

Mule deer (*Odocoileus hemionus*) detect coyote (*Canis latrans*) scent.

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Abstract

A trophic cascade is an ecological process in which predators affect the producer biomass and community composition of an ecosystem by limiting plant consumption by herbivores. Predators not only control herbivore populations through predation, but their mere presence can affect herbivore behavior. I investigated whether mule deer (*Odocoileus hemionus*) reduce foraging in the presence of signals that indicate a predator.

I set up feed blocks at two predetermined sites. Once the deer were consistently eating the food, I started the treatment period. During this period, I would place one of two treatments at the site: one containing coyote urine (experimental) or one containing water (control). I quantified behavior whenever a deer was within 10 meters of the feed block. To avoid pseudoreplication, only the first set of behavior observations (focal) from each individual deer was analyzed.

I found that there is a significant overall change in deer foraging behavior and time spent in the study area when they are exposed to coyote scent. When examined on the basis of time bins within the focal, there is a significant decrease in time allocated to foraging after the first minute when the deer were exposed to the coyote treatment, but this difference disappears over time. I believe that this disappearance is due to the deer habituating to the coyote scent. Concerning trophic cascades, these results lead me to believe that perhaps the strength of the change in behavior depends on the species of predator. Other studies have found that the type of predator determines how strongly the deer will react. When these results are related to wildlife management, I see that coyote scent is an effective repellent in small doses, but other repellents become essential if one wants to deter deer over a long period of time.

Introduction

A trophic cascade is an ecological process in which predators affect the producer biomass and community composition of an ecosystem by limiting plant consumption by herbivores (Ripple & Beschta 2008). Predators not only control herbivore populations through predation, but their mere presence can affect herbivore behavior (Preisser et al. 2005). One herbivore behavior in particular that affects plant biomass is foraging. Multiple studies have produced evidence that herbivores change their foraging behaviors when they sense that, either by sight or by smell, a predator is nearby or has recently passed through the area. For example, Kluever, et al. (2009) found that when cattle scented wolf urine, they increased the amount of time allocated to vigilance and decreased the amount of time allocated to foraging. Holbrook & Schmitt (1988) found that surfperch shifted their food preference from low growing *Zonaria farlowii* algae to the tall algae *Sagassum palmeri* when a predator was present. Perhaps the best example of trophic cascades affecting foraging and, therefore, plant biomass is the reintroduction of wolves into Yellowstone National Park. Prior to the return of wolves, quaking aspen (*Populus tremuloides*) was in sharp decline, over grazing by elk being identified as the most prominent cause (Ripple et al. 2001). After wolf reintroduction, researchers found that the amount of aspen grazed by elk in areas where wolves were present was significantly lower than in areas where the wolves were absent (Ripple, et al. 2001).

While this change in behavior should be present when all prey species detect a predator, concrete evidence is needed to confirm this idea. I investigated whether mule deer (*Odocoileus hemionus*) reduce foraging in the presence of signals that indicate a predator. Like all members of the deer family, mule deer mainly rely on their sense of smell to detect danger (n.d.). Wagner & Nolte (2001) showed a decrease in mule deer foraging behavior when deer repellents that

contained the scent of predators were hung at the foraging location. The predator species that I used in this investigation, in the form of a urine sample, was the coyote (*Canis latrans*). The coyote is an animal that is known to prey on mule deer (Anderson & Wallmo 1984). While coyote urine was found to be an effective deer repellent in the Wagner & Nolte (2001) study comparing the effectiveness of various commonly used and commercial deer repellents, a similar investigation by Andelt, et al. (1991) found that when mule deer were hungry enough, they would eat food treated with this substance. In contrast to my own methods, both of these studies kept the repellents and controls present throughout the whole duration of the experiment.

