

**The Landscape of Fear and Trophic Cascades: Does Human
Presence at RMBL Affect Deer Behavior?**

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Abstract Humans have a long history of disturbing the environment. While physical scars on the earth are quite evident, humans can have more insidious influences on the behavior of wildlife as well, including altering spatial and temporal land use of animals. The hypothesis of this study was that this behavioral alteration manifests itself at RMBL in coyotes (*Canis latrans*) avoiding the townsites and mule deer (*Odocoileus hemionus*) flocking to the townsites to avoid coyotes (*C. latrans*), causing a gradient in herbaceous plant fitness within Gothic. The aim of this project was to see whether a human-coyote-deer-plant trophic cascade was occurring at RMBL. To estimate deer density, we used a paintball marker to mark deer and the Lincoln-Peterson mark-resight method to estimate deer population. To see if coyote scent affected deer browsing rates, we established three study sites with two stations in each: one with coyote urine, one with water as a control, 120 meters apart. Weekly observation sessions allowed us to quantify behavior and relative distance to treatment and control stations. Behavioral observations were quantified using the program JWatcher and relative distance data were compiled in the program ArcMap. There was no relationship between distance to treatment station and time allocated to foraging or vigilance, for all animals or for those observed within 60 m of a scent station. Differences between foraging and vigilant levels between sexes were found, with females averaging more vigilant behavior and less foraging behavior. We also compared average minimum distance to cover vs. the same number of random points within the observer's field of view at each site. In study site 2, deer observation points averaged significantly ($p=0.007$) closer to cover than random points while in the other two sites, little difference between deer observation points and random points were found. We speculate this is because site 2 consisted of mostly open meadow habitat, while the other sites had a large amount of cover, inhibiting deer from reaching their "minimum distance to cover threshold" of approximately 14m as they can in site 2.

Keywords: Trophic Cascade, Landscape of Fear, Predator and Prey Interactions, Mule Deer, Coyote, *Odocoileus hemionus*, *Canis latrans*.

Introduction

In trophic cascades, organisms at high trophic levels (i.e. predators) alter the abundance, behavior or biomass of organisms at lower trophic levels (i.e. primary consumers and producers) through direct and indirect effects in numerous ecosystems (Moran & Hurd 1999; Pace et al. 1999; Schmitz et al. 2000; Beschta & Ripple 2009). Shown in many marine and freshwater systems, only relatively recently has this trend been documented in terrestrial ecosystems as well (Pace et al. 1999).

Humans may be an integral component of such trophic cascades. Humans have caused range contractions in many large predators in the 20th century due to over hunting and human

growth (Laliberte & Ripple 2004). Human expansion also has behavioral effects on predators. For instance, grey wolves (*Canis lupus*) actively avoid areas of high human activity in Banff National Park while bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) alter their temporal behavior and land use due to high human activity, in some cases avoiding the areas altogether (Hebblewhite et al. 2005; George & Crooks 2006).

Predator scent alone has been shown to alter a prey species's foraging rate, physiology (body mass), behavior, reproduction, and spatial distribution (Apfelbach et al. 2005). Of particular interest to this study is the resulting spatial distribution of prey species from these relationships. This phenomenon, elegantly dubbed the "Landscape of Fear" by Laundre et al. in 2001, is a well documented and widely accepted occurrence shown to dictate how a given prey species is distributed in its environment based on the threat of predation. Indeed, multiple studies show prey species actively avoid areas of high predator activity, creating a "landscape" of prey density based solely on perceived predation risk (Laundre et al. 2001; van der Merwe and Brown 2008; Tolon et al. 2009). This has been revealed in many different systems, affecting many taxa, including ungulates (Hernandez & Laundre 2005). In turn, areas with coyote removal have been shown to have a positive impact on mule deer (*Odocoileus hemionus*) density (Harrington and Conover 2007).

There is evidence, both formal and anecdotal, that this "Landscape of Fear" affects the local mule deer population here at the Rocky Mountain Biological Laboratory in Gothic, Colorado; a 2005 REU study by Renee Arozqueta suggested that deer are indeed more prevalent inside the RMBL fence than outside. Black tailed deer (*O. hemionus columbianus*), a subspecies of the subject species mule deer, have an innate and dramatic aversion to predator scents,

including that of coyote (Müller-Schwarze 1972). Black tailed deer also browse less on plants treated with predator odors (Melchior & Leslie 1985).

From this evidence, we hypothesized that deer densities are higher in the RMBL townsite than the surrounding habitat because humans inhibit coyote activity in the townsite, and mule deer take advantage of this predator-free zone, raising browse rates within RMBL. We also hypothesized that the presence of predator scents raised vigilant behavior and lowered browsing rates in local deer.

The aim of this project was to see whether a human-coyote-deer-plant trophic cascade is occurring at RMBL. More specifically, my portion of this project aimed to accomplish the following objectives: 1) To census the population of deer in and around town. 2) To determine the distribution of deer in and around town. 3) To determine the distribution of coyotes in and around town. 4) To determine whether deer behavior is influenced by experimentally applied coyote scent. 5) To determine whether deer behavior is influenced by distance to cover.

Methods

How many deer are there?

Deer were marked with oil-based paintballs, which allowed us to make rough estimates on population size (Mahoney et al. 1998; Skalski et al. 2005; Pauley & Crenshaw 2006). We used green, orange, and red paintballs to mark the deer using recreational paintball equipment (Tippmann 98 Custom, Tippmann LLC, Fort Wayne, Indiana, USA). Patterns and colors of marked deer were recorded on deer silhouette sheets, along with the date, time, and approximate location tagged. Each individual was then given a number up to 25, as that is what the original permit allowed for (Colorado Department of Natural Resources, Division of Wildlife).

We also noted any scars or identifying marks as well to further distinguish between animals. According David Inouye's personal observations, the marks lasted approximately 10-14 days, perhaps due to deer shedding winter coats. We therefore used a two week sliding window for marks being lost in addition to the traditional method. The original license was amended on July, 13, which allowed us to tag up to 25 more individuals. These individuals were given numbers as well, starting with number 26. We used the Lincoln-Petersen mark and resight method, to estimate the local deer population, using scan samples of marked animals as "recaptured" data (Mahoney et al. 1998). The formula for this method is:

$$N=MC/R$$

Where N=population estimate, M=number of deer marked, C=total number of deer seen, R=total number of marked deer resighted. We estimated population size on a weekly basis, both by site and across all sites. Due to the high variability of our weekly estimates, we averaged the four weeks that produced the estimates with the narrowest range, reasoning that these were likely to be the most accurate. The range of estimates over these four weeks was ± 17 deer.

Due to the large size of site 3, we thought it was possible that some deer were so far away from the observer that recognizing marked deer would be impossible. We tried to account for this by excluding these deer from estimates and adjusting the area of sight accordingly. We defined a deer as "too far away" if it was on the West side of the East River and subtracted them from the weekly number resighted. The new area of sight was recalculated as any area in sight on the East side of the East River.

Many deer were only marked on 1 side, leaving the possibility that some deer recorded as unmarked could in fact be marked individuals. To account for this, we attempted to modify the

Lincoln-Peterson formula by doubling the number resighted or the number marked. This led to either doubling or halving the population, and so was not used in subsequent analyses.

To calculate deer density, we used Arcmap to estimate the area of observation at each site by outlining what the observer could see in the program and using the measuring tool to then calculate the area of view for each site.

Where are deer?

