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The effect of coyote and woodrat scat on surrounding desert vegetation

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ABSTRACT

The recycling of nutrients is a valuable process throughout all ecosystems, but it is particularly important in extreme environments like deserts since acquiring nutrients poses a greater challenge for survival due to their scarcity. In our study, we focused on animal scat (coyote and woodrat) and its influence on plant communities and growth since they aid in the recycling of nutrients. We collected data on plants surrounding three different types of sites: areas with presence of accrued coyote or woodrat scat and areas without. We found that the distribution of scat across the desert landscape does not greatly affect the distribution of annual plants and their overall height. However, we delineated a clear difference between the surrounding perennial communities of our three sites. Differences in pH between the soil found in woodrat and coyote sites highlight the ability of scat to alter soil and potentially affect vegetation. Our study demonstrates a need to better understand the role of scat in a nutrient-deficient environment.

Keywords: scat, coyote (*Canis latrans)*, woodrat (*Neotoma sp.*), perennial plants, annual plants

INTRODUCTION

Accessing nutrients is a major factor in the survival of organisms across taxa and ecosystems (Noy-Meir 1974). The distribution of nutrients is greatly affected by the behavior of organisms who play an active role in nutrient deposition, ensuring nutrients are available throughout an ecosystem (Mackay et al. 2021). For example, nutrient deposition within producers occurs when plant materials shed and create a layer of surface plant litter which can then disperse via wind across a landscape or decompose and nourish the soil (Ma et al. 2021). Nutrients are also recycled from higher trophic levels, specifically in the form of scat. Waste from consumers contains nutrients, like nitrogen, that re-enter the soil after being excreted (Ritchie et al. 1998).

The nutritional content of animal scat differs based on diet. Primary consumers have scat rich in vegetation, while secondary consumers have scat consisting of the remains of their prey (Elbroch et al. 2012; Swingen et al. 2015). These dietary preferences alter the quality of the nutrients present in scat, as animal waste composed of plant material may be more readily available to the surrounding plant communities as opposed to the remnants of small mammals found in secondary consumer scat (Elbroch et al. 2012). This difference in ease of access to nutrients may be important to some organisms more than others. In desert ecosystems, where nutrients and water are limiting factors, annual vegetation may need more accessible nutrients to utilize in its short period of growth compared to its perennial counterparts, which have greater nutrient-storage capabilities (Noy-Meir 1973).

In addition to differences in nutrient composition, the sites of scat deposition vary between organisms. For instance, coyotes (*Canis latrans*) actively search for openings amongst the shrubs and bushes of their surrounding landscape to ensure that conspecifics are aware of their preferred territory, even participating in latrine behavior, when a pack releases their waste in a concentrated area (Elbroch et al. 2012). These behaviors contrast with woodrats (*Neotoma sp.*), which construct their excrement-filled middens within yuccas, chollas, and rock outcrops. These spots are chosen due to their protection from the elements and potential predators and are occupied for long periods of time (Cosmero et al. 2017). Both behaviors suggest that woodrats and coyotes are influenced by the distribution of perennial plants in the places they release their waste, but, based on the effects of scat on soil and nutrients, perhaps animal waste has an effect on this surrounding vegetation.

Considering the role of scat in nutrient recycling, the variance in waste composition, and the different depositional areas between organisms, we wanted to see how different animals' scat affects the growth of annuals and the distribution of perennials nearby. In our study, we looked at these aspects as a function of scat presence via coyote latrines and woodrat middens in a desert ecosystem. We predicted annuals would be more abundant and taller near woodrat middens compared to those surrounding coyote latrines due to the more readily available nutrients of the herbivore scat. Furthermore, we expected woodrat middens to be surrounded by a different and more numerous assemblage of perennials compared to coyote latrines as a result of the herbivore scat nutrient content.