Methods

Mule deer were studied in and around the Rocky Mountain Biological Laboratory. I identified two locations where mule deer are often spotted and mapped them using GeoXT equipped with Terrasync (Trimble Navigation Limited, Sunnyvale, CA). The two locations were Western Bench Meadow (latitude: 38.95, longitude: -106.99) and a meadow across the road and north of Ore House (latitude: 38.96, longitude: -106.99). I set up feeding stations in both areas consisting of a feed block specifically designed for deer (Purina Premium Deer Block, Purina Mills, St. Louis, MO) containing corn and molasses. Both feed blocks were set 30 meters from the nearest cover (defined as the nearest area of tall, dense growing foliage). Since mule deer first must detect and habituate to the presence of food, I did not start the manipulation period until habituation occurred. I considered the deer to be habituated when they ate the food. One to two days after I observed the deer eating the food, I began the manipulation. To conserve the feed blocks, when the observation session ended at each of the two sites, I covered the feed block with a large black plastic planting pot. To ensure no animals got to the block underneath, I placed rocks from each of the respective areas on top of and around the pot, in addition to using ropes and four stakes to secure the pot to the ground.

For the manipulation, I placed a Petri dish with a mixture of 10 mL polycrylamide gel (Terra-Sorb, Garden Harvest Supplier Incorporated, Berne, IN) and 15 mL of either coyote urine ordered from PredatorPee.com or water on a plate whose face has been spray painted black. One plate was specifically for the water gel while the other was for the urine gel. If I had placed the Petri dish directly on the ground, the crystals could have spilled, allowing the scent to seep into the ground and contaminate the area. The Petri dish and plate were placed next to the feed block only during the observation periods. When I arrived at the site, I placed the Petri dish and plate at the appropriate place and removed it when I had finished observing. To prevent contamination with the coyote scent, I wore gloves while preparing and handling the treatments.

The two hour observation periods took place either in the early morning around sunrise (5:00 AM to 7:00 AM), close to sunset (7:00 PM to 9:00 PM), or, if possible on a given day, both times. I alternated the sites every observation and later on when I presented the deer with the treatments. When the treatment period began, I alternated treatments at every visit to the site. Since I began treatments at Ore House sooner, I completed data collection at this site first. After I was finished with the Ore House site, I did treatments exclusively at Western Bench Meadow until, despite precautions when I was not at the site, the bait was completely eaten. By the end of the treatment period, I had spent a total of 29 observation periods in the field, 14 of which were at the Ore House area and the other 15 at Western Bench Meadow. The water treatment was used 14 times and the coyote urine 15 times. Fifteen of the sessions were in the morning and 14 were in evening. I did not observe when there was precipitation and/or the wind was above a 3 (gentle breeze at 7 to 10 knots) on the Beaufort scale. Any wind speed above a 3 on the Beaufort

scale will impact how the coyote scent is transmitted through the air. Also, high wind speeds tend to scare the deer, which would prevent them from coming out into the open (Michels 2004). While observing the deer in the meadow north of Ore House I was 45 meters away from the feed block. While observing the deer in Western Bench meadow I was 115 meters away from the feed block.

I recorded all behavior observations both during the habituation and manipulation periods only when the deer was within 10 meters of the feed block. Individuals were identified based on pelt color and unique markings. While I noted the total time the deer spent in the study area, I only recorded behaviors occurring during the first ten minutes. All observations were recorded using a tape recorder. The observations (focals) I made during the manipulation period were also scored and analyzed in three ways using the JWatcher program (Blumstein & Daniel 2007) after each observation period. The observations consisted of behaviors listed on a predetermined ethogram, or set of behaviors (Table 1).

