



2014-12-01

# The Impacts of Feral Horses on the Use of Water by Pronghorn on the Sheldon National Wildlife Refuge, Nevada

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The Impacts of Feral Horses on the Use of Water by Pronghorn on the Sheldon  
National Wildlife Refuge, Nevada

Amy M. J. Gooch

A thesis submitted to the faculty of  
Brigham Young University  
in partial fulfillment of the requirements for the degree of  
Master of Science

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December 2014

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## ABSTRACT

### The Impacts of Feral Horses on the Use of Water by Pronghorn on the Sheldon National Wildlife Refuge, Nevada

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Feral horses occupy 31.6 million acres throughout western North America. Feral horses share similar habitats with a wide range of animal species, including pronghorn. Since horses are larger and often more aggressive than other animals of this region, they are generally socially dominant over all other native ungulate species. Pronghorn share water sources with horses in areas where both occur. In situations where horses exclude pronghorn from water, pronghorn fitness may be impaired, especially during the hottest months of the year when water is limited. The purpose of this study was to investigate interference competition between pronghorn and feral horses at water sources. During spring and summer 2010-11, we placed motion-sensitive cameras at water sources across the Sheldon National Wildlife Refuge in northwest Nevada. Cameras were used to examine the overlap of water use by pronghorn and horses and to determine the occurrence of spatial or temporal partitioning of water between these species. Additionally, we made direct observations of horses and pronghorn at high-use water sources to record the occurrences and outcomes of pronghorn/horse interactions as well as differences in pronghorn behavior in the presence and absence of horses. Pronghorn spent more time on vigilance behavior and less time foraging or drinking in the presence of horses than in their absence. Nearly half of pronghorn/horse interactions at water resulted in pronghorn exclusion from water. Our data also suggest that temporal partitioning of water between horses and pronghorn on an hourly basis may be occurring.

Keywords: *Antilocapra americana*, *Equus caballus*, feral horses, interference competition, pronghorn, Sheldon National Wildlife Refuge

## ACKNOWLEDGMENTS

I would like to express my gratitude for all those who helped me complete this project. I am grateful to Dr. Steven Petersen for dedicating so much time and energy to this research at every stage, as well as for his guidance, patience, and unflagging optimism. I appreciate Gail Collins for her support and direction in planning and carrying out this research. I thank Dr. Tom Smith and Dr. Brock McMillan for their ideas and input. I appreciate all the techs and volunteers who devoted long field days and many lab hours to this research. I would also like to thank all the other professors and students of the PWS and statistics departments who contributed to this project. Most importantly, I would like to express my deep love, gratitude, and appreciation for my husband Benjamin and my parents William and Jackie. Without their help, encouragement, and support I could not have succeeded in this endeavor.

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## INTRODUCTION

Equids, including feral (or wild, free-roaming) horses (*Equus caballus*), originally evolved in North America (Simpson, 1951), but disappeared from the American continents during the late Pleistocene extinction event 10,000-14,000 years ago (Grayson, 2006). The reintroduction of horses to North America occurred near the end of the 16th century by the Spanish Conquistadors, followed by numerous subsequent introductions of released or escaped animals (Wagner, 1983). Additionally, rapid population growth rates and the lack of natural predation that help maintain stable population densities have allowed horse populations to reach annual population growth rates of 20% or higher (Beever, 2003). In the United States, the Bureau of Land Management (BLM) manages rangelands that support the majority of free-roaming horses in the country, with an estimated 49,209 feral horses and burros occurring over 10 states and 31.6 million acres. The BLM estimates that this number of horses is two times greater than western rangelands can support. Nevada, the state with the largest feral horse population, alone contains approximately 25,035 animals (BLM, 2014).