METHODS

2.1 Natural History of the Study Site

Our study was conducted at the University of California's Sweeney Granite Mountains Desert Research Center (34.80880° N, 115.62842° W) in San Bernardino County, California from May 3–7, 2022. Our research was conducted amongst vegetation associated with enriched woody and succulent scrublands, where multiple shrubs and succulents co-dominate, such as creosote bush, cholla cactus, and yuccas. Our study aimed to collect data pertaining to both perennial and annual plants as well as soil samples that lie within three types of sites: coyote latrines, woodrat middens, and control sites.

2.2 Coyote Latrines

We found coyote latrines by searching across 770 kilometers. Latrines had to possess at least 5 different pieces of scat that lay within ~5 m of each other. We marked the farthest scat deposits to identify the perimeter of the area containing the scat (Perimeter 1; Fig. 1), which was used to survey percent cover of annual plants. We measured the length and width dimensions of this area using a transect. We established a second perimeter (Perimeter 2; Fig. 1) extending 2 m from Perimeter 1. The site was used if it was more than 10 m away from another latrine or woodrat midden. A total of eight coyote latrines were found for our study.

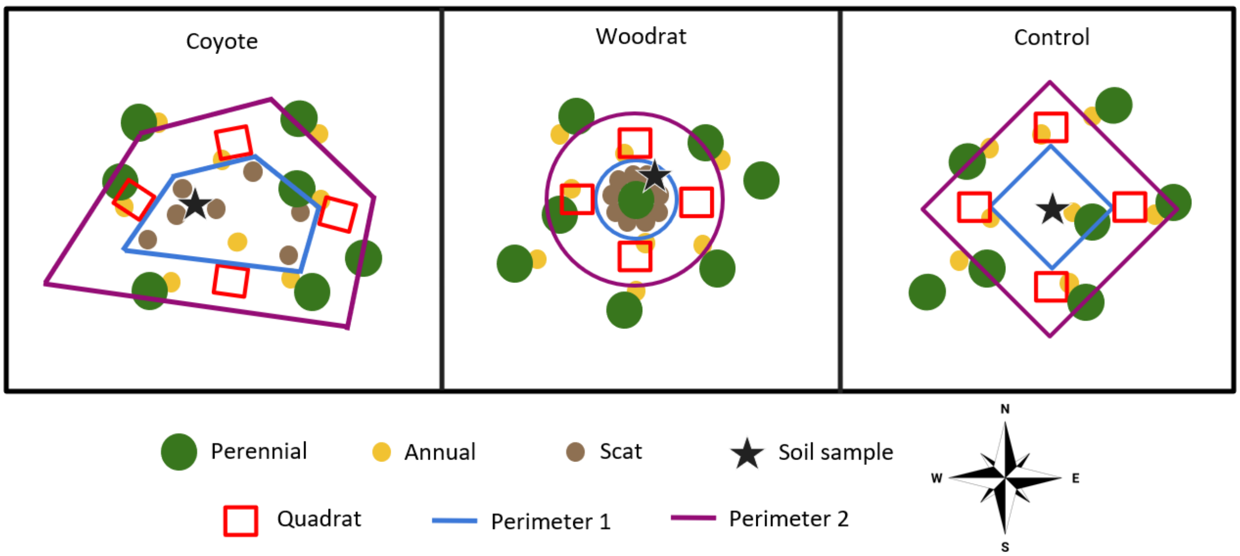

Figure 1. Diagram of Methodology. Coyote latrine, woodrat midden, and control sites were identified, and a perimeter (Perimeter 1) was established around the farthest scats within the site. Perimeter 2 was placed 2 m away from Perimeter 1. A quadrat was placed directly outside of Perimeter 1 in the four cardinal directions to record percent cover and height of annual vegetation. All perennials within the area of Perimeter 2 (including the area within Perimeter 1) were recorded. A soil sample was collected from the area of greatest scat density for latrines and middens and from the center of the plot for control sites.