By observing deer off the townsite in separate, weekly observation sessions from fixed locations, we were able to document deer spatial distribution on a larger scale. An observer went out at dawn and dusk 3 times a week and simply did a scan at 10 minute intervals for 1.5 hours, marking the number and position of deer on an aerial photograph of the observation area. Sites in north and south Gothic provided out of town locations, while an observation site in Johnson meadow provided in town data.

We also looked at the total number of sightings per site, ranking them from highest human activity to lowest with Site 1 having the highest human activity, and Site 3 having the lowest human activity. Since site 1 is in the middle of the townsite, we reasoned it has the highest human activity, which falls off with distance from Gothic center. Therefore site 3, the farthest away from Gothic proper was reasoned to have the lowest human activity.

To see if road activity could possibly affect deer activity, we looked at the average distance to road in the four cardinal directions for each station, as measured in Arcmap. We then compared these distances with the number of deer seen in that area to see if there is less deer activity during the day near roads. Stations with major obstacles (i.e., forest or rivers) between them and a road were not counted.

To examine other site effects, we looked at the average distance to road and average distance to cover for each station. Measurements were done in Arcmap in the four cardinal directions, which were then averaged together.

Where are the coyotes?

To estimate coyote activity, we walked the following transects twice this summer: Deer Creek Trail, Copper Creek trail, Happy Valley Road, Trail 401, Kettle Ponds Road, and Avalanche Cabin Road. The first transect walk was on June 18, 2010, and the second walk was on August 2, 2010. We marked positions of coyote sign (coyote sign defined as scat or prints) using a GPS (GeoXT, Trimble Navigation, Ltd., Sunnyvale, California). We also noted age, type and species of sign if different from coyote. If the sign included scat, we collected it on the first so as not to double count it on the next walk. Using Arcmap again, we measured the distance of each transect and calculated the number of coyote signs per km inside and outside the RMBL fence. We estimated transect length with the Arcmap measuring tool. We then divided transect length by the number of scats per area (in town vs. out of town) and converted that into number of scats per km.

Is deer behavior influenced by distance to predator scent?

To simulate high coyote activity within the town area, we defined 3 study sites, in the Johnson Meadow (Site 1), the Research Meadow (Site 2), and South Gothic (Site 3) (Fig 1). These sites were chosen due to their similar vegetation quality, with *Valeriana occidentalis*, a favorite of deer this time of the year, prevalent at all sites. Each site had one scent station with coyote urine, and as a control, one station with water approximately 120 meters away, giving a total of two stations per site. To avoid possible bias, we randomized the position of the scented

and the control stations by flipping a coin. Each station consisted of four Petri dishes at the corners of a 1 meter square, with a central flag marking the middle. We used polyacrylamide gel (Terra Sorb, Plant Health Care Inc., Pittsburgh, PA, USA), which absorbs the liquid and releases it slowly over time (Parsons & Blumstein 2010). We filled the Petri dishes with 10mL of Terra Sorb and 15mL of either coyote urine (Lexington Outdoors Outdoor Solutions Inc., Maine, USA) or water, depending on the station. We refilled the stations twice a week (on Wednesday and Saturday). Each station also had flags spaced 10 meters away from the central flag in the four cardinal directions to aid in estimating deer distance to stations.

To assess the frequency of vigilant behavior in mule deer in proximity to coyote-scented stations, we established a schedule of observation sessions. To ensure no observer bias, one observer collected all focal and scan data for the summer. Each observation session had the following 2 objectives: (1) To assess the frequency of vigilance behavior of deer in proximity to scent stations and (2) To note the number and location of deer in the observation area every 10 minutes.

Objective (1) was achieved with 2 minute individual focal observations. The observer chose a deer in the area and noted their relative position to the nearest station, using the 10 meter flags to reference distance and direction from the nearest station. The I.D. of the deer (marked or unmarked) and time of focal was noted as well. Approximate wind speed and direction was also noted. The observer then watched and recorded the individual's foraging and vigilance related behavior into a tape recorder for 2 minutes. We chose 10 behaviors commonly related to either foraging or vigilance: look chew, foraging, walking-head down, walking-head up, stand look, sniffing ground, scratching, running, stotting, and other, with an additional option for "out of sight." These were then combined into four categories: foraging, vigilant (look chew, stand look,

walking-head up, running) non-vigilant (scratching, sniffing ground, walking head down) and high vigilant (stand look, stotting, running). Behavioral data recorded in the field were quantified using the program JWatcher (Blumstein et al. 2001), which allowed us to study the proportion of time foraging and vigilant with respect to distance from the scent stations and as a function of sex. Relative positions to scent or control stations were recorded into the mapping program Arcmap (ESRI, California), enabling us to quantify distance to the scent and control. We estimated observer error by first having the observer estimate the distance of 10 randomly placed flags around a station and then comparing these estimates to the actual distance of the flags to the station, measured with a measuring tape. This produced an average error estimate of 3.3 meters (SD= 3.80m).

Objective (2) was accomplished in the following manner: each individual's I.D., position, and time sighted, was noted on an aerial photograph of the site. These data were also recorded into the program Arcmap to quantify the spatial distribution of the deer around the scent and control stations.

To maximize the probability of sighting deer, observation sessions occurred when deer were most active, i.e. dawn (~0530) and dusk (~1830) as scheduling allowed. We carried out 1.5 hour observation sessions in the morning and evening 3 times a week, starting June 5, 2010 and ending on July 25, 2010. This allowed us to observe each site for the same amount of time at the same time of day each week.

We fitted linear regression models to explain variation in our dependent variables (proportion time allocated to vigilance and foraging) by our independent variable (distance from scent). Additionally, we looked at focals within a 60m radius of stations, broken into 10m increments, as a sub-set of the larger sample to see if there was a distance threshold for scent detectability. We

then tested for sex effects in two ways: first, by seeing if there were differences in proportion of time allocated to vigilance or foraging by sex (using a t-test), and then by regressing distance from scent against our measures of time allocation. We explored this distance effect on several spatial scales, seeing if there was any difference in sexes' behavior within 60 meters of scent, both within and between stations.

Is deer behavior influenced by distance to cover?

Cover may have profound effects on large ungulates (White & Berger 2001; Lee 2005). To see if there were distance to cover effects, we estimated minimum distance to cover for all observation points (scans and focals) in Arcmap and compared those numbers to the same number of random points (generated by Arcmap) within the areas of observation. For our purposes, cover was defined as any significant patch of willows (i.e. more than 2) or forest edge. Unpaired t-tests were used to analyze these data and Cohen's d-score calculation was used to estimate effect size. We further broke this down by looking at proportions of vigilance and foraging behaviors between sexes and minimum distance to cover, again using an unpaired t-test and Cohen's d-score to analyze the data.

Results

How many deer are there?

Area of sight for site 1 was approximately 0.03km^2 ; site 2 was 0.02km^2 and site 3 was approximately $.61\text{km}^2$. Summed area of sight across all sites was 0.66km^2 . Mean deer population across all sites (without 2 week sliding window) for the most accurate 4 weeks (weeks with

range of ± 17 individuals) was estimated to be 57.69 individuals per 0.66 km^2 across all sites or 87.42 individuals per km^2 (Table 1). The minimum number known alive was 18 individuals.

Estimates were considerably lower when using the two week sliding window (Table 2). Mean deer population across all sites was 15.94 or 24.15 individuals per hectare.

