studies that address the response of wildlife to olfactory cues as attractants (Monterroso et al. 2011) and the impact of human activity on wildlife (Griffiths and van Schaik 1993, Ngoprasert et al. 2007, Ohashi et al. 2013), none have explicitly addressed the subtler effect of researcher scent. In the latter studies, mammals in areas of high human disturbance were more active at night, when humans were less so. Several non-camera trap studies report that the influence of human scent and scent-masking products had variable effects on nest or seed predation by mammalian predators. Some found that masking human scent decreased predation (Whelan et al. 1994, Duncan et al. 2002) whereas others found no scent-related effect (Skagen et al. 1999, Donalty and Henke 2001). Furthermore, Shivik (2002) reported that the effectiveness of trained search-dogs at finding targets was not altered by scent-masking clothes. By simultaneously using hygiene, clothing, and chemical products, our methods may address scent-effects more comprehensively than the aforementioned studies; however, we cannot directly compare our work to theirs because the perceived 'rewards' associated with scent in these studies differ (e.g. a camera trap versus a prey item in a nest). Our study is the first to examine whether scent-masking products affect camera trap surveys, and our results are useful as a spring-board for future research on this topic.

There are several potentially confounding variables inherent in a study of this nature that we attempted to address. First, persistence and range of detection of olfactory stimuli are extremely difficult to assess. We visited cameras only every two weeks to help control for this, but it is unknown how long our scent remained on-site. It was also difficult to determine a priori how far apart cameras should be spaced to avoid cross-treatment contamination. We attempted to offset this by placing cameras as far apart as our study site boundaries would allow and by mapping widely-spaced travel routes for servicing cameras. However, we recognize the size of our study areas may have confounded treatment effects. We recommend that future research on human scent and camera traps include a greater number of large study areas that allow greater spacing of cameras, a higher number of camera traps, longer camera deployment periods, and simultaneous surveys at multiple sites. Given the 'switch' in some species' capture rates between the baseline and treatment periods, we believe that a crossover design would provide stronger evidence to support an effect from human scent. It may also be beneficial to add a third treatment, including items that are well-saturated with human scent (such as unwashed socks) to provide stronger negative stimulus for passing wildlife. This could potentially allow for a better determination between a scent response and a scent-masking product response.

Table 4. The parameter estimation of Beta (± SE) and its 95% Wald confidence interval for treatment effect sizes for all species included in GEE analysis. Negative values indicate captures were higher at Scent-masked cameras, and positive values indicate higher captures at Unmasked cameras. Values are derived from models that include both Treatment and Survey period regardless of model likelihood (Table 2, 3).

Species	Haw River Site	Rocky River Site
White-tailed deer	−4.350 (± 0.175); (−0.778, −0.091)	0.293 (± 0.107); (0.083, 0.502)
Eastern gray squirrel	−0.121 (± 0.161); (−0.437, 1.94)	−1.198 (± 0.108); (−1.412, −0.985)
Eastern cottontail rabbit	0.860 (± 0.210); (0.447, 1.272)	N/A
Raccoon	−0.107 (± 0.185); (−0.469, 0.255)	−0.353 (± 0.166); (−0.678, −0.029)
Opossum	0.264 (± 0.218); (−0.165, 0.639)	−2.38 (± 0.242); (−0.712, 0.236)

Our results indicate that selection of appropriate camera locations and implementation of surveys during seasons of high wildlife activity may be more important than masking human odor to conduct effective camera trap surveys for species that show no strong aversion to human activity. In other words, researcher use of commonly available scent-masking products may not substantially increase camera trap capture rates for many Piedmont mammals. It is important to note that our results may not be representative of other locales or species. For example, canids and felids are generally wary of human activity (Sequin et al. 2003), and we would expect them to be more sensitive to scent at camera locations. Unfortunately, our data did not yield enough captures to include them in our analysis. Furthermore, the Piedmont region of North Carolina possesses a high human population, so there are few areas where animals have not experienced some level of human activity. Despite this, we were able to detect that human scent (or the masking of human scent) potentially affected the activity of a species that adapts well to suburban areas, where human scent should be prevalent. It seems likely that human scent could have a larger impact on camera trap surveys for species that 1) exist in lower densities than white-tailed deer, 2) are in areas where human scent is less common (and may therefore be perceived as a novel threat), or 3) are extremely cautious and do not acclimate well to human scent or activity. Because our results cannot definitively support that some species exhibit scent-related effects, it might be beneficial for camera trap studies to take some scent-masking precautions to maximize effectiveness. This is again particularly true if wary species (i.e. canids and felids) are the focus. In as much as camera traps are used for monitoring rare, declining, or endangered species, ensuring that camera trap surveys capture and detect animals effectively is important for accurately informing conservation decisions. Therefore, we believe our study provides a good starting point for further research that addresses the role of human scent and scent-masking products in camera trap surveys.

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