2.3 Woodrat Middens

We found woodrat middens across the same area where latrines were located. The middens were identified by the presence of woodrat scat and the placement of cholla bits at the base of either a Mojave Yucca (*Yucca schidigera*) or a Buckhorn Cholla (*Cylindropuntia acanthocarpa*). Using the same protocol as the coyote latrines, we marked Perimeter 1 using the farthest woodrat droppings and then established Perimeter 2. A total of eight middens were used for our study.

2.4 Control Sites

Over the same area the other sites were found, we set up eight control sites that did not contain a latrine or midden. The same protocol was used for control sites with the exception of Perimeter 1 being determined from the average length and width of the first 11 sites we surveyed (6 coyote latrines and 5 woodrat middens). Our control sites had a length of 350 centimeters with a width of 263 centimeters.

2.5 Data Collection

Once sites were set up, we collected approximately 280 g of soil, 8–13 cm beneath the soil surface and underneath the greatest density of scat for the latrines and middens. For control sites, the soil sample was taken at the approximate center of Perimeter 1.

We collected data on both the perennial and annual plants within our perimeters. For annuals, we collected data on percent cover and height by first placing a 0.25 m^2 quadrat at the edge of Perimeter 1 in the four cardinal directions (Fig. 1). We then took a visual estimate of the cover of annuals in the quadrat, and measured the heights of the three tallest annuals within the quadrat using a meter stick. For perennials, we identified all species that fell within the area of Perimeter 2 (including the area within Perimeter 1) and counted the abundance of each to get an idea of the perennial communities in each site.

Soil samples from each site were taken to measure their respective pH using a pH meter. We mixed 28 g of water with 28 g of a soil sample. This 1:1 ratio was placed in a red Solo® cup for processing and the pH of each soil sample was collected.

Additionally, a woodrat and coyote scat sample was collected near a coyote latrine and midden. These samples were not completely dried and still brown or dark in color, facilitating our dissection of them. With the same methods described earlier, we tested the pH levels of each scat solution.

2.6 Data Analysis

Analysis was conducted using JMP statistical software v16 (SAS Institute Inc.), and figures were synthesized with the same program and Microsoft Excel. ANOVA was used to compare the visual percent cover of annuals, the number of perennials, the annual height, and the pH of soil and scat among coyote, woodrat and control sites. Additionally, perennial composition, measured by species present, was examined between sites using a multivariate discriminant analysis. Eight of each type of site were sampled for analysis, for a total of 24 sites.

RESULTS

Overall, there was no difference in the percent cover of annual vegetation (N = 8; F = 1.2828; p = 0.30; Fig. 2), nor was there a difference in their average height when comparing either the latrines or middens to the control. However, there was a marginal difference between annual plant height in woodrat middens when compared to coyote latrines (N = 8; F = 2.7394; p = 0.08; Fig. 3).

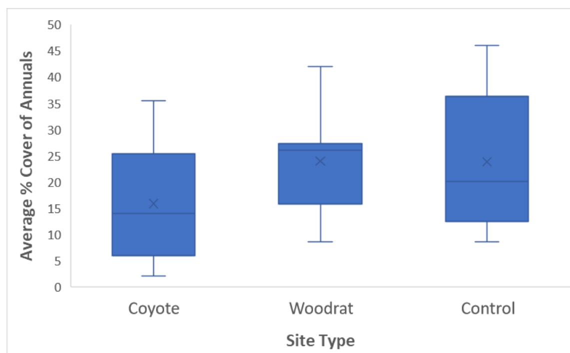

Figure 2. Boxplots of Each Site's Abundance of Annuals. Boxplots were generated to compare each site's percent cover of annual vegetation. There is a lot of overlap between each type of site's ranges, with their averages being between 15% and 25%. (N = 8; F = 1.2828; p = 0.30.)