All analysis I performed on the data was to compare behavior between the two treatments and was only done on the proportion of time allocated to each behavior as calculated by JWatcher (Blumstein & Daniel 2007). Once the data collection was completed, I entered proportion of time allocated values from JWatcher (Blumstein & Daniel 2007) into Excel (Microsoft Corporation, Redmond, WA), and I performed a preliminary analysis using scatter plots or bar graphs in the following areas: (a) comparison of the mean change in each behavior over the first minute divided into 15 second time bins, (b) comparison of the overall means of each behavior, (c) comparison of the mean change in each behavior over the course of 10 minutes divided into 1 minute time bins, (d) comparison of the mean change in relaxed behavior (mean forage + mean scratch + mean sniff + mean walking head down) over the first minute divided into 15 second time bins, (e) comparison of the overall means of relaxed behavior, and (f) comparison of the mean change in relaxed behavior over the course of 10 minutes divided into 1 minute time bins. I then performed a t-test in SAS JMP 8 (SAS Institute, Cary, NC) on the proportion in sight values for all behaviors between the two treatments. I then entered proportion in sight values for foraging behavior from the overall values, 1min/0-15sec, 1min/15-30sec, 1min/30-45sec, 1min/45-60sec, 0-1 minute, 1-2 minute, and 9-10 minute into SPSS (IBM, Armonk, NY), and analyzed for differences between the two treatments. To avoid pseudoreplication, I only analyzed the first focal obtained from each individual in SPSS (IBM, Armonk, NY). After analysis, I determined that I had collected focals on 14 unique individuals from the Ore House site and 6 unique individuals from Western Bench Meadow for a total of 20 individuals. I also analyzed these same foraging values for individuals that had focals for each treatment in Excel (Microsoft Corporation, Redmond, WA) using scatter or bar graphs. For those deer exposed to both the water and coyote urine, I performed a paired t-test comparing overall values for time allocated to foraging in SAS JMP 8 (SAS Institute, Cary, NC).

Results

Overall time allocated to foraging

The overall model ($p=0.072$) containing the effects of treatment, sex, location, and the following interactions: (a) location and treatment, (b) location interacting with sex, (c) treatment interacting with sex, and (d) location, sex, and treatment was not significant. 35.1 percent of the time allocated to foraging's variation was explained by these effects and interactions. The treatment effect ($p=0.019$) was significant (Figure 1). Time allocated to foraging decreased by

56.5 percent when the deer were exposed to the coyote scent. The location effect ($p=0.596$) was not significant. The sex effect ($p=0.597$) was not significant. The location and treatment interaction ($p=0.129$) was not significant. The location and sex interaction ($p=\text{not estimable}$) was not significant. The treatment and sex interaction ($p=0.874$) was not significant. The location, sex, and treatment interaction ($p=\text{not estimable}$) was not significant.

Total time in sight

The overall model ($p=0.009$) containing the effects of treatment, sex, location, and the following interactions: (a) location and treatment, (b) location interacting with sex, (c) treatment interacting with sex, and (d) location, sex, and treatment was significant. 27.8 percent of the time spent in sight's variation was explained by these effects and interactions. The treatment effect ($p=0.016$) was significant (Figure 2). Time allocated to foraging decreased by 56.1 percent when the deer were exposed to the coyote scent. The location effect ($p=0.106$) was not significant. The sex effect ($p=0.710$) was not significant. The location and treatment interaction ($p=0.453$) was not significant. The location and sex interaction ($p=0.178$) was not significant. The treatment and sex interaction ($p=0.067$) was not significant. However, there was a trend for the effect of treatment to vary between male and female deer. The location, sex, and treatment interaction ($p=\text{not estimable}$) was not significant.

First minute of focal

The overall model ($p=0.245$) containing the effects of treatment, sex, location, and the following interactions: (a) location and treatment, (b) location interacting with sex, (c) treatment interacting with sex, and (d) location, sex, and treatment was not significant. 24.8 percent of the time allocated to foraging in the first minute's variation was explained by the effects and interactions. The treatment effect ($p=0.213$) was not significant (Figure 3). The location effect ($p=0.898$) was not significant. The sex effect ($p=0.306$) was not significant. The location and treatment interaction ($p=0.083$) was not significant. However, there was a trend for the effect of location to vary between the water and coyote urine treatments. The location and sex interaction ($p=\text{not estimable}$) was not significant. The treatment and sex interaction ($p=0.657$) was not significant. The location, sex, and treatment interaction ($p=\text{not estimable}$) was not significant.

