The Impacts of Anthropogenic Disturbance on the Behavior of Rangeland Mammals

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ABSTRACT

Understanding the behavior of wild mammals is essential to effectively manage them. Rangelands provide recreational opportunities and economic benefits of grazing, but at the cost of reducing habitat value. For instance, rangeland mammals can avoid interacting with humans and domesticated animals by shifting their temporal activity patterns. To determine whether mammals in Yuba Narrows, California behave differently in response to the presence of humans and domesticated animals, 12 camera traps were placed to monitor anthropogenic and wildlife activities. I ran a regression analysis of the number of mammals detected in response to different rates of anthropogenic disturbance. I found that mammals avoided the study area when cows were present but did not behave differently when humans, horses, or dogs were present. I found that herbivores were more likely than omnivores to avoid the study site when cows were present. Moreover, I looked at mammal and anthropogenic activities on a site-by-site case to determine whether mammals avoided sites recently visited by humans and other domesticated animals. I found that there was no significant difference in response to the two different groups. I also monitored the behavioral responses of different species to spatial disturbance. I found that bears and mountain lions were more abundant on sites that were highly disturbed by humans, horses, and dogs. Minimizing disturbance on days and sites with high disturbance rates can prevent behavioral changes of mammals in response to them.

KEYWORDS

Wildlife, cattle, recreation, behavioral adaptations, camera traps

INTRODUCTION

The "sixth mass extinction" is often used to describe the current era of rapid extinctions. Mammals are not an exception to this; as of 2008, more than a fifth of all global mammals face the threat of extinction (Milius 2008). Mammals contribute to seed dispersal, maintain trophic cascades through predation, and provide food and clothes for people (Schipper 2008, Jone and Safi 2011). Despite their ecosystem services, mammals are put at risk by anthropogenic activities. Habitat destruction and degradation are some of the biggest factors influencing extinctions and declines of terrestrial mammals (Schipper 2008, Munguia et al. 2016). Protecting wildlands can prevent further decline, however human populations continue to move further into those areas (Woodroffe et al. 2005, Dickman 2010). As a result, it is not uncommon for humans and wildlife to have spatial overlaps, particularly in rangelands where recreation and livestock are permitted.

The presence of humans and domesticated animals in rangelands can lead to changes in the physical landscape, resource availability, and community structure. Recreation can disrupt inter-community interactions, such as predation and competition, which can influence reproductive success and survival (Knight and Gutzwiller 2013). The presence of dogs leads to a decline of wildlife populations because of dogs' influence on ecological dynamics such as competition, predation, and transmission of pathogens (Lessa et al. 2016). Hiking, the most popular type of recreation, can lead to trampled flora and the spread of diseases and pathogens (Marzano and Dandy 2012). Mountain biking has the same ecological impacts as hiking (Thurston and Reader 2001). All-terrain vehicles (ATVs) cause on-trail erosion and vegetation disturbance (van Vierssen Trip and Wiersma 2015). Artificial light, such as those from ATVs and cars, can be detrimental to nocturnal animals, especially to those sensitive to artificial light (Sanders and Gaston 2018). Equestrian activities can lead to the formation of new, wider and deeper trails, and seeds from livestock fodder can enter previously unvegetated areas, spreading invasive plants (Schmudde 2015). Grazing in rangelands can lead to wild carnivores' predation on livestock, hunting of carnivores by ranchers and increased wildlife mortality due to entrapment in fences (Strassmann 1987, Woodroffe et al. 2006, Drouilly et al. 2018). Grazing also directly affects vegetation dynamics and can influence wildlife behavior (Bokdam and Gleichman 2000, Mullen et al. 2013, Kuiper et al. 2015). Mammals can behave differently when humans and domesticated animals are present.

Mammals can either benefit or suffer from how they respond to anthropogenic disturbances. Benefits include taking advantage of and foraging for resources provided by visitors (Wauters et al. 1997, Fedriani et al. 2001). However, some mammals can change their behavior by spending more time scanning and staying vigilant instead of foraging (Ciuti et al. 2012). Others can avoid interacting with humans and domesticated animals by shifting their temporal activity pattern (Tsunoda et al. 2018, Gaynor et al. 2018). This shift can influence individual fitness and reproductive success, and ecosystem level trophic cascades (Preisser et al. 2005, Patten and Burger 2018). Furthermore, mammals can also avoid humans and domesticated animals on a spatial scale (Hilbert 2010). This behavior can limit access to suitable feeding and breeding sites (Beale and Manoghan 2004).

Although action is necessary, discrepancies and gaps in literature about mammal responses to anthropogenic disturbance can delay progress and prevent efficiency in conservation actions. One study concluded that mammals that hardly interact with humans are expected to be negatively impacted by their disturbance (Oberosler et al. 2017). However, another study observed that the more temporal overlap in human and wildlife activities, the more influential human disturbance activities are on those species (Nix et al. 2018). Not much is known about how rangeland mammals respond to human and grazing disturbance. It is hard to apply the conclusions of one study done in one place to another; different communities may respond differently to the same type and intensity of disturbance (Hansen and Clavenger 2005). However, monitoring and understanding wildlife dynamics of a specific community is crucial to effectively managing the animals that are part of it.