Feral horses can impact many aspects of rangeland ecosystems, including vegetation, hydrologic processes, and native wildlife. They directly impact vegetation through grazing and trampling. In Great Basin sagebrush communities they are associated with lower grass, shrub, and total vegetative cover; lower grass abundance; less continuous shrub canopy; and lower plant species richness (Beever et al., 2008, Ostermann-Kelm et al., 2009). Feral horses impact vegetation indirectly through soil compaction, erosion, disturbance of biological soil crusts, and invasive seed dispersal, particularly cheatgrass (*Bromus tectorum*) (Beever and Herrick, 2006, Belnap et al., 2001, Knapp, 1996, Jessop and Anderson, 2007, Beever et al., 2008, Beever, 2003, Ostermann-kelm et al., 2009, Belsky and Gelbard, 2000). Feral horses can be particularly

impactful to sensitive riparian habitats. They decrease plant species richness, cover, and abundance of grasses and shrubs near water sources (Beever and Brussard, 2000). The loss of vegetation through grazing and trampling can result in the entrenchment and instability of stream banks, lowered water tables, compaction or disturbance of floodplain soils, and increased erosion (Belsky et al., 1999). Feral horses can also negatively impact native wildlife. In the Great Basin region of western North America, feral horses are associated with decreased species richness and abundance of ants (Beever and Herrick, 2006), reptiles (Beever and Brussard, 2004), small mammals (Beever and Brussard, 2000), and birds (Earnst et al., 2005). It has been suggested that feral horses compete with native ungulate species for limited water and food resources (O’Gara and Yoakum, 2004, Meeker, 1979, FWS, 2008, NDOW, 2008-2009).

Feral horses and pronghorn (*Antilocapra americana*) occupy many of the same areas on western rangelands. Though spatial overlap is common, most studies have found minimal dietary overlap between sympatric horses and pronghorn, with horses consuming mostly grasses and pronghorn favoring shrubs and forbs (McCinnis and Vavra, 1987, Meeker, 1979, Smith et al., 1998, Hanson and Anthony, 1999). However, dietary overlap can vary depending upon the season and abundance of each species’ preferred forage: high horse numbers and low availability of winter forbs could lead to competition between horses and pronghorn in the early spring (O’Gara and Yoakum, 2004). Additionally, pronghorn fawn recruitment is higher in habitats with higher densities of grasses, forbs, and shrubs, so vegetation deterioration related to feral horse foraging and trampling could have a detrimental impact on pronghorn recruitment (O’Gara and Yoakum, 2004). Though several studies have examined forage overlap between pronghorn, little data exist on whether feral horses may be excluding pronghorn from water.

In arid and semi-arid ecosystems, water is a scarce and concentrated resource, increasing the potential for competition between feral horses and other water users. Intraspecific interference competition has been observed among feral horses at water (Stevens, 1988), and it is possible that they could be competing with native ungulates as well. In a study of interactions between bighorn sheep and horses, horses were experimentally placed near water sources. No evidence of direct competition (e.g. aggression) was observed, but the presence of the horses resulted in a 76% decline in bighorn use of water holes at those locations (Ostermann-Kelm et al., 2008). In his observations of watering holes on the Sheldon National Wildlife Refuge (SNWR), Meeker (1979) found no evidence of negative interactions between horses and pronghorn. He noted some positive interactions, in which pronghorn waited outside the water holes until horses entered first (Meeker, 1979). However, some anecdotal reports describe aggressive interactions in which horses chased pronghorn from water (NDOW, 2008-2009). More research is needed to determine if horses are competing with pronghorn for water.

When competitive interactions do occur, horses are likely to exclude native species. Social dominance is influential in interference competition, with subordinate species displaced by larger, more aggressive competitors (Valeix et al., 2007). Due to their large size (typically 1.3-1.6m tall at the shoulder and weighing 315-450kg) and often aggressive behavior, feral horses are dominant in their social interactions with native Great Basin ungulates. Even solitary horses are able to displace groups of deer, bighorn sheep, or pronghorn (Berger, 1985).

When horses compete with pronghorn for water, pronghorn will likely respond by reducing costly interactions via behavior alterations (Atwood et al., 2011) such as flight responses, increased vigilance, or avoidance (Frid and Dill, 2002, Gavin and Komers, 2006, Ping et al., 2011). Interference competition could occur directly in interactions between horses and

pronghorn through horse aggression towards pronghorn and pronghorn flight responses when horses approach. Interference competition could also occur through changes in activities such as vigilance and foraging. Increased vigilance is usually associated with a decrease in time spent on foraging and drinking behaviors, which may result in decreased consumption of water and forage (Wakefield and Attum, 2006). Pronghorn may avoid horse competition by spending less time at water when horses are present. However, avoidance behavior is more commonly expressed through niche partitioning, with the subordinate competitor (pronghorn) altering their spatial or temporal resource use patterns depending upon the presence or absence of the dominant competitor (e.g. horses) (Atwood et al., 2011).