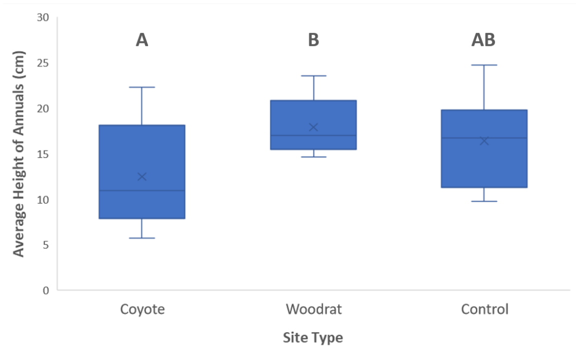

Figure 3. Boxplots of Annual Growth. To compare annual growth between each site type, boxplots were generated to see if any site with respect to the heights of the tallest annuals they contained. There appears to be a marginal difference between the sites, with coyote and woodrat sites deviating the most from each other. The averages were between 13 centimeters and 18 centimeters. (N = 8; F = 2.7394; p = 0.09.)

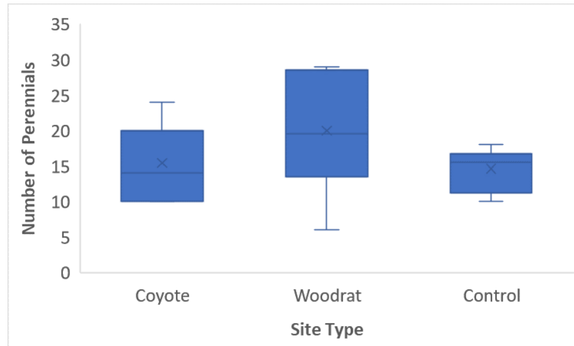

Figure 4. Boxplots of Each Site's Abundance of Perennials. Boxplots were generated to compare each site's amount of perennial vegetation. Though woodrat sites were observed to have relatively high plant presence, there is a lot of overlap among the three sites' abundances, with their averages being between 14 to 20 perennials. (N_{coyote} = 7, $N_{woodrat}$ = 8, $N_{control}$ = 8; F = 1.7818; p = 0.19.)

There was no effect of the scat presence or type of scat on surrounding perennial abundance (N_{coyote} = 7, $N_{woodrat}$ = 8, $N_{control}$ = 8; F = 1.7818; p = 0.19; Fig. 4). However, there did seem to be affiliations between particular perennial species and either latrines, middens, or controls. Coyote latrines were associated with California juniper (*Juniperus californica*), woodrat middens were associated with buckhorn cholla (*Opuntia acanthocarpa* var. *coloradensis*) and Mojave Yucca (*Yucca schidigera*), and sites without scat were associated with sweetbush (*Bebbia juncea* var. *aspera*) (N_{coyote} = 7, $N_{woodrat}$ = 8, $N_{control}$ = 8; Fig. 5).

The average pH of the soil found under woodrat middens was 8.4 while the pH of the soil found under coyote latrines and the control soil were similar, measuring about 7.5 and 7.6 respectively (N_{coyote} = 8, $N_{woodrat}$ = 8, $N_{control}$ = 7; F = 45.1805; Fig. 6). The pH of the isolated coyote scat sample was 7.2 while the woodrat scat was 8.4, similar to their respective soils' pH measurements.