By monitoring temporal dynamics and spatial distribution of mammals in rangelands, the impacts of anthropogenic disturbance on the behavior of these mammals can be better understood. One of my objectives is to determine whether mammals try to avoid directly interacting with humans, horses, dogs, and cattle. I tracked the behavior of all mammals and the behavior of individual diet-based groups of mammals. My second objective is to determine whether changes in landscape due to anthropogenic disturbance influences the likelihood that specific species of mammals will visit those areas. I monitored how different species of mammals respond to sites with varying levels of anthropogenic disturbance. By determining whether anthropogenic disturbances influence mammals, and identifying groups of mammals that are vulnerable to these disturbances, protected areas management can effectively provide for their needs or remove factors that discourage their recovery.

METHODS

Study site description

I conducted my study in Yuba Narrows (YN), California. This 530-acre rangeland, accessible to the public, cattle, and wildlife is situated between Yuba and Nevada counties and runs along 2 miles of the Lower Yuba River. YN is part of a collaborative conservation project between the California Department of Fish and Wildlife (CDFW) and Bear Yuba Land Trust (BYLT). YN provides habitats for native species and promotes habitat connectivity. CDFW acquired this property in September 2011 with the goal of protecting it for wildlife and making it accessible to the public.

Camera traps were placed in multiple sites in the study area (Figure 1). BYLT crews have built trails and other public amenities, like parking lots, to increase accessibility. People can access YN through the Black Swan trail. This trail runs through the Black Swan Ranch, which is also part of the conservation project. Visitors can also use the Miner's Ditch trail, which was used by hydraulic miners during the gold rush era.