The purpose of this study was to examine interference competition between horses and pronghorn at water sources located in northwestern Nevada. To accomplish this, we examined the use of water by horses and pronghorn to determine if the use of water by pronghorn was consistent with the hypothesis that pronghorn alter their spatial or temporal water use to avoid interactions with horses. We also assessed the behavioral responses of pronghorn during horse interactions through three main study questions: 1) When in the riparian area, do pronghorn alter the proportion of time they spend on foraging and vigilance behavior when horses are nearby?, 2) What are the typical outcomes of pronghorn-horse interactions at water (e.g. is pronghorn exclusion from water the typical outcome?), and 3) Do pronghorn leave water sooner when horses are present compared to when horses are absent (i.e. does the presence of horses decrease the amount of time pronghorn spend at water?).

## METHODS

### *Study Area*

The Sheldon National Wildlife Refuge, administered by the US Fish and Wildlife Service (FWS), is located in Northwest Nevada. It stretches across 575,000 acres of high desert sage-steppe habitat (41.867995, -119.015493). The SNWR ranges in elevation from 1,280 – 2,223 m with an annual precipitation of 15 – 33 cm, and 2011-2012 summer temperatures ranging from 31°F (-0.6°C) to 103°F (39.4°C). For the duration of this study, the SNWR supported large numbers of sympatric pronghorn and feral horses. In a series of surveys taken in the summer of 2010, 1,727 pronghorn were counted on the SNWR, and the horse population was estimated at 1,236 individuals (Collins, 2010). Water resources on the SNWR are scarce, and 80% of refuge springs and 44% of stream reaches have been classified as receiving heavy to severe use by horses (FWS, 2008).

#### *Camera Site Selection*

We assessed spatial and temporal partitioning using remote camera data. We selected camera sites based on personal communications with SNWR staff (personal communication Collins, 2011), and a survey of SNWR springs taken in 2007-2008. The survey documented the majority of springs on the Sheldon, along with their flow type (dry, intermittent, or perennial), evidence of animal visitation (scat, tracks, animals observed), and many other parameters. In 2011, our selection criteria included sites which were perennial, likely to have open water available all season, and showed evidence of pronghorn visitation. We excluded springs that were on major roads or campsites, and sites that were farther than 1.6 km away from any roads or trails. From these criteria, we identified 34 potential camera sites: 12 with no or little sign of horse use, and 22 with signs of heavier horse use. Because there were far fewer springs with no horse use, we selected all the springs which had only pronghorn sign, and randomly selected the

remaining sites from among the springs with both pronghorn and horse sign. In 2011, we selected 22 camera sites in all.

The summer of 2012 had much drier conditions than 2011, eliminating many of our previously used and potential camera sites. Only 11 of the 2011 sites still contained water in 2012. To find enough sites, we expanded our criteria to include sites at any distance from roads. We also located additional sites based on Sheldon personnel and visitor recommendations. From this we located 21 total sites that fit our criteria. Additionally, due to the drier conditions, in 2012 we used all suitable sites found (See appendix A, figures 2 and 3 for maps of camera sites).

Camera sites included streams, ponds, and guzzlers. At stream sites, we placed cameras at the closest accessible point to the headwaters. Accessible points were those with open water available, with relatively flat topography, without tall vegetation, and ideally with pronghorn sign. We avoided areas with steep banks, narrow channels, and heavy tall sagebrush.

### *Cameras*

In 2011 we placed motion-sensitive Reconyx PC900 or PC85 cameras at each site. Cameras recorded date, time, and temperature with each image recorded. Cameras were set to take 10 photos per trigger, one photo per second. A timed photo was also taken every 15 minutes from dawn to dusk (0500 – 2100 h). We later determined that this was too frequent. In 2012 we used only PC900 cameras. Cameras were set to take three pictures per trigger three seconds apart, with a 30 second delay between triggers. They were also programmed to take one timed photo every 15 minutes.