When excluding deer that were too far away to recognize marks at site 3, estimates changed considerably (Table 3). The recalculated area of sight was $.12 \text{ km}^2$ across all sites. The average of the 3 weeks with the narrowest range was 17.22 individuals. Density estimates were dramatically higher with the inclusion of the smaller area of sight at 143.52 deer per km^2 .

Where are deer?

Betsy found deer were more prevalent in town than out of town ($p = 0.027$, Fig. 2).

Site 1 control station has a mean distance to road of 79.95m, while the scent station is an average of 156.22m from road. Site 1 had 4 and 14 focals within 60m of the control and scent stations respectively. Site 2 was not used in analyses as only the scent station had an unobscured path to a road, and that was only in the Western direction (109.6m). Site 3 had the lowest average distance to road, with the scent station being a mean of 62.99m from a road and the control station averaging 9.21m from road. There were no focals within 60m of either station at site 3.

The site 1 scent station had the shortest average distance to cover (113.40m) and the most deer activity within 60m (20 focals, 19 scans). The control station was 45.60m away from cover and had less activity (4 focals, 7 scans). Site 2 control station was 63.053m away from cover and had 8 focals and 17 scans within 60m while the scented station was 153.45m from cover and had 5 focals and 13 scans within 60m. The site 3 control station was an average of 72.035m, while

the scent station was 161.64m from cover. There were no focals within 60m and each station had just 2 scan samples within 60m.

There were 81 total observation points (47 scans, 33 focals) at site 1, the area of highest human activity. Site 2 had 60 total observation points (36 scans, 24 focals). The site with the lowest human activity, site 3 had 61 observation points (59 scans, 2 focals).

Where are coyotes?

On June 18, 2010, we walked 4640.96m of coyote transect, with 1246.49m of transect inside the Gothic fence and 3394.47m outside the Gothic fence. Between our two walks, we found 11 coyote scats in town and 22 scats out of town, giving an in town scat density of 0.009 per meter or 8.82 per km, and an out of town density of 0.006 per meter or 6.45 per km ($p=0.2382$). Overall scat density was 0.007 per meter or 7.11 per km (Fig 3). Our second transect walk on August 2, 2010 yielded only 1 coyote scat on the Copper Creek transect (out of town). Deer Creek Trail had been recently trampled by cattle throughout the entire length of the transect outside of the gothic fence, which could have greatly reduced the number of scats found on the second walk.

Is deer behavior influenced by distance to scent stations?

There was no relationship between distance to coyote scent and proportion of focal spent foraging ($R = 0.02$, $p = 0.829$; Fig. 4). Summed vigilance (walking head up, stand look, look chew, and running) proportions compared to distance from scent station also showed no relationship ($R = 0.055$, $p = 0.68$; Fig. 5). Additionally, we looked at focals within a 60m radius of stations as a sub-set of the larger sample; Fig. 6 shows these results ($p = 0.105$, $d = 0.859$ for site 1;

$p=0.233$, $d=0.518$ for site 2). Total deer scans per station within 60m show a similar pattern (Table 4).

Statistically significant differences were found between sexes behavior, with females foraging less than males ($p=0.029$, $d=0.529$) and males exhibiting less vigilant behavior than females ($p=0.014$, $d=0.361$). Only were differences in high vigilance behaviors not statistically significant ($p=0.055$, $d=0.351$; Fig. 7). We found mixed results when comparing deer minimum distance to cover with that of random points (Fig. 8). Sites 1 and 3 showed no difference between random points and deer ($p=0.448$, $p=0.458$ respectively). At site 2 however, deer averaged 13.88 meters from cover, while random points were an average of 22.6m from cover. This proved to be a highly significant result ($p=0.0007$).

Is deer behavior influenced by distance to cover?

We found no relationship between distance to cover and vigilant or foraging behavior across all sites. Time allocated to foraging was not related to minimum distance to cover across all sites ($R=0.017$, $p=0.892$). Similarly, vigilance proportions did not change significantly with minimum distance to cover ($R=0.068$, $p=0.61$). Summed non-vigilance behavior (foraging, scratching, sniffing ground, walking head down) were also not found to be related to minimum distance to cover ($R=0.051$, $p=0.704$). Summed high vigilance (stand look and running) behaviors did not seem to change with minimum distance to cover as well ($R=0.02$, $p=0.874$).

Discussion

These results do not provide strong support the trophic cascade hypothesis; we found no differences in coyote presence, nor did we see effects of coyote urine in the ways that we

measured it. Accounting for fading marks on deer seemed to provide a more accurate estimate of the population for this area. (Kufeld et al. 1987; Unsworth et al. 1999). Deer do seem to be more common within the RMBL fence than outside of it, as well as most common around the site with the highest human activity (site 1) when compared to the other sites. Coyote density appears equal both in and out of town, a surprising result given what George and Crooks (2006) indicated in their study. Deer seem to be behaviorally unaffected by coyote scent, as we found no relationship between foraging, non-vigilance, vigilance, and high vigilance behaviors and distance to coyote scent. We did however find behavioral differences between sexes, with males being significantly less vigilant than females, which is a similar finding to other studies on large ungulates (White & Berger 2001; Childress & Lung 2003). Similarly, there was a difference in distance to cover and sex, with males tending to stay out in the open more than females.

I will now discuss each result and possible explanations for them.

Deer population estimates

Mule deer estimates for montane habitat in Colorado range from 14 to 29.6 deer/km² (Kufeld et al. 1987; Unsworth et al. 1999). Our estimate using the traditional method were much higher than these estimates (87 deer per km²). Accounting for deer too far away to recognize a mark were dramatically higher as well (143.52 deer per km²). Once mark loss was taken into account, however, estimates fell dramatically (24 deer per km²). Although this estimate does fall in the "expected" range of deer density for this area, it is still difficult to gauge accuracy without additional testing. There could still be biases in the data, as some assumptions (no immigration or emigration, individuals have equal chance of being resighted etc.) of the Lincoln-Peterson method were still broken. We know that animals moved around, and we know that not all

individuals had an equal chance of being re-sighted. These violations have skewed results, though it is impossible to tell in what way.

Additional summers of data should put these estimates into context and allow us to better gauge their accuracy. Furthermore, marking all animals on both their left and right sides would eliminate any ambiguity for deer observed as "un-marked," which would also increase estimate accuracy.

Where are deer?

It appears deer are most prevalent in the areas with the highest human activity (Site 1), though given the ambiguity of other results, it is difficult to attribute this trend to a "Landscape of Fear." In addition, there were more deer sightings in site 3 than in site 2 (61 and 60 respectively), further lessening the credibility of our original hypothesis that deer are more prevalent in RMBL to avoid coyotes. Minimum distance to cover could provide an explanation here however, as the sites with the lowest average minimum distance to cover also had the most deer activity. Given that our observation sessions were in fawning season and lactating ungulates stay closer to cover (White & Berger 2001) we could be seeing not a "Landscape of Fear" but a "Landscape of Maternity."

Where are coyotes?

It appears that early season coyote density was relatively the same both in and outside the townsite. Because we only found one coyote scat on the second census, we're not really able to estimate coyote abundance during the summer. Based off George & Crooks (2006) findings, coyotes may only avoid the RMBL townsite during the summer when human activity is at its highest. Since only 1 "fresh" coyote scat was ever found, many of our samples could have come

from before human activity was high enough for coyotes to avoid, thus skewing our data. In addition, the most coyote active transect, Deer Creek Trail, had had a high amount of cattle traffic by the second walk, potentially destroying or obscuring a number of new coyote scats and leading to an underrepresentation of ñout of townò data. Finally, there was some difficulty distinguishing between fox and coyote droppings, particularly with the oldest deposits. This could bias results considerably, though it is hard to say in what way.