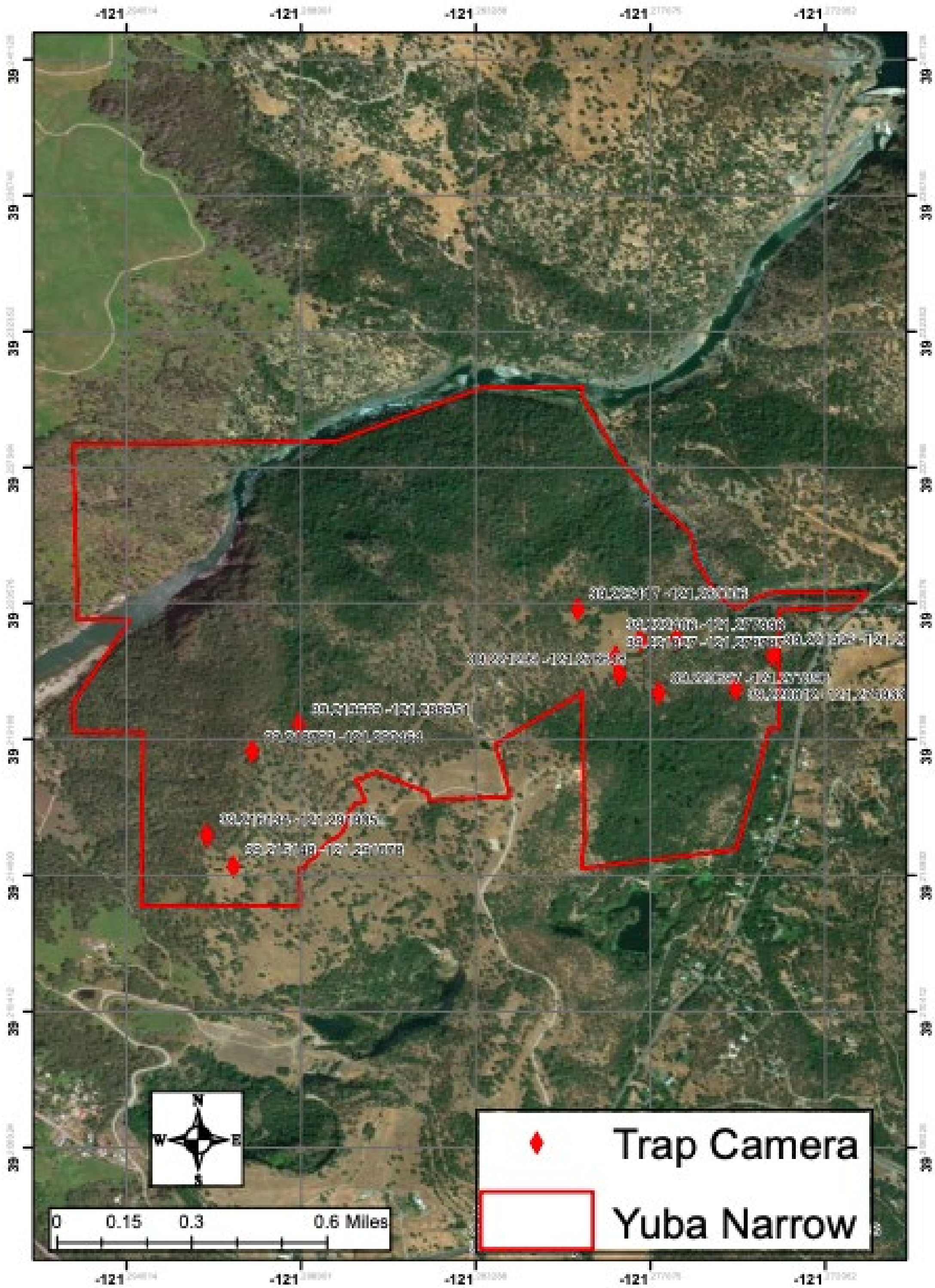

Figure 1. **Locations of the 12 camera traps in the study area.**

Data collection methods

Camera trap placement

To determine if there is a correlation between anthropogenic disturbance rate and the number of mammals detected, I monitored mammal activity via camera traps. 12 Reconyx Hyperfire camera traps were placed from April 2018 to December 2018. Camera traps were placed in locations near roads or areas of public use for easy access. The cameras were placed at an angle that would capture the most activity. This camera model takes 3 photos per motion activation and can shoot in infrared to capture nocturnal events. Each photo includes the date, time, moon phase, and temperature stamps. Batteries and memory cards were changed every 2 months.

Photo analysis

After the survey was done, I converted the photo data into comma-separated values (CSV) to quantify them. Each photo needs to have date and time stamps and biological parameters in order to analyze. I manually examined each photo and identified the species of mammals present and how many were present. Even if the same animal is present within multiple consecutive photos, I counted this detection as one event with one animal. Consecutive mammal sightings have to be separated by at least 30 minutes to be counted as separate events (Silver et al. 2004, Kelly and Holub 2008). The only exception is if two evidently different animals (different age or species) are present in the study area within 30 minutes.

To determine if there was a correlation between mammal detections and human disturbance rate, I had to strictly define human disturbance rate. Additionally, I assumed that one person has the same level of impact on wildlife activities as two or more people because disturbance rate rather than the intensity of the disturbance is more useful for quantifying disturbance (Ciuti et al. 2012). For each human event observed, I identified the type of activity (includes activities of CDFW employees). Hiking included walking, dog walking, hunting, and biking. Because the rate of the occurrences of dogs in protected areas is positively correlated with the rate of human visitation, I counted dogs as part of the human disturbance rate (Reed and Merenlender 2010). Similarly, I included horses in the human disturbance rate because horses were always accompanied by people. I defined consecutive human events as separate events if they were separated by at least one hour (Patten and Burger 2018).

Cows were also present in the study area. I analyzed the impacts of cows separately from humans. I defined consecutive camera shots of cattle as independent if they were separated by at least one hour (Borchard 2013). I tracked the disturbance rate of cows, but not the intensity of disturbance.

Data analysis

Using R Studio version 1.1.442 (R Core Team 2018), I analyzed the ecological impacts of human disturbance on mammals residing in YN by studying the temporal dynamics of mammals, humans, and domesticated animals. The number of mammals detected was used to estimate the number of mammals present in the study site for a certain period. The number of times humans, horses, dogs, and cows were detected was used to estimate human and cow disturbance rate.

To study the temporal dynamics of the study area, I divided the survey period into individual days. Human and cattle disturbance vary from day to day in the study area, and mammals may respond differently to those changes. Each day is one data point and the following are associated with each data point for the whole study area: human disturbance rate (number of events per day with humans, horses, or dogs), cow disturbance rate, total number of mammals detected, and number of mammals detected in each diet-based group. I categorized deer (*Odocoileus virginianus*) and rabbits (*Sylvilagus floridanus*) as herbivores. Omnivores include coyotes (*Canis latrans*), bears (*Ursus americanus*), grey foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), squirrels (*Sciurus griseus*), and skunks (*Conepatus leuconotus*). I categorized mountain lions (*Puma concolor*) and bobcats (*Lynx rufus*) as carnivores.

To test whether the rate of anthropogenic disturbance can influence the behavior of mammals on a study area level scale, I analyzed how human disturbance rate and cow disturbance rate influence the detectability of mammals. I ran regression analyses with daily human and cow disturbance rate as predictor variables versus the number of mammals detected. To determine which diet-based group of mammals are most impacted by anthropogenic disturbances, I first analyzed how each group's detectability changes with respect to human disturbance rate and cow disturbance rate. Then, I compared the changes in detectability between the groups.

To assess temporal avoidance of mammals on a smaller, spatial scale, I compared the delays in mammal visitations to each site after humans and cows were present with delays after other animals were present. Significantly higher delays in mammal sightings after human and cow events are indications of direct avoidance of humans and domesticated animals by mammals. I excluded delays that were 24 hours or longer because delays that long would not indicate avoidance.

I calculated average daily human and cow disturbance rates of each sampling site to assess the spatial dynamics of the study area. I ran a regression analysis of the abundance of each species per site in response to average daily disturbance rate to determine whether the abundance of the most abundant species was influenced by the disturbance rate of each site. Characteristics of a site can change depending on disturbance rate; mammals may be more or less attracted to a site as a result of disturbance.