Second minute of focal

The overall model ($p=0.192$) containing the effects of treatment, sex, location, and the following interactions: (a) location and treatment, (b) location interacting with sex, (c) treatment interacting with sex, and (d) location, sex, and treatment was not significant. 45.1 percent of the time allocated to foraging in the second minute's variation was explained by the effects and interactions. The treatment effect ($p=0.032$) was significant (Figure 3). Time allocated to foraging decreased by 47.6 percent when the deer were exposed to the coyote scent. The location effect ($p=0.136$) was not significant. The sex effect ($p=0.818$) was not significant. The location and treatment interaction ($p=0.550$) was not significant. The location and sex interaction ($p=\text{not estimable}$) was not significant. The treatment and sex interaction ($p=0.776$) was not significant. The location, sex, and treatment interaction ($p=\text{not estimable}$) was not significant.

Last minute of focal

The overall model ($p=0.362$) containing the effects of treatment, sex, location, and the following interactions: (a) location and treatment, (b) location interacting with sex, (c) treatment interacting with sex, and (d) location, sex, and treatment was not significant. 74.1 percent of the time allocated to foraging in the last minute's variation was explained by the effects and interactions. The treatment effect ($p=0.532$) was not significant (Figure 3). The location effect ($p=0.291$) was not significant. The sex effect ($p=0.708$) was not significant. The location and treatment interaction ($p=\text{not estimable}$) was not significant. The location and sex interaction ($p=\text{not estimable}$) was not significant. The treatment and sex interaction ($p=\text{not estimable}$) was not significant. The location, sex, and treatment interaction ($p=\text{not estimable}$) was not significant.

Discussion

The purpose of this experiment was to investigate whether mule deer change their foraging behavior when exposed to the scent of a predator. I found that the deer foraged less and spent less time in the study area when the urine treatment was present compared to when the water treatment was present (Figures 1 and 2). However, a closer analysis that examined the data using the minute by minute time bin division indicated that while there is a difference early on in time allocated to foraging between the two treatments, over time that difference disappears (Figure 3).

Figure 1 shows that deer spend less total time foraging when exposed to coyote scent than when exposed to water. This result agrees with Wagner & Nolte (2001) and Kie (1999) who both noted that deer tended to forage less overall when they were at a higher risk for predation, such as when they detected a predator. Figure 2 shows that deer spend less total time in the study area when exposed to coyote scent than when exposed to water. Kie (1999) remarks that when deer are under a higher risk of predation, they spend less time foraging and more time doing other activities, including traveling between areas. These results show that the deer could differentiate between the coyote and water treatments and responded to this difference.

As shown in Figure 3, there was initially no difference in time allocated to deer foraging behavior, but a difference emerged between the first and second minute, and then disappeared by the final minute. This non significance in the first minute was most likely due to general deer vigilance upon entering an area that was void of cover. Altendorf et al. (2001) points out that deer are more vigilant in areas that are on the edge of cover compared to full cover. The reason for the disappearance of a significant difference in time allocated to foraging is most likely due to deer habituation to the coyote scent over the course of the observation session. Andelt et al. (1991) noted that coyote scent only works for a short time, and Maregni (2003) said that if the food is palatable enough (as was the case with my feed blocks) the deer will disregard the scent and eat the food.

One problem identified at the Ore House site is the noise caused by passing cars. While this study site was not especially close to the local road, it was close enough that noises from the engines of passing cars could be heard by both me and any deer in the study area when one happened to go by. While not an issue in the first week or so of data collection, as the summer progressed, more and more cars happened to drive on the road by the area during observation periods. As a result, some of the deer may have looked more often to see the cause of the noise, and one buck was scared off in the middle of the focal by a particularly loud car engine. I am certain this noise was the cause of the buck's departure because he looked up right as the car's noise was growing louder and ran off when the noise volume reached its peak. Car noise was not

an issue at Western Bench Meadow because of the considerable distance between the study area and the road.

When applied to the concept of trophic cascades, my findings suggest that changes in prey behavior may depend upon the predator in question. Borer et al. (2005) propose that one of the factors affecting the strength of a trophic cascade lies with the type of predator. In my study, the coyote may not be a threatening enough predator to cause long term changes in deer foraging behavior. Repeating this study with the scent of a larger and more aggressive predator such as a wolf (*Canis lupus*) or a mountain lion (*Puma concolor*) could result in a longer lasting behavior change in the deer. Melchior & Leslie (1985) found that browsing by deer decreased more when wolf (17 percent) or mountain lion (27 percent) scent was applied to an area versus coyote scent (8 percent).