We collected camera data from June-September each year. Because of the difficulty locating additional open water sites in 2012, we began data collection on two of the sites later than others (one in early July, and one in early August). We exported all data collected by

cameras to Microsoft Excel via RECONYX MapView Professional software and Exifer software (a Microsoft Windows based freeware for IPTC editing and viewing EXIF data). From the photos, we recorded pronghorn visits from arrival to departure (hereafter referred to as “camera events”), with each event separated by a minimum of 30 min with no pronghorn appearing in any photos. We recorded horse visits in the same manner (Michalski and Peres, 2007).

For each event, we recorded arrival time, departure time, and the number, sex (for adults), and age of pronghorn. We recorded horses in the same way, except that we did not attempt to identify sex. We made no attempt to identify or track individuals of either species. Data were recorded in Microsoft Access. We used these data to calculate the number of pronghorn and horses present every day (counts per day), and their average daily use of each site. We chose to use animal counts per operational camera day (i.e. the total number of animals observed at a site over the total days the camera was in operation) rather than absolute counts because cameras were operational and functioning for different lengths of time (VerCauteren et al., 2007).

### *Behavior Observations*

We collected data on pronghorn behavioral responses to horse interactions via field observation. We selected three observation sites (site 138 [West Catnip], site 142 [WRB\_142], and site 32 [Little Buckaroo]) in proximity to stream systems (see appendix A, figure 4 for a map of observation sites). We chose these sites because they regularly maintain available drinking water from spring through fall, and support high horse and pronghorn use (based on 2011 camera data). We made observations from June to September 2012. We randomly assigned observation order, observing sites in one-week intervals before relocating to the next site. We observed each

site once within a three-week block before observing any site again, repeated four times, resulting in 12 weeks of observations.

We made observations in teams of two observers from 0700 – 1900 h, with alternating six hour morning or evening “half” days and 12 hour “full” days to prevent observer fatigue. Observers were concealed within a camouflaged blind 150-300 m away from the water. Binoculars and spotting scopes were used for observing animals. We observed animal behaviors within a 500 m radius of the water, and any animals outside of this observation area were considered “out” and not counted in our scans. We divided the observation area into either riparian or upland habitats. We defined riparian habitat or area as any land located within five meters of riparian vegetation or water (Ostermann-kelm, 2008). All other areas were considered uplands habitat.

We divided pronghorn observations within riparian areas into group visits, or “observation events.” An observation event began when the first pronghorn of a group entered the riparian area, and ended when the last pronghorn left the riparian area and no other pronghorn entered again for at least one minute. Solo pronghorn were treated as a group of one. We considered it an interaction any time one species came close enough to the other to influence their behavior (Smith, 2002). Based on preliminary observations, we determined that an appropriate interaction distance for horses and pronghorn in this environment was approximately 120 m, because this was the maximum distance that pronghorn and horses typically reacted to each other conspicuously enough for us to recognize. We considered it a riparian interaction when at least one of the two species was in the riparian area. Although we recorded all upland pronghorn and horse interactions, only riparian observation events and interactions are reported here.



We used a scan sampling method (Altmann, 1974) to record pronghorn behaviors. During each observation day, we scanned the entire observation area every 15 minutes, recording the time of day and all pronghorn or horses present. When pronghorn or horses were spotted we recorded their distance from water, location, and group size. Additionally, we recorded each pronghorn's sex and age, distance from horses, and behavior (defined below). When pronghorn entered the riparian area, we began scan sampling every minute. When horses were within interaction distance of pronghorn, we sampled every 30 seconds. We recorded all occurrences of aggression or alarm by either horses or pronghorn during interactions (Altmann, 1974). We considered animals to be in the same group if they were within 100 m of each other (Ostermann-Kelm, 2008). Since the majority of the pronghorn in our study were not marked with tags or collars we made no attempt to identify individual animals, but groups were assigned temporary identification numbers as long as they were visible for recording purposes.