RESULTS

Data Collection

Camera trap placement

The data set represented 228 days and captured 28,006 pictures. I only used 9,148, which were pictures of wild mammals or anthropogenic activity (including cattle), for analysis. Several complications impacted data collection: Camera 5YN stopped functioning after August, a few of the cameras were set later than the others while the batteries for some cameras ran out sometime during the sampling period. Camera 22YN had the highest number of observed mammals while camera 28YN had the highest disturbance rate. Camera 31YN had the lowest average number of mammals detected while 21YN and 24YN had the lowest average daily rates of disturbance (Table 1).

Table 1. Logistical information for each camera. Average daily disturbance refers to the average number of events that involved humans, horses dogs, and cows per day. Counts of events were normalized to average per day to account for the different number of days that each camera was out.

Camera Name	Days Camera was out	Average daily disturbance	Total Disturbance events	Total number of mammals sighted	Average daily number of mammals
5YN	227	0.287	35	102	0.836
12YN	176	0.006	1	59	0.335
21YN	159	0	0	17	0.107
22YN	227	0.097	22	244	1.075
23YN	227	0.317	72	59	0.260
24YN	176	0	0	31	0.176
25YN	227	0.044	10	88	0.388
26YN	227	0.040	9	64	0.282
28YN	227	0.453	103	74	0.326
29YN	227	0.154	35	43	0.190
30YN	225	0.120	27	20	0.089
31YN	222	0.054	12	69	0.311

Photo analysis

I only used wildlife events with mammals for analysis. There were 7,081 pictures of mammals, 10 mammal species observed, and 732 mammal events. The most observed mammals, in decreasing order of species detected, were deer, rabbit, grey fox, coyote and skunk. Each diet-based group had the following number of pictures: 5,935 for herbivores, 603 for omnivores, and 60 for carnivores. The number of events per diet-based group are the following: 539 for herbivores, 134 for omnivores and 11 for carnivores. The most abundant group is herbivores.

Camera traps detected 300 events that involved humans and domesticated animals. A total of 2,079 pictures of humans, horses and dogs were taken. There were 168 events with humans, horses, and dogs; and some days experienced higher rates of each activity than others (Figure 2). Visitors to the area included: hikers, horseback riders and ATV riders. Hiking usually occurred in the late morning and early afternoon, and happened in 3 sites (Figure 2, Table 2). Horseback riding usually occurred around the same hours as hiking, and occurred in 5 sites (Figure 2, Table 2). ATVs were detected late in the afternoon and at night, after visiting hours, and occurred in 3 sites. Employees drove around in either cars or low-speed vehicles around late morning and early afternoon in 7 sites.

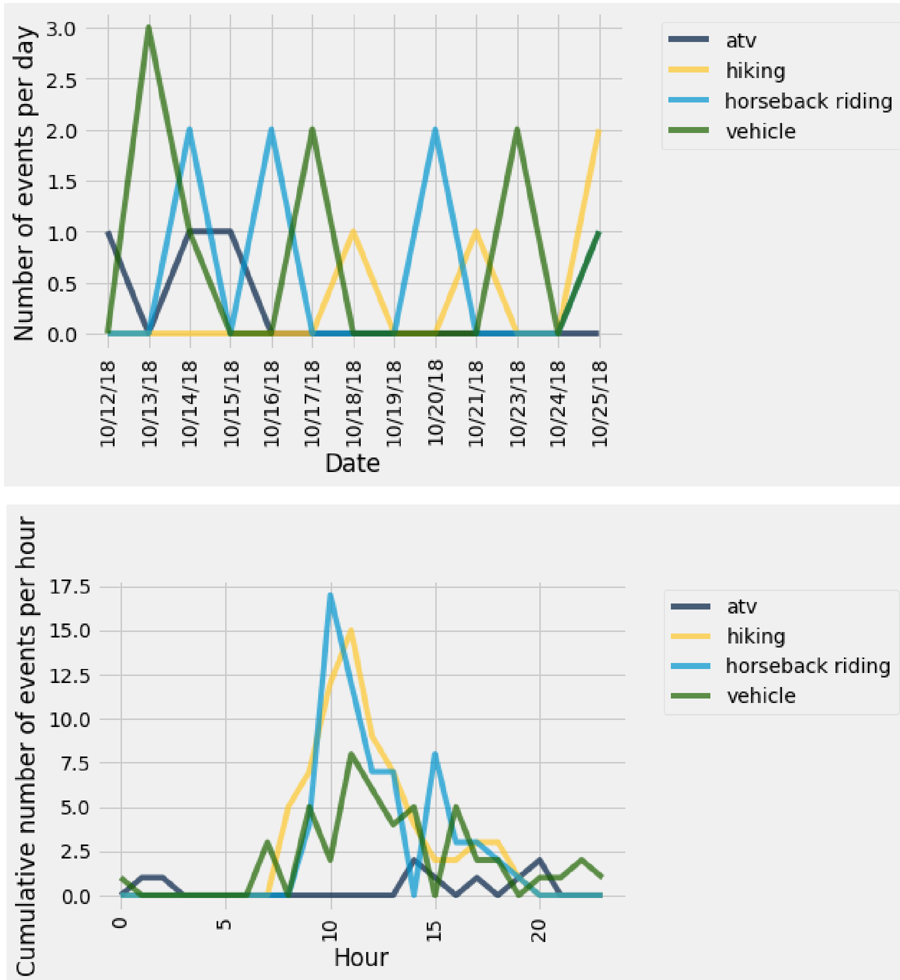

Figure 2. The intensity of human, horse, and dog activities from day to day, and from hour-to-hour on a 24-hour clock. Number of humans (includes horses and dogs) detected by date is only a sample of the survey period. Cumulative number of events refers to the total number of events of each activity across all sites for each hour.