Perhaps the most relevant application of my findings is in the field of wildlife management. While the deer sampled in this study do change their behavior when first exposed to the scent of a predator, over time, this scent does not deter them from eating the food blocks. By applying this conclusion to wildlife management, I can say that while coyote scent is a good short term repellent, it will not deter the deer from the area over the course of weeks or months. If people wish to keep deer out of their yards and gardens for long periods, other repellents will become necessary over time.

Also, this study's findings support the use of biodegradable repellents to deter deer. Too often people use toxic or ecologically harmful chemicals to keep deer away from gardens and other areas. This study's findings should be used as a catalyst for researching additional, and even combinations, of biodegradable repellents. If success comes of these future endeavors, this type of repellent could then be used to not only keep deer away from gardens and farms where they are a pest problem, but also areas that are harmful to deer, including busy highways and industrial plants. Keeping deer away from these areas would in the long term help to ensure a healthy population of the species in the years to come.

I found that while there is an overall change in deer foraging behavior and time spent in the study area when they are exposed to coyote scent, when examined on the basis of time bins within the focal, there is a significant difference between the two treatments after the first minute, but this difference disappears over time. Concerning trophic cascades, these results lead me to believe that perhaps the strength of the change in behavior depends on the species of predator. When these results are related to wildlife management, I see that while coyote scent is an effective repellent in small doses, other repellents become essential if one wants to deter deer over a long period of time.

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Figures and Tables

Table 1: Deer ethogram with the key for each behavior to score observations on JWatcher

Behavior	Vigilant or Relaxed	Key for Behavior on JWatcher
Ear twitch	Vigilant	E
Tail wag	Relaxed	G
Look/chew	Vigilant	C
Foraging	Relaxed	F
Walking, head down	Relaxed	K
Walking, head up	Vigilant	W
Stand/look	Vigilant	L
Scratching	Relaxed	S
Sniff	Relaxed	N
Running	Vigilant	R
Stotting	Vigilant	T
Alarm walk	Vigilant	A
Out of sight	N/A	O
“Other”	N/A	Z

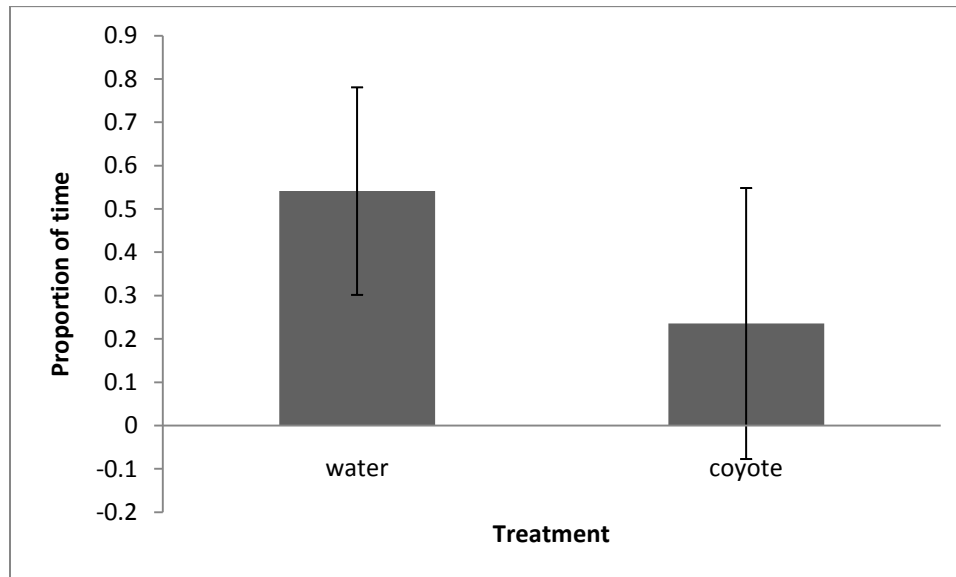


Figure 1. Comparison of the overall time allocated to foraging when exposed to the two treatments.