Based on preliminary observations recorded in 2011 we determined that riparian horse and pronghorn interactions often occurred too quickly for manual recording in the field, particularly when the animals were in large groups. To resolve this concern, we recorded all riparian pronghorn observations via video recorder for later viewing and analysis, with digital voice recorder as a backup in case of video failure. Videos were later analyzed using Noldus Observer XT software. We recorded all 15 minute scans of riparian and upland areas via digital voice recorder.

### *Pronghorn Behavior*

For field observations we composed a pronghorn ethogram, separating behaviors into primary and secondary categories, with mutually exclusive behaviors within each category. Primary behaviors described the activity state of a pronghorn (standing, walking, running, or

bedding). Secondary behaviors described the specific activity of a pronghorn (vigilance, foraging, sparring, etc). Though we observed many behaviors in the field, not all were relevant to our question. Therefore, for the purpose of this study we analyzed only the two secondary behaviors germane to our thesis: vigilance and foraging. We defined vigilance as “any time the pronghorn had its head above shoulder height while scanning the surroundings” (Gavin and Komers, 2006). We defined foraging as: “any time an individual [was] consuming vegetation or searching with their head below shoulder height.” (Gavin and Komers, 2006). We could not always distinguish whether the animal was consuming forage or drinking, so we lumped these two behaviors. See appendix B for the full ethogram.

### *Outcomes of Interactions*

To determine the nature of typical pronghorn and horse interactions on the SNWR, we reviewed the riparian interaction videos collected during field observations. We recorded the date and time of each interaction, the initiator (horse or pronghorn), the nature of the approach (walking or running in, and walking directly towards or to the side of the animals already in the riparian), pronghorn age/sex and group size, horse age and group size, and the minimum distance between horses and pronghorn during the interaction. We defined each interaction as neutral, negative, or positive. We categorized an interaction as neutral when pronghorn exhibited no detectable, costly negative reactions to the presence of horses (defined as no detectable reaction, or minor reactions categorized as: raising their heads, moving a few meters but remaining in the riparian area, or leaving the riparian area but quickly returning). We categorized an interaction as negative when pronghorn left the riparian area as horses entered or immediately after, or when pronghorn left some time after horses entered but in direct response to horse actions (aggression, activity, or approach). We also considered an interaction negative when the pronghorn stopped

foraging and drinking due to horse activity, and did not resume foraging or drinking while there were horses present (Valeix et al., 2007). We categorized an interaction as positive if pronghorn waited to enter the riparian area until horses entered first.

### *Camera Analyses*

#### Spatial Partitioning

First, we examined the relationship between horse and pronghorn use at a site level, averaging pronghorn and horse daily counts across all days by location to determine if sites with overall higher horse use would have lower pronghorn use. Using SAS, we ran a mixed models regression to compare pronghorn and horse use. There was no significant relationship for either year. We then examined the daily relationship between horse and pronghorn use, to determine if horse and pronghorn use within sites would be negatively correlated (i.e., if days when water was heavily utilized by horses would have corresponding low pronghorn counts). We ran a mixed models regression using average daily counts for horses and pronghorn, blocked the data on site, and included average daily temperature as a variable. Because of the differences in water availability, we ran a separate analysis for each year.

#### Temporal Partitioning

To examine temporal partitioning, we broke the 2012 data from each site into average horse and pronghorn camera events per hour. We used the number of recorded arrivals of animal groups to determine the camera events per hour. We tallied the total arrivals for each species that occurred in each hour block over the functioning camera time at each site, then divided by the days the camera was operational at that time block and multiplied by 100 to give the number of camera events per 100 camera days. For example, a camera operational from 0800 – 0859 h for

72 camera days which captured 13 pronghorn arrivals during that hour would have approximately 18 pronghorn camera events at that hour/100 camera days.