Is deer behavior influenced by distance to scent stations?

No statistically significant relationships were found between vigilance/foraging rates vs. distance to treatment station. Some deer, however, seemingly did react to the scent; one actually jumped when downwind from the treatment station and evidently got less vigilant with distance from the scent. This anecdotal evidence suggests deer were, in fact, detecting the scent, making these results that much more puzzling.

Other studies have demonstrated that mule deer react dramatically to coyote scent. Müller-Schwarze in 1972 found mule deer have an innate aversion to coyote scent, not foraging at all at feeding stations treated with coyote feces. Similar results have been found when urine is used as the coyote odor. Sullivan et al. in 1985 found decreased browse levels on salal leaves with coyote urine applied directly to them. Similar to this study, Lee in 2005, an REU student here at RMBL, used urine-soaked scent trays instead of applying the scent directly to foliage. She, too, found vigilance behavior increased around coyote urine. Belant et al. (1998) again used ambient coyote scent (i.e. not applied directly to foraging matter) in the form of ñscent dartsò to represent predator presence. Their results were not as dramatic as other studies, however (24% reduction in foraging). Important to note is the authors of this study, much like ours, set urine at

ground level approximately 5m away from feeding stations. Such a moderate result in their study implies a small active space for coyote scent and any behavioral reaction may decrease dramatically with distance from urine

Given these other studies have demonstrated that mule deer react to coyote scent I will further speculate on why we did not observe an effect in our study:

Micro-habitat preference of mule deer

Within a 60 meter radius of a station at both Site 1 and Site 2, deer sightings were more common at the station with the closest average distance to cover, regardless of treatment. For instance, in site 1, the *scent* station has an average distance to cover of 45.6 meters and the control station is an average of 113.4 meters from cover. At site 2, the *control* station averages much closer to cover than the scent station (63.05m vs 153.45m) and also had more focal and scan samples (15 and 16 respectively) than the scent station (5 and 13 respectively). This result is similar to a 1988 study by Kufeld et al., showing that mule deer preferred ecotone habitat. Additionally, a recent REU study demonstrated that deer tend to stick to forested edge when presented with coyote urine (Cahalane, 1968; Lee 2005). As shown above however, subsequent analyses indicate only in Site 2 were deer more likely seen close to cover. A minimum distance-to-cover threshold could provide a possible explanation to this anomaly. If open meadows are present, deer will stick to the exterior near cover and only in site 2 is there enough meadow habitat for this to occur; the other sites are so full of cover, they don't have the ability to maintain this threshold of approximately 14m.

These results could be slightly biased: the overwhelming majority of individuals in Site 1 were female (91.6%). Even in Site 2 and 3, the majority of samples taken were of females

(58.3% and 72.1% respectively). Subsequent analyses showed a difference in male and female vigilance rates similar to other large ungulates (White & Berger 2001; Childress and Lung, 2003). White & Berger more specifically found that lactating moose (*Alces alces*) are more vigilant and stay closer to cover than other individuals. A similar pattern could be at work here and these data points could be skewed towards that end.

Proximity of roads to stations and resulting temporal displacement

Like distance to cover, the distance to nearest road and average distance to nearest road seems to be correlated to an absence of deer focal samples. Of the three plots, it is Site 3 that has by far the fewest focal observations, with only 2 total, neither of which are within 60 meters of either plot. It also has by far the lowest mean distance to road, with the scent station an average of 62.99 meters from a road, and the control a mere 9.21 average meters from the road. Site 1 also has a similar pattern with the control station an average of 79.95 meters from the road and only 4 focals within 60 meters. Compare that to the data gathered from the scent station: 156.22 average meters and 14 focals within 60 meters. Based on preliminary reports from Betsabe, there is in fact foraging at these sites, which seems to suggest the deer are foraging at night. George & Crooks (2006) found that mule deer tend to be mostly nocturnal in areas of highest human activity.

This could also be attributed to the behavioral and foraging characteristics of mule deer in open habitats. A 1988 study by Kufeld et al. found mule deer prefer to rest and forage at night in similarly open grasslands. They also hypothesized this was due to cover: the areas were simply too exposed during the day to risk foraging. However, this study was done during the winter, which could have an effect on mule deer behavior when compared to summer habits.

Proximity of fox den in Site 1

At the Johnson meadow site, a pair of red foxes (*Vulpes vulpes*) moved their litter of three into the empty den in late June, approximately 55 meters in between the treatment and control stations. Red foxes have the potential to take deer, particularly fawns (Blankenship 2001). Additional anecdotal observations of these foxes revealed they had taken at least 3 mule deer fawns and possibly more. Regardless, does certainly consider them a threat to fawns, as there are several accounts of townspeople witnessing does chasing the foxes away from their fawns. This likely kept does and their fawns out of the Johnson meadow for some time until the fawns could fend for themselves. It also could have kept them from the control station, as it has a much higher average distance to cover (113.4 meters) when compared to the scent station (45.6 meters). Given the extra danger posed by the foxes, it is not an illogical conclusion that this simply gives fawning does an extra disincentive to venture out into the relatively open space near the control plot, especially when one takes into consideration the fact that does tend to lead their fawns into the willows around town (though no formal evidence was found concerning this). This could also account for the lack of observation points near the control station in site 1.

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Week	Number Marked by end of week (M)	Total seen for the week (C)	Total resighted (R)	Pop. Est (MC/R)
1	18	34	6	102
2	22	4	0	N/A
3	25	27	13	51.9230769
4	25	7	3	58.3333333
5	25	8	3	66.6666667
6	29	48	1	1392
7	29	13	7	53.8571429

Table 1: Deer population data without 2 week sliding window. The four weeks averaged for population estimates were 3, 4, 5 and 7.

Week	#marked by end of week (M)	Total seen for the week (C)	Total resighted (R)	Pop. Est (MC/R)
1	18	34	6	102
2	22	4	0	N/A
3	13	27	13	27
4	8	7	3	18.7
5	4	8	3	10.7
6	4	48	1	192
7	4	13	7	7.43

Table 2: Deer population data with 2 week sliding window. The four weeks averaged for population estimates were 3, 4, 5 and 7.

Week	#marked by end of week (M)	Total seen for the week (C)	Total resighted (R)	Pop. Est (MC/R)
1	18	29	6	87
2	22	4	0	N/A
3	13	25	13	25
4	8	6	3	16
5	4	8	3	10.66666667
6	4	30	1	120
7	4	12	7	6.857142857

Table 3: Population estimates excluding deer too far away to recognize a mark at site 3. The four weeks averaged for population estimates were 3, 4, 5 and 7.

Total number of deer scans in 60m			Deer per scan		
	scent	control		scent	control
Site 1	19	7	site 1	0.137681	0.050725
Site 2	13	17	site 2	0.094203	0.123188
Site 3	2	2	site 3	0.014493	0.014493
Total	34	26		0.246377	0.188406

Table 4: Total deer scans within 60m and average deer seen per scan.