Table 2. Number of human and cow events by site. Same events could have occurred in multiple sites.

Site	ATV	hiking	horseback riding	vehicle	cows
5YN	0	0	0	0	33
12YN	0	0	0	1	0
21YN	0	0	0	0	0
22YN	7	0	2	8	4
23YN	1	6	28	23	11
24YN	0	0	0	0	0
25YN	0	0	2	2	6
26YN	0	0	0	0	0
28YN	0	57	20	6	16
29YN	0	2	12	5	16
30YN	0	0	0	0	0
31YN	1	0	0	1	10

There were 10,034 pictures of cows and 132 cow events. Cows were present at the study area for 4 out of the 9 months of the survey period. The disturbance rate of cows varied from day to day (Figure 3). Cows were present in seven sites (Table 2), and were most active in the early morning and late afternoon.

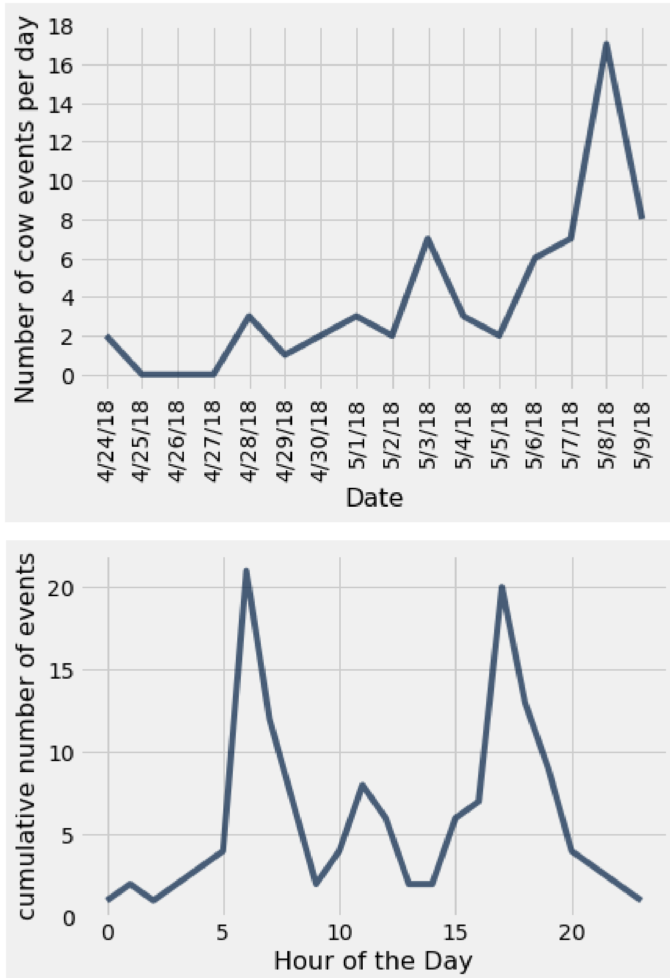

Figure 3. The intensity of cow events from day to day and from hour to hour on a 24-hour clock. Cow detections by date is only a sample of the survey period. Cumulative number of events refers to the total number of cow events across all sites for each hour.

Data analysis

Through the camera trap survey, I found that certain types of anthropogenic disturbances can influence the number of mammals detected. The number of mammals present at the study site was not influenced by disturbance rate of humans ($F(1,217)=1.05$, $P=0.3066$) (Figure 4). The number of mammals present significantly increased with decreasing cow disturbance rate ($F(1,215)=11.26$, $P=0.001444$) (Figure 4). The number of cows for each event had no effect on mammal detectability.