### *Field Observation Analyses*

#### Behavior Analysis

We only included riparian observation events with pronghorn present in the behavior analysis. We used logistic regression to determine the effect of site, pronghorn cohort, the presence of pronghorn young, pronghorn sex, pronghorn group size, horse group size, time of day, distance to horses (from 0-120 m), and the presence of horses on pronghorn behavior. We categorized pronghorn “cohort” as being comprised of solitary pronghorn and groups of all females, females with young, all males, or mixed (Ping et al., 2011). We included “young present” as a yes/no variable, indicating whether there were young within the pronghorn group. Pronghorn “sex” categories were male, female, and adult when sex could not be determined. We only reported results for males and females when significant, though adults were included in the analysis. We broke up “time of day” into 3 categories: morning (0700 – 1059 h), day (1100 – 1459 h), and evening (1500-1900 h). “Distance to horses” represents the distance between each pronghorn and the nearest horse to that individual. We included “horse presence” as a yes/no variable indicating whether any horses were within interaction distance (120 m) of each pronghorn.

We ran a model for each behavior of interest (vigilance and foraging). All variables were counted as fixed effects except site, which was a random effect. We used backwards selection to eliminate the non-significant variables and find the best model. We made no attempt to identify individuals, but since individuals were likely sampled multiple times over the course of each event, the data were blocked by event to correct for this lack of independence. We considered

individual pronghorn observations as a statistical unit. We performed these analyses using SAS statistical software. We considered a p-value of less than 0.05 significant.

### Time at Water

We used a Cox proportional hazards model to assess the effect of several variables on the length of stay of pronghorn at a watering site. These covariates included distance of horses from the pronghorn group, the site where the event occurred, the time of day, the number of horses present, and the number of pronghorn present. We performed these analyses with a pronghorn group (i.e. “observation event”) as the statistical unit. We tested multiple varieties of these variables including dummy variables, categorical versions and continuous versions. Only the number of pronghorn had a significant effect on the length of stay with a p-value of  $<0.0001$ . The number of horses was marginally significant with a p-value of 0.0892. Additionally, a likelihood ratio test indicated with a p-value of 0.2818 that including number of horses as a covariate did not significantly improve the model. Martingale residuals also show a lack of non-linearity, supporting the use of this model. Finally, the proportional hazard assumption is met as indicated by the p-value of 0.2494. If the test for proportional hazards gives a p-value below .05, this assumption would be violated and a different model would have to be used. If the p-value was below .05, this assumption would be violated. As such the final model contains one covariate, the number of pronghorn present at the watering hole.

## RESULTS

### *Camera Results*

2011 was an exceptionally wet year. Water was atypically plentiful and use of individual camera sites was much lower than expected. Some sites received no pronghorn use at all. At other sites, camera malfunctions rendered the data too incomplete to be used. We collected

usable data from only 14 of the 22 sites, with 25-87 operational camera days per site for a total of 852 camera days across all sites. In 2012, one of the original 21 sites dried up just one or two weeks after we began data collection. We collected usable data from 20 sites, with 29-93 operational camera days across all sites for a total of 1,623 usable camera days across all sites.

### Spatial Partitioning

Contrary to our hypothesis, we found that both temperature and horse use were positively correlated with pronghorn use in 2012. When horse average daily use increased by one, pronghorn average daily use increased by .26 (SE=0.02238, t-value=11.51,  $p<0.0001$ ). For every one degree average temperature increase, pronghorn average daily use increased by .18 (SE=0.03237, t-value=5.43,  $p<0.0001$ ). In 2011, there was a very slight positive relationship between temperature, the use of water by pronghorn, and the use of water by horses, but none of the relationships were significant. Pronghorn use increased by 0.03 when horse use increased by one (SE=0.03584, t-value=0.79,  $p=0.4324$ ). For every one degree average temperature increase, pronghorn use increased by 0.02 (SE=0.01555, t-value=1.08,  $p=0.2783$ ).

### Temporal Partitioning

Some of the camera sites had very inconsistent, erratic patterns of pronghorn use due to low rates of pronghorn use, or too few camera days, and these sites were eliminated from consideration. We used sites which received an average of less than one horse event per day to assess the “typical” patterns of pronghorn use, with which to compare patterns of pronghorn use at sites with higher horse use. The typical hourly pattern of pronghorn use was a peak in the morning, with a decrease in use throughout the rest of the day (see appendix E, figure 5), or a more crepuscular pattern of use (see appendix E figure 6). The hourly horse use patterns varied widely by site, making it harder to discern their effects on pronghorn use. However, when

looking at each type of horse activity pattern individually, some patterns indicating hourly temporal partitioning did emerge.