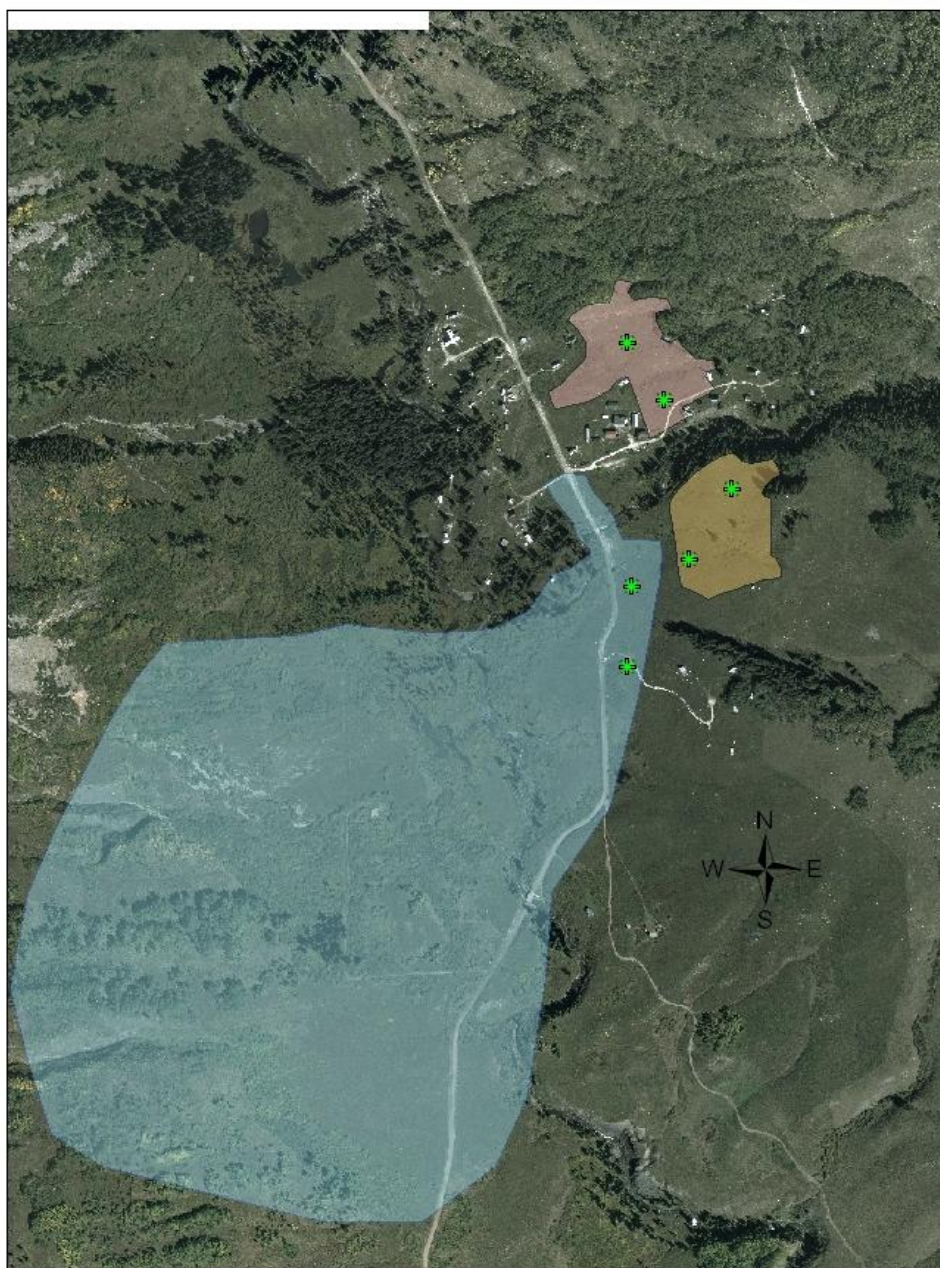


Figure 1: Study areas with area of sight polygons and scent/control station points. Red= Johnson Meadow site (Site 1). Orange= Research Meadow site (Site 2). Blue= South Gothic site (Site 3).

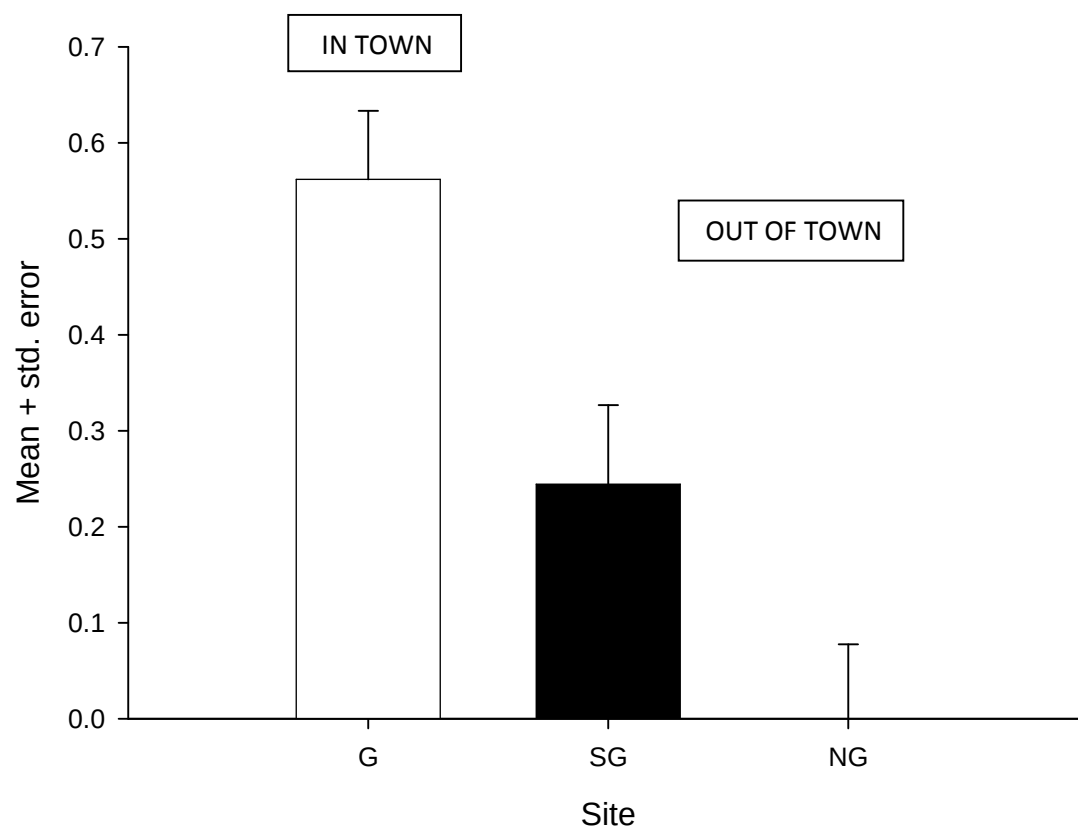


Figure 2: Graph taken from Castro 2010 (unpublished) showing mean number of deer seen in and out of the RMBL fence ($p = 0.027$).