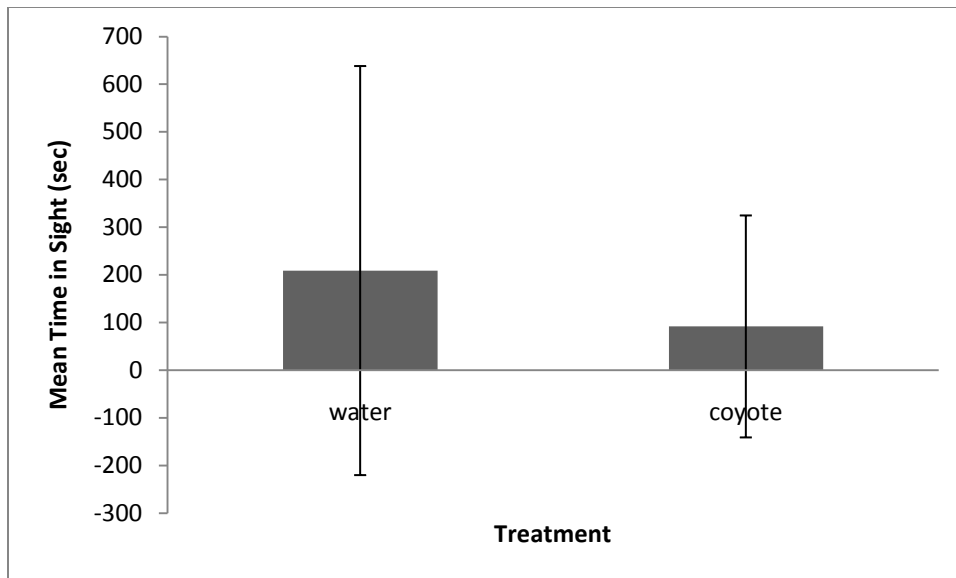


Figure 2. Comparison of the total time in the study area when exposed to the two treatments.

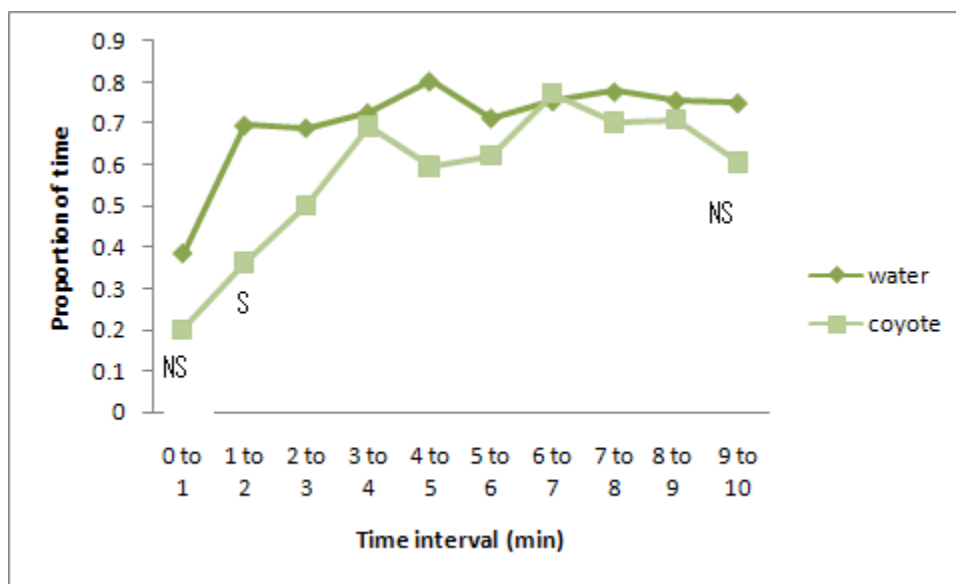


Figure 3. Comparison of time allocated to foraging behavior over minute by minute time bins when exposed to the two treatments. NS=not significant, S=significant. Those time bins without letters were not tested in SPSS.