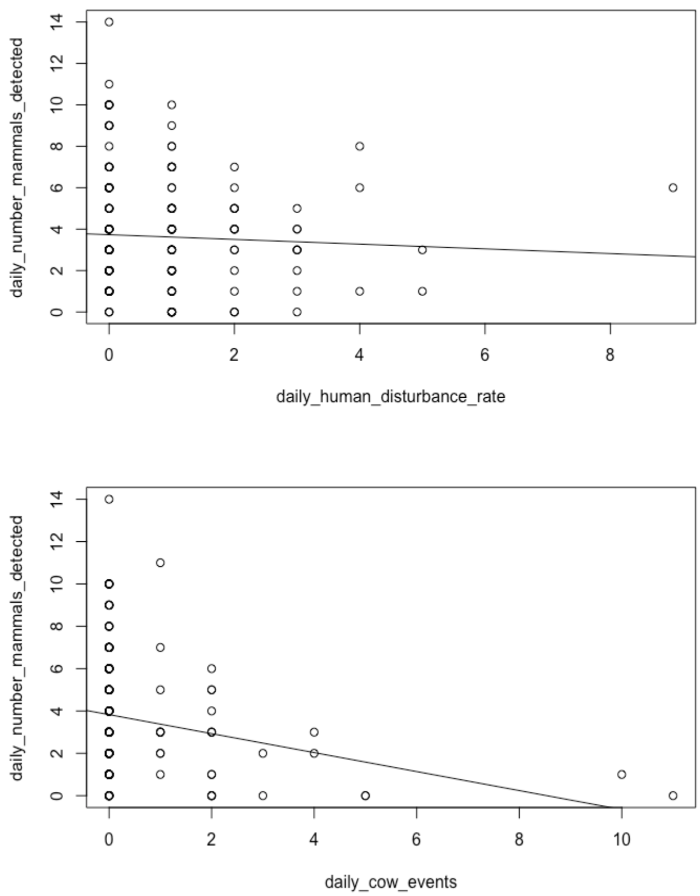

Figure 4. Regression analysis of daily number of mammals detected as the dependent variable and daily disturbance rate of humans and cows as predictor variables.

The degree of disturbance effect differed between diet-based groups. I removed carnivores from the analysis due to a low number of detections. I found that the number of omnivores (F(1,215)= 5.874, P= 0.0207) and herbivores (F(1,215)=7.196, P= 0.01218) present at the study site significantly decreased as disturbance rate of cows increased (Figure 5**)**. Herbivores ($\beta = -0.3074$)were more impacted by the presence of cows than were omnivores ($\beta = -0.14451$).

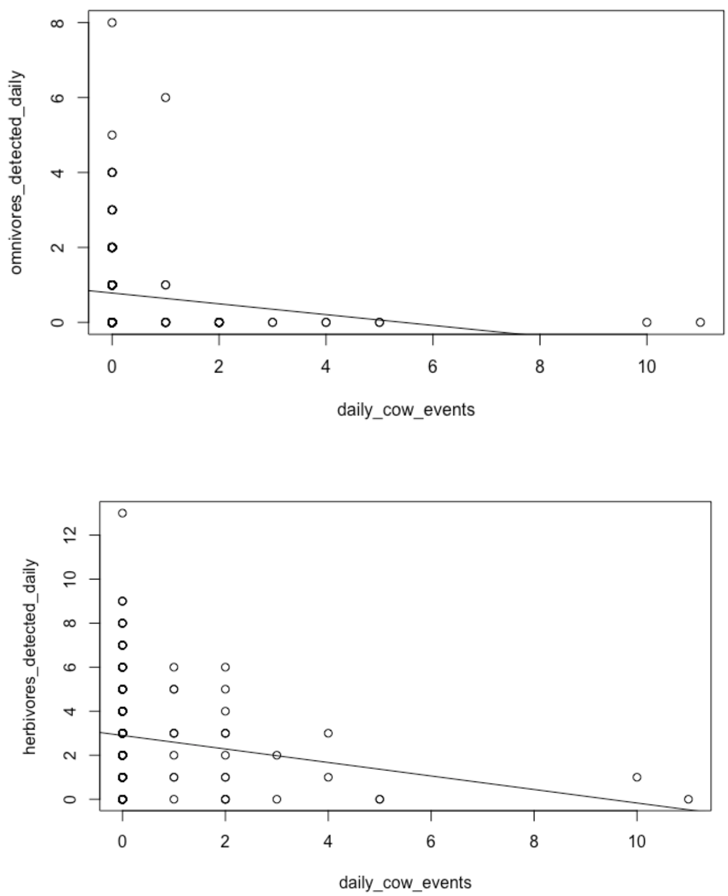

Figure 5. The number of herbivores and omnivores detected each day relative to daily disturbance rate of cows.

For each site, I found that delays in mammal sightings after humans, horses, and dogs visitations were not significantly different from delays after visitation of other animals (P = 0.07197) (Figure 6). I excluded delays after cows in the analysis because of the insufficient number of delays less than 24 hours.