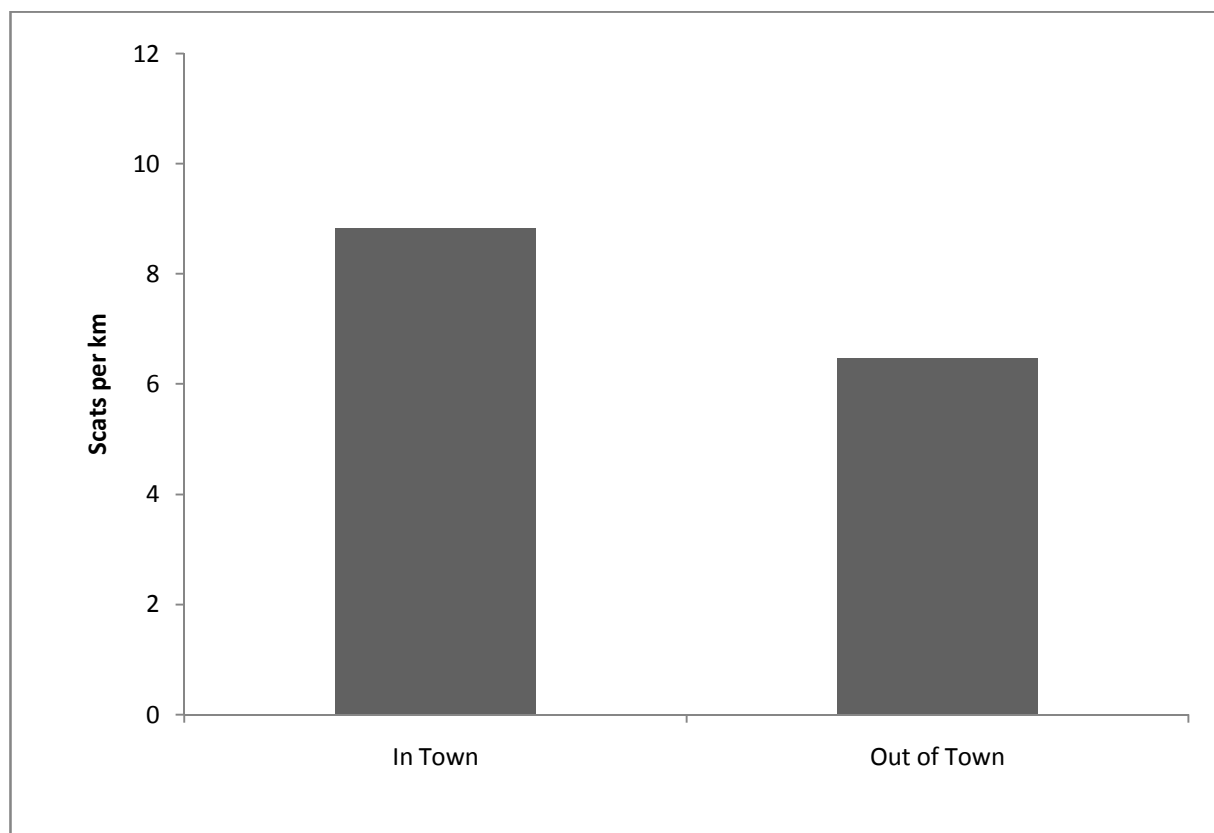


Figure 3: Coyote scats per km after both transect walks.

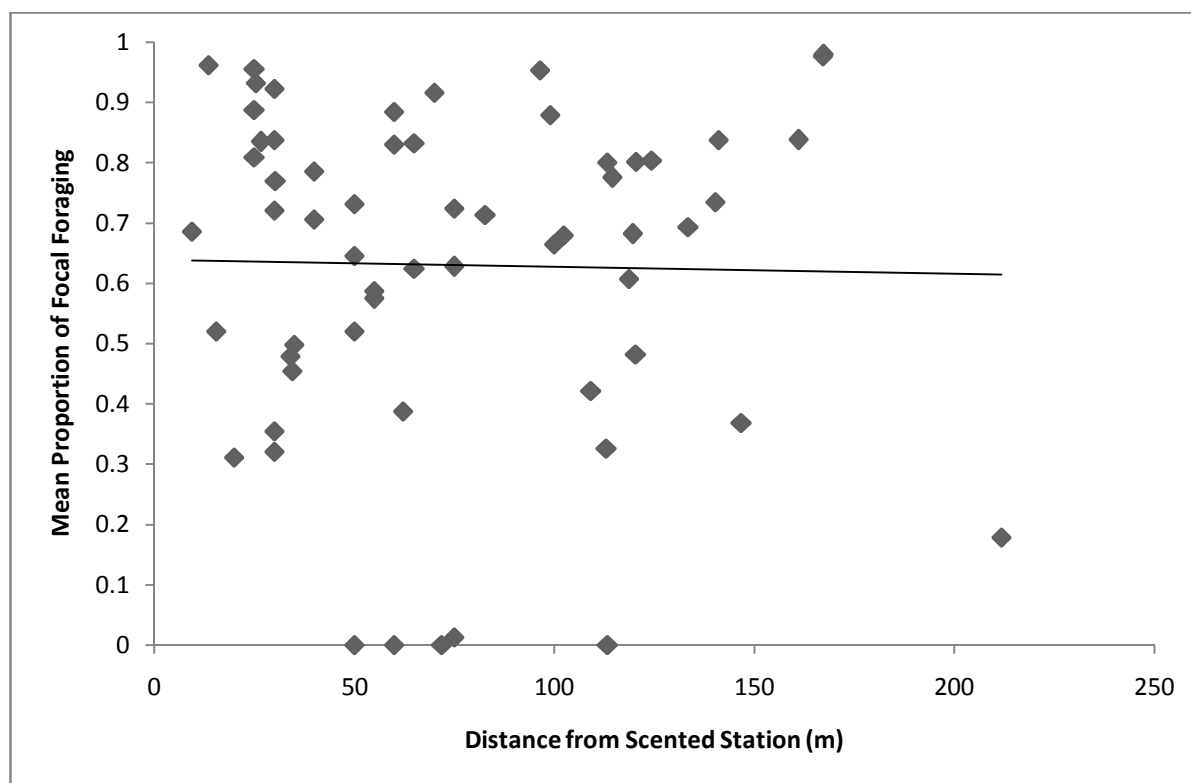


Figure 4: Distance from treatment station vs. foraging rate ($n=60$); $R = 0.02$, $p=0.829$,
 $y = -0.0001x + 0.6393$.