At three sites, horse use gradually increased throughout the day to peak in the evening. With these sites, pronghorn patterns did not deviate from the “norm,” which might be expected since horse use in this case complimented typical pronghorn use patterns (see appendix E, figure 7). The exception to this was Little Buckaroo (site 32), which showed a more crepuscular pattern of pronghorn use (see appendix E, figure 8). At five sites, horse use was crepuscular. Pronghorn use at these sites still followed the typical pattern of peaking in the morning then trailing off. However, pronghorn use typically peaked during the lulls of horse use, sometimes peaking later in the day than was typical at other sites (see appendix E, figures 9 and 10). The exception to this pattern occurred when pronghorn use was dramatically higher than horse use. In this case, the horse use did not appear to affect patterns of pronghorn use, though horse use was high (see appendix E, figure 11). At one site, we observed that horse patterns were high and fairly constant throughout the day. At this site, a similar pattern was observed for pronghorn, which differed from typical pronghorn patterns (see appendix E, figure 12). There was only one site where the typical pronghorn pattern was actually reversed, with low use in the morning and a peak in the evening. This was also the only site with a high horse peak in the morning and decreasing horse use throughout the day (see appendix E, figure 13).

### *Behavior Observation Results*

We observed site 138 for 13.5 days, site 142 for 13.5 days, and Site 32 for 14 days, for a total of 492 observation hours over the course of the summer. Due to time constraints, we analyzed the video and voice recorder data from June 25 – July 14 only, for a total of 12 observation days and 102 hours analyzed: 42 hours at site 138, 24 at site 142, and 36 at site 32.

We analyzed 166 pronghorn observation events, 34 of which included interactions, and 12,186 observations of pronghorn behavior in the riparian area: 8940 at site 138, 1566 at site 142, and 1680 at site 32. We excluded individual observations in which pronghorn behaviors were influenced by observer presence, and we also excluded whole observation events which consisted mostly of observer-biased observations.

### Behavior Analysis

The vigilance best model included the variables pronghorn sex (F-value=51.52,  $p < 0.0001$ ), time of day (F-value=51.09,  $p < 0.0001$ ), distance from horses (F-value=13.49,  $p = 0.0002$ ), pronghorn cohort (F-value=6.52,  $p < 0.0001$ ), and horse group size (F-value=5.51,  $p = 0.0189$ ). The foraging best model included the variables distance from horses (F-value=67.28,  $p < 0.0001$ ), time of day (F-value=17.05,  $p > 0.0001$ ), pronghorn sex (F-value=6.55,  $p = 0.0002$ ), and pronghorn cohort (F-value=2.49,  $p = 0.0412$ ), with distance from horses as the most important variable influencing foraging. The influence of horse group size was not significant, and it was not included in the model (see appendix C, figure 2 for full results of all variables). Distance to horses and horse presence/absence were highly correlated variables. Both were initially included in each model, but the less significant variable of the two was removed. This was consistently the “horse presence” variable.

Using logistic regression, we found that the probability of foraging was significantly higher for pronghorn farther from horses. Likewise, the probability of vigilance was significantly lower for pronghorn farther from horses (see Table 1). Larger horse group sizes were also associated with a significantly greater probability of pronghorn vigilance. However, this variable was not significantly associated with pronghorn foraging (See Table 1).



Table 1 Effect of distance to horses and horse group size on pronghorn vigilance and foraging behavior.