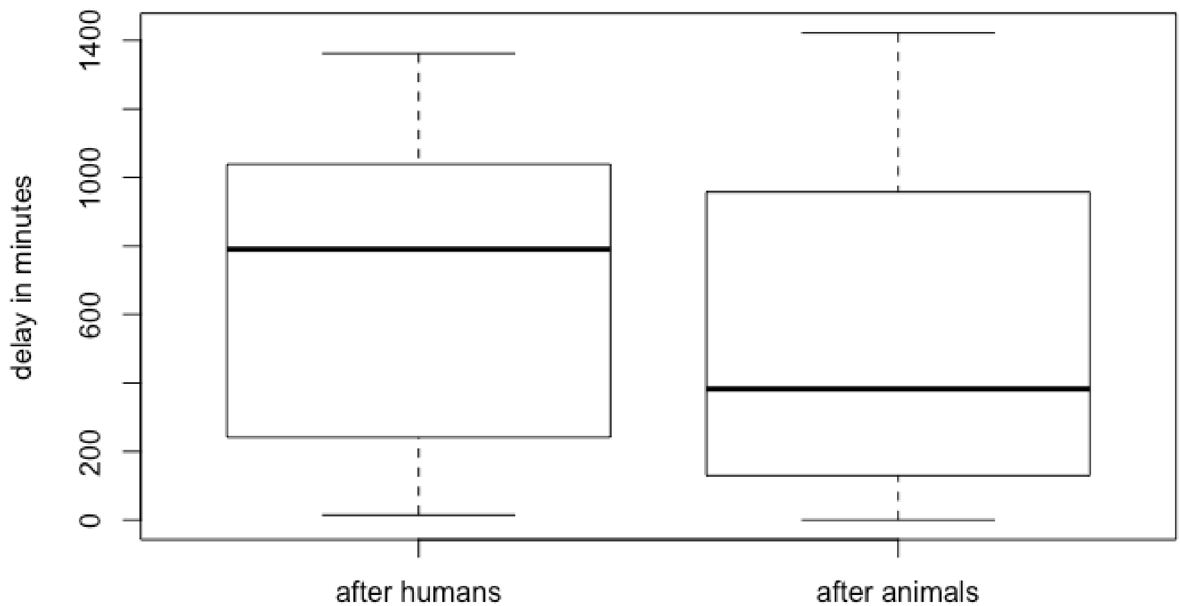

Figure 6. Delays of mammal sightings after humans and after other animals.

Disturbance rate differs between sites, which can influence the abundance of mammals on each site. I found that bears and mountain lions were more abundant on sites that had relatively high human disturbance rates (Table 3). The presence of cows did not significantly impact the abundance of any species on a spatial scale.

Table 3. The impact of humans (includes horses and dogs) and cows on the abundance of the 6 most abundant species of mammals on a spatial scale.

Effect on Mammal Abundance	Humans	Cows
Bear	positive	not significant
Coyote	not significant	not significant
Deer	not significant	not significant
Fox	not significant	not significant
Mountain Lion	positive	not significant
Rabbit	not significant	not significant

DISCUSSION

Disturbance caused by humans and domesticated animals can impact the behavior of mammals in protected areas. This study monitored the dynamics of anthropogenic activities and mammal activities to see how mammals respond to humans and domesticated animals. There were days and certain periods of the day when disturbance rate was high (Figure 2, Figure 3). The detectability of mammals did not change given changes in recreation intensity and the mobility rates of employees. Herbivores and omnivores did not alter their behavior in response to human disturbance rates. Mammals did, however, avoid the study area on days with high rates of cow disturbance. There was a significant decrease in the number of herbivores and omnivores detected on days when there were higher rates of cow mobility in the study area. Herbivores avoided the study area more than omnivores on days when cows were more mobile. Mammals did not significantly avoid sites recently visited by humans, horses, and dogs. Lastly, bears and mountain lions were more abundant in areas with relatively higher rates of disturbance.

The impacts of humans, horses and dogs on mammals

Anthropogenic activities in YN involved both the movement of employees from one site to another via the use of vehicles, and recreational activities like hiking, ATV riding, and horseback riding. Recreation intensity and rates of employee mobility had no effect on the detectability of mammals. Mammals from all diet-based groups did not avoid the study area on days when human disturbance rate was high. Moreover, they did not avoid going to sites that were recently (less than 24 hours) visited by humans, horses and dogs. My findings contradict conclusions from previous studies (Papouchis et al. 2001, Claudet 2010, Oberosler et al. 2017). There might be a threshold of human disturbance rate that can warrant a change in animal behavior (Wright et al. 2007). Human disturbance in YN might not be high enough to lead to a change in the behavior of mammals. Furthermore, mammals that live in human-disturbed wildlands can become adapted to human disturbance (Greenberg 2017, Diaz-Ruiz 2015). As a result, they might not feel threatened by humans and domesticated animals. Although mammals can try to minimize interactions with humans, these interactions can be inevitable at times due to fragmented landscapes (Kojola et al. 2016).

Temporal dynamics of herbivores and omnivores were not influenced by the presence of humans, horses, and dogs. Previous studies have concluded that humans and dogs can lead to behavioral changes in wild herbivores. Herbivores exhibit avoidance behavior due to their fear of being hunted by humans (Cromsigt et al. 2013). Predator scents, such as those of dogs, may not always lead to avoidance of disturbed areas. However, they can deter herbivores from staying in those areas for too long or from colonizing (Sparrow et al. 2016). Many studies have concluded that omnivore densities tend to increase with anthropogenic disturbance (Hegerl et al. 2015, Rovero et al. 2017). Omnivores typically avoid people, except for instances when they start to associate people with food (Hygnstrom 1994). It is very likely that the omnivores in YN are still adapting to having humans in the vicinity. Dogs are predators and, at high densities, dogs can be successful competitors of wild animals (Butler and Toit 2006). There is a possibility that with higher human disturbance rates, humans, horses, and dogs can affect the behavior of mammals.