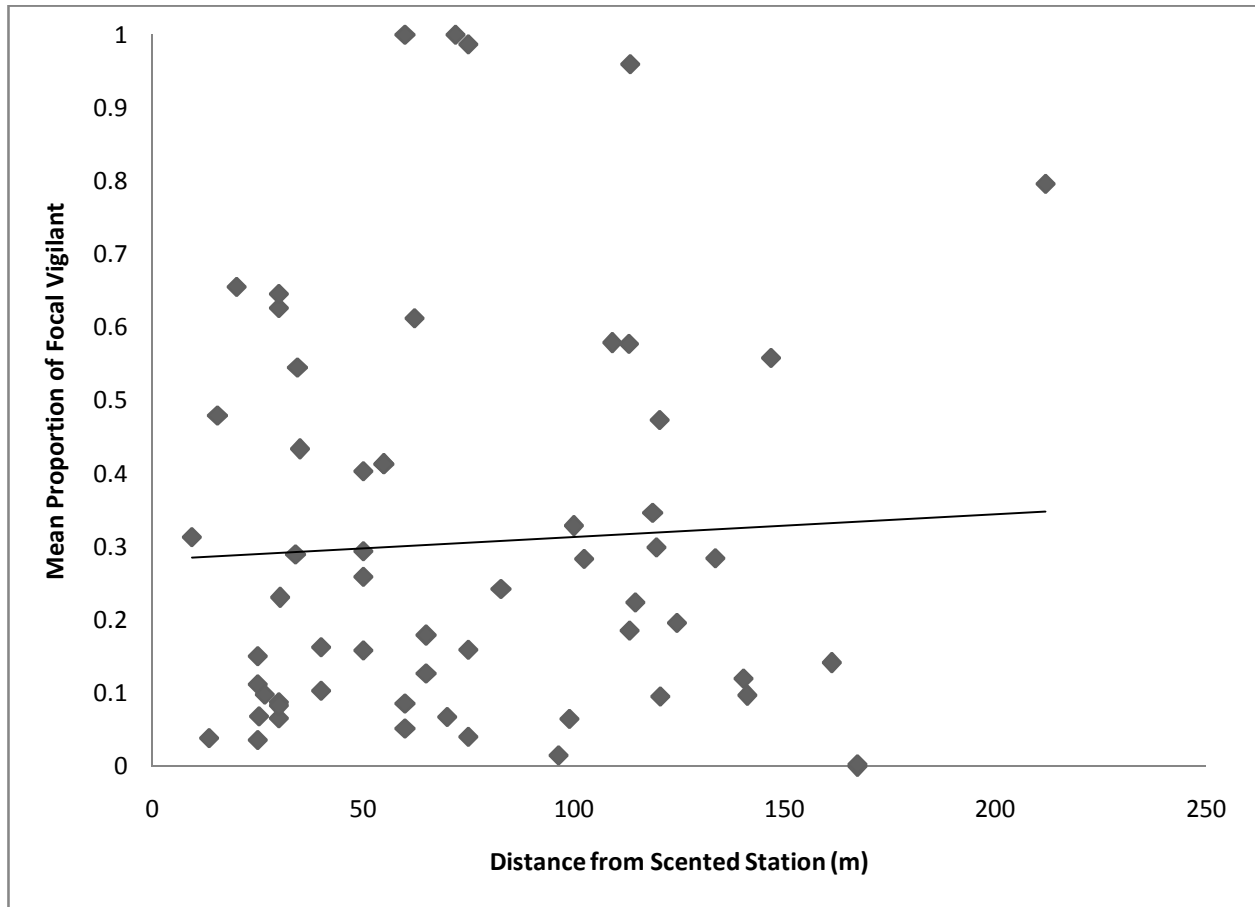


Figure 5: Summed vigilant behavior vs. distance from treatment station ($n=60$). Summed vigilant behavior includes the following observed activities: walking head up, stand look, look chew, and running. $R = 0.055$, $p=0.68$, $y = 0.0003x + 0.2826$.

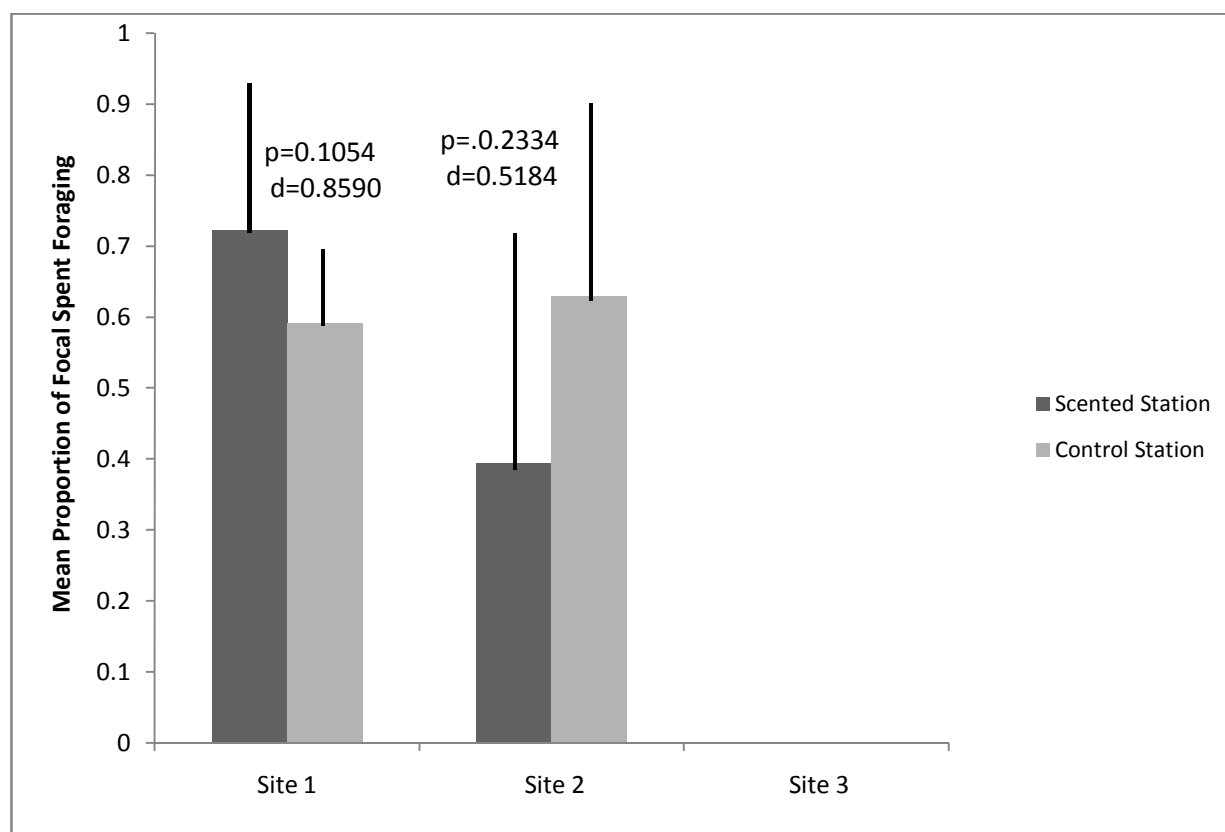


Figure 6: Mean (+SD) proportion of focal spent foraging within 60m of a station.