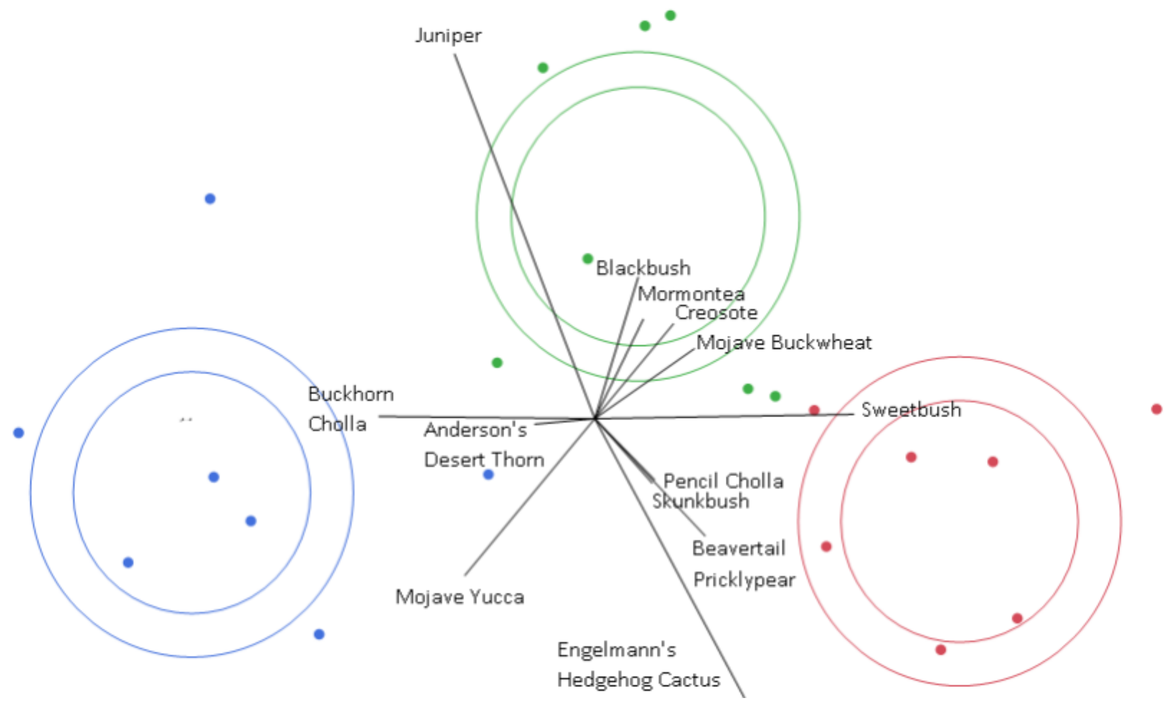

Figure 5. Perennial Communities of Different Sites. A canonical plot compares the different plant communities via unique perennial species between each type of survey site. The proximity and direction of each species' ray to a particular ring indicate an affiliation between a perennial and a type of site. The greater the affiliation, the greater the predictive power for the computer to correctly assess which data point belongs to which site type based on the data point's perennial community. 85.7% of coyote site data points were assessed correctly. For the woodrats, it was 87.5%, and for control sites, it was 100%. Green rings and dots correspond to coyote sites, blue ones correspond to woodrat sites, and red ones correspond to control sites. ($N_{coyote} = 7$, $N_{woodrat} = 8$, $N_{control} = 8$.)

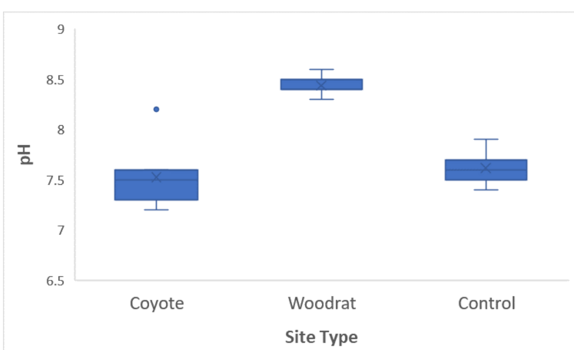

Figure 6. Boxplots of Each Site's Soil pH. Boxplots of each site's average soil pH values show the similarity between coyote and control sites, measuring about 7.5 and 7.6 respectively, while woodrat sites yielded a noticeably high 8.4. Additionally, pH values of isolated scat samples of each animal were taken. Coyote scat yielded 7.2, and woodrat scat yielded 8.4, similar to their respective soils' pH measurements ($N_{coyote} = 8$, $N_{woodrat} = 8$, $N_{control} = 7$; $F = 45.1805$; $p < 0.0001$.)