The impacts of cattle on mammals

Mammals avoided the study site when cows were present. These findings coincide with those from previous studies. Wild mammals can have spatial overlaps with cattle but can be temporally separated from them (Stewart et al. 2002, Cooper et al. 2008, Mullen et al. 2013). However, having more cows at a time does not decrease the probability of detecting a wild mammal. This behavior indicates that the likelihood that mammals will avoid cows will not decrease if less cows were present. The presence of a small herd of cattle is sufficient for mammals to exhibit avoidance behavior. However, cattle numbers can have significant implications for cattle-wildlife interactions beyond avoidance behavior. For instance, an increase in the number of cows can increase the risk of disease transmission from wildlife to cattle (Kilpatrick et al. 2009, Tolhurst et al. 2009) or cattle to wildlife (Randall et al. 2006, Morgan et al. 2006).

The impacts of cattle on diet-based groups

The presence of cows impacted the detectability of both diet groups, indicating that avoidance of cattle is exhibited by both herbivores and omnivores. Other studies have focused on the impacts of cattle on spatial distribution of wild mammals, often finding that wild mammals avoid areas grazed by cattle (Clegg 1994, Coe et al. 2001, Barasona et al. 2014). There are few studies on the impacts of cattle on temporal distribution of wild mammals. However, there is evidence from multiple taxa of resource partitioning. For example, different species can utilize the same resources at different times (Schoener 1974). I found that cattle presence had more impact on herbivore behavior than on omnivore behavior. Elk use areas grazed by cattle when cattle are absent, but move elsewhere when cattle are present (Stewart et al. 2002). Herbivores that stay in the area when cattle are present would have to resort to eating a secondary choice of forage (Coet et al. 2005). Omnivores are more resourceful and might not have as much overlap in their niches as herbivores do. Omnivores have a more diverse diet and employ a wide range of search tactics (Bastille-Rousseau et al. 2013). Omnivores may have to compete with cattle for resources but they do not have to adjust their diet as much as herbivores do. Wild mammals may avoid cattle temporally for the same reason they avoid cattle spatially: to prevent direct competition for resources.

Impacts of human disturbance on a species level

On a spatial scale, some species of mammals were more abundant on sites with higher disturbance rates of humans, horses and dogs. Some sites had a higher rate of disturbance than others (Table 2). I found that bears were more likely to be found in sites with higher disturbance rates. Previous studies on bears support these findings. Bears exhibit opportunistic feeding behaviors, eating anything from anthropogenic waste and crops to carcasses left by hunters (Sato et al. 2005, Baruch-Mordo et al. 2014). I also found that mountain lions frequented sites with higher rates of human activities. My findings contradict those of previous studies. Mountain lions, and other carnivores, tend to avoid areas used by humans (Maletzke et al. 2017, Wang et al. 2013). Mountain lions are more reluctant to go to areas with high human development. There is likely a threshold of anthropogenic disturbance in which mountain lions will start avoiding areas that have reached this threshold (Maletzke et al. 2017). For mountain lions, differential responses to human disturbance can be dependent on age and sex of mountain lions (Benson et al. 2016).

Limitations

This study does not account for behavioral changes in wildlife, humans, and domesticated animals that may occur during the winter. Moreover, the survey was only done in one year. There could be year to year variations in weather that might influence wildlife behavior. The camera traps were placed on a section of YN. Wildlife dynamics might be different in other places, depending on the resources available, such as water and forage.

Small animals are not detected by the camera traps, limiting my study to mammals. There are also inter-community interactions that I could not control for. Animal behavior can change if prey, predators, or competitors are nearby.

Future Directions

This study can be expanded to other taxa. Although different data collection methods would be required, the data analysis methods can certainly be applied. It would be more practical do expand data collection to all months of the year, and for multiple years to account for season-to-season and year-to-year variation in weather. A study that spans multiple months and years would result in a huge data set. As a result, multiple confounders can be accounted for without the risk of having a small sample size. For instance, days with high and low temperatures can be taken out of the dataset. Biological confounders are important to control for, such as prey, predators, competitors, etc. Having a bigger data set can allow for a species-specific study, particularly for species that are declining and need to be closely monitored

Conclusions

The management of protected areas should be flexible and adaptive, especially to recent studies. The demand for recreation and products from cattle should not interfere with, or at least hinder conservation goals. Humans, horses, and dogs do not seem to influence the behavior of mammals in YN, but they can still have significant ecological impacts on fitness and reproductive success of individuals. Mammals do avoid the study area when cattle are present. These behavioral changes can influence species from other taxa, which can result in significant changes in community dynamics.

Regardless of behavioral changes in mammals, visitation and cattle mobility should be monitored and limited. Restricting visitors and cattle access to areas that wildlife frequent minimize the consequential impacts of disturbances. An increase in personnel for enforcing rules and controlling traffic may be necessary on days and hours with high human disturbance rates. Educating the public about the impacts of their actions in protected areas, and the sensitivity of wildlife to those actions, can contribute to biodiversity conservation.

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