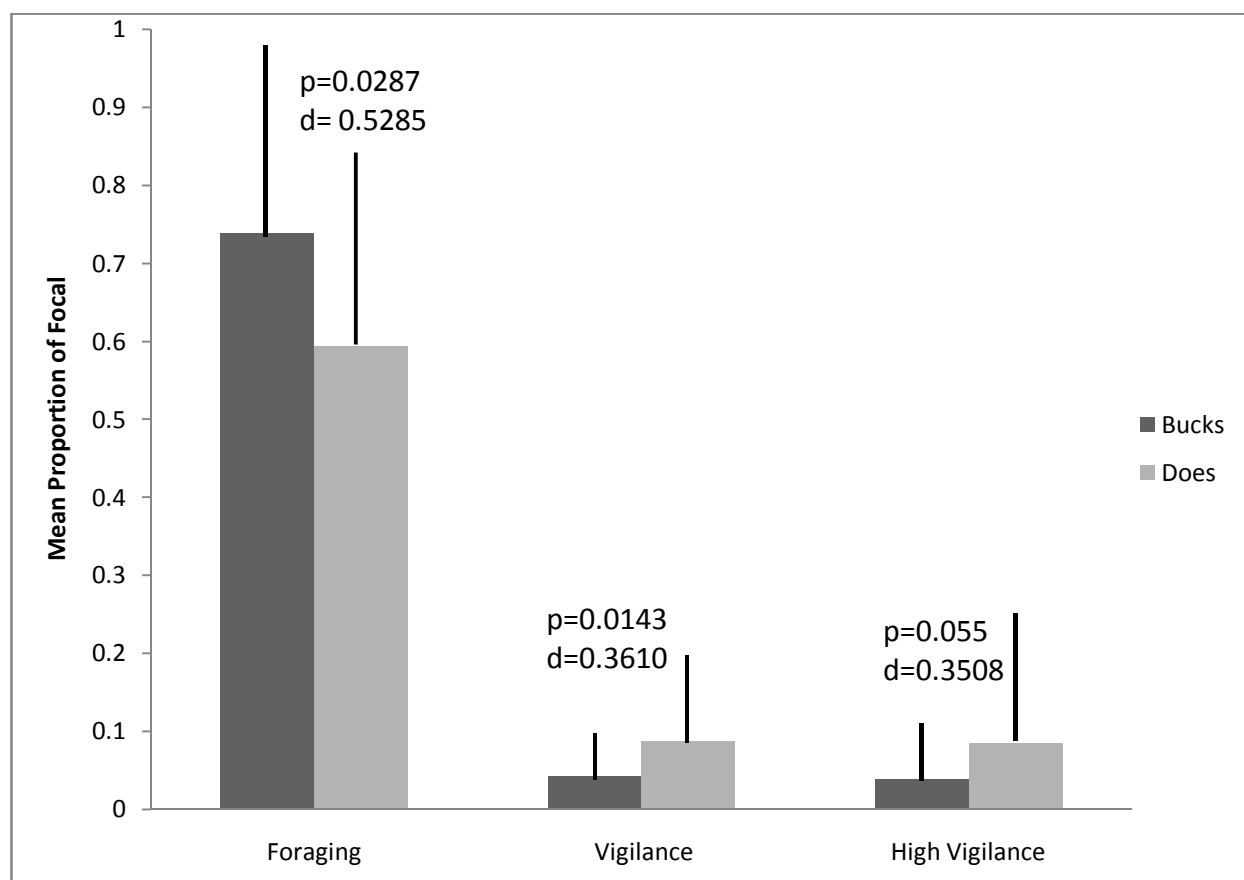


Figure 7: Mean (+SD) proportion of focal behavior by sex ($n=60$).

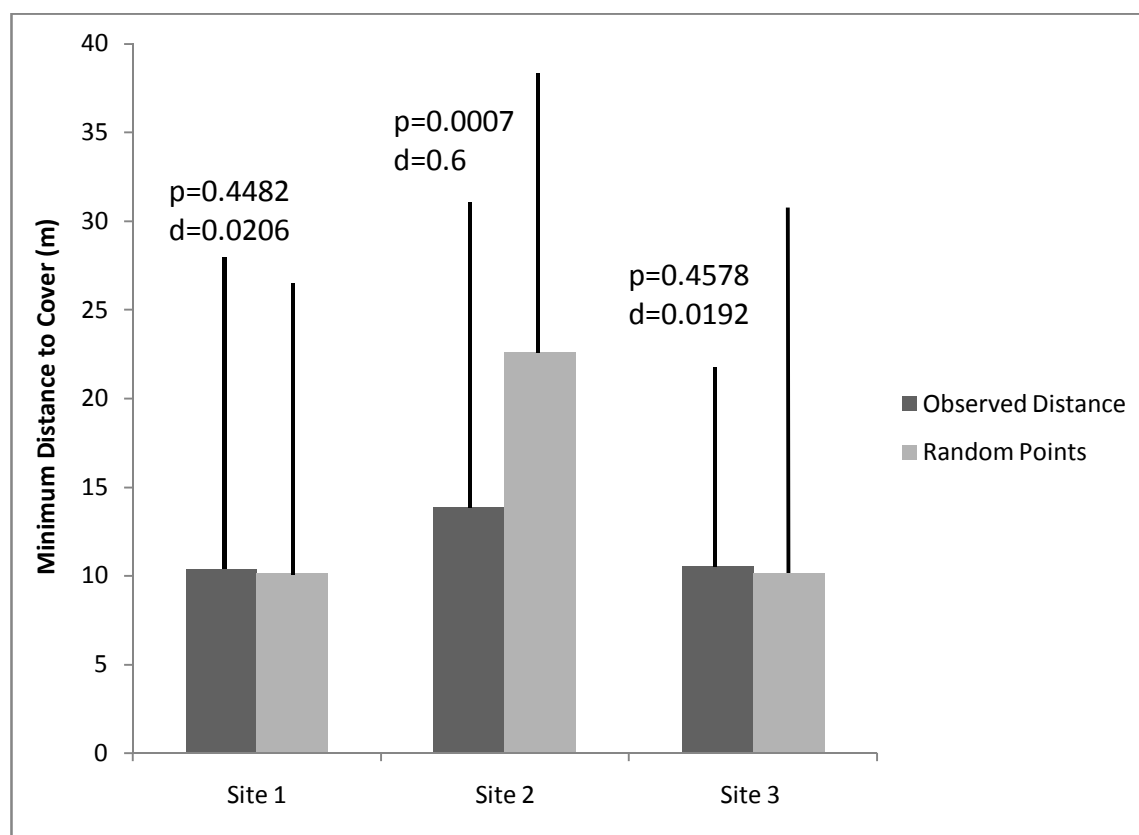


Figure 8: Average (+SD) minimum distance to cover of all points vs. random points.

Appendix 1: Deer ID data.

Deer #	Date	Color	Location of mark(s)/ scars
1	5/30/2010	orange	2 on Front legs, 1 mid back (Left side), 1 mid hip (Right)
2	5/31/2010	green	1 front shoulder (Left) 1 flank (Left)
3	5/31/2010	red	1 streak lower shoulder (Left) possible on shoulder (Right)
4	5/31/2010	orange	1 anterior of flank (Right)
5	6/2/2010	green	1 upper front (Left)
6	6/2/2010	none	crescent scar on flank (Left)
7	6/2/2010	green	2 on either side of tail
8	6/3/2010	orange/green	1 green mid-shoulder, 1 green rear leg, 1 orange flank, 1 orange back of neck (ALL LEFT SIDE)
9	6/3/2010	orange	1 mid back (Left)
10	6/3/2010	green	1 Front Ankle (LEFT)
11	6/5/2010	green	1 flank (LEFT) 1 Ear (LEFT)
12	6/5/2010	orange	Multiple marks along belly (Right)
13	6/3/2010	red	2 front shoulder (Right)
14	6/6/2010	red	1 upper back (Left) 1 upper back (Right) 1 Mid front shoulder (Right) 1 mid-belly (Right)
15	6/6/2010	red	1 mid-flank (Left) 1 Ear (Left)
16	6/7/2010	orange	1 Mid shoulder (Right) Nicks in both ears
17	6/15/2010	green	1 mid back (Right) Buck in velvet
18	6/15/2010	orange	1 orange mid shoulder (Right)
19	6/17/2010	Orange	1 upper shoulder (Left) 1 on Elbow (Left)
20	6/7/2010	red	1 on flank (Left)
21	6/8/2010	red	1 on Shoulder (Left)
22	6/19/2010	red	1 on shoulder (Right) 1 on mid-belly (Right)
23	6/20/2010	red	1 on shoulder (Left) Buck
24	6/20/2010	red	1 mid belly (Left) 1 streak Shoulder/Neck (Right)
25	6/21/2010	Red	1 Mid shoulder (Left)
26	7/16/2010	Orange	1 Right Rump Reddish Coat
27	7/15/2010	Green, Orange, Red	2 orange on left flank, 1 red right flank, 1 green right neck
28	7/14/2010	Red	1 large red splotch on left middle
29	UNKNOWN	Green	1 right ear, 1 left rump