DISCUSSION

Overall, our predictions were not completely accurate. While we predicted that desert annual vegetation would be more abundant and taller near woodrat middens, our findings allude that annual abundance is unaffected by either coyote or woodrat scat and that woodrat scat may only marginally encourage annual height. It is possible that the long-term deposition and content of scat within these middens increases the nutrients available in the surrounding soil, ultimately encouraging annual plant heights (Campos et al. 2019). This is further supported by our findings that soil pH was more basic between middens when compared to both our latrine and control sites. Additionally, we found consistencies between pH in different organisms' scat and the pH in the soil of their deposition areas, suggesting that scat does impact soil pH as previous studies suggest (Adeniyan et al. 2011). This difference in pH could mean that annual plant heights are promoted by higher pH levels as present in woodrat middens, as plant distribution can be affected by pH (Medeiros and Drezner 2015).

As our data on annual plants was collected on the perimeter directly adjacent to the area of the scat (Fig. 1), desert annual plants near woodrat middens experienced an increased amount of shade as compared to annuals surrounding latrines. To control for factors such as shade in the collection of desert annual height and ensure that the differing nutrient quality in soil is indeed the major variable explaining annual height differences, a bioassay could be conducted, wherein scat and control samples could be observed in how they promote plant germination and growth rate. This would give us a better understanding of scat's direct effect on the growth of desert annuals, with less worry over extraneous factors.

For perennial vegetation, one prediction we had was that diversity between different site types sites would be different. The results of the multivariate discriminant analysis support this, however our methodology does not allow us to clearly determine whether the different communities of perennials around these sites are the direct results of scat. As mentioned for annuals, the difference in pH of soil between different sites also potentially explain the differing perennial plants due to the effect of pH levels on plant distribution (Medeiros and Drezner 2015). On the other hand, our results could be a demonstration of how woodrats and coyotes choose sites to excrete based on the surrounding perennial plant communities, affirming what is already known about the behavior and area preferences for coyote and woodrat waste deposition (Cosmero et al. 2017; Elbroch et al. 2012). In order to understand whether scat is directly affecting the presence of certain perennial species over others, another bioassay can be utilized to determine the ability of different plants to grow and survive in different scat samples.

Additionally, we predicted that woodrat middens would be surrounded by more perennial vegetation compared to coyote latrines, but there was no difference in abundance between our study sites. If there were more individuals in one site type versus another, this would possibly suggest that the recruitment of longer-lived plants is affected by nutrient inputs from scat or provide more insight into animal choice for ideal locations to waste. Ultimately, this was not the case. An experiment, wherein naturally occurring latrine or midden areas and control sites are planted with seeds of perennials found within the focal area, can facilitate better understanding of whether scat can impact perennial abundance via nutrient release as seed growth is monitored.

To conclude, it is interesting that our data suggests that annual height is marginally affected by the presence of scat from differing consumers. Further studies will need to be conducted to establish a causal relationship between the presence of scat and the growth of desert annuals. Our findings suggest that neither primary nor secondary consumers directly affect the composition and abundance of perennial plant communities, instead suggesting that perennial plants determine where coyotes and woodrats place their latrines and middens. However, our findings also indicate that middens have a discernible effect in the soil and annual height, while coyote latrines had no effect, so a study on the specific nutrient content between the differing animal scat and their respective soil could aid in assessing the relationship between the consumers and their nearby producers, seeing just how much of a contribution they're offering to the vegetation, and vice versa. Better understanding how nutrients cycle throughout the entire ecosystem is invaluable to understanding how organisms can live and even thrive in extreme environments such as the desert. With this knowledge in mind, we hope to better understand the role of scat as it may inform the promotion of plant communities in a nutrient-deficient environment.

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