Foraging				
	Estimate	Standard error	t-value	p-value
Distance to horses	0.0063	0.0008	8.2	<.0001
Vigilance				
	Estimate	Standard error	t-value	p-value
Distance to horses	-0.003	0.0007	-3.67	0.0002
Horse Group Size	0.0225	0.0096	2.35	0.0189

### Time at Water

Because a pronghorn group was the statistical unit, all results refer to groups rather than individuals (except in the case of a group of one). The median length of stay at a watering hole for pronghorn was 37 minutes. Just under 50% (95% confidence interval of 33 – 74%) of pronghorn stayed at a watering hole for this amount of time. This wide interval is due to the wide range of the number of pronghorn present at any given time. Not every recorded number of pronghorn was present multiple times in the data, preventing precise estimation. When pronghorn group size increased in number by one, the odds of survival increased by 1.9. When there are five more pronghorn, the odds increase by 22.2. Another way to interpret this is the probability of staying longer at the watering hole increased 65.1% with one more pronghorn. There is a strong relationship between the number of pronghorn and how long they stayed at the watering hole.

The survival curve is as follows:

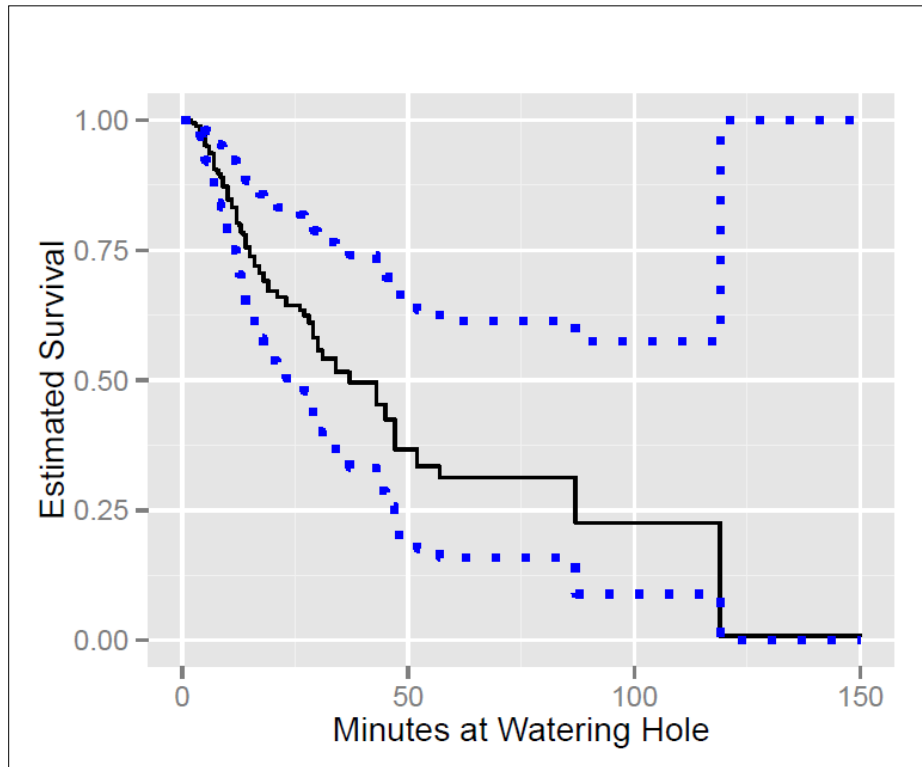


Figure 1 Survival curve showing the probability of pronghorn remaining at water. The solid black line shows the curve, the blue dashed lines indicate the 95% confidence interval surrounding the estimate of pronghorn watering. The initial tight spread indicates high certainty around pronghorn behavior early into a watering event. However, certainty decreases dramatically after an hour, as evidenced by the wide confidence interval.

As mentioned before, the median can be seen at approximately 37. Groups tend to stay shorter amount of times, but there appears a certain point where the pronghorn just stay at the watering hole. In other words if a group of pronghorn stayed past an hour, the group tended to stay very long amounts of time before leaving. These large drops towards this end of the curve come due to few data points towards the end. Although the longest watering event was nearly 4 hours, in order to see the changes in the estimated survival the plot was cut off at 2 and a half hours because the survival was already close to 0 (see appendix D, table 3 for full results).

## Outcomes of Interactions

In the majority of interactions, pronghorn individuals within groups responded to horses in a similar manner. Thus, we summarized pronghorn responses based on group response.

Pronghorn group response was not uniform in only four interactions. In these cases, we counted the response of the majority of pronghorn in the group as the group response. We witnessed 34 pronghorn/horse interactions. 14 (41%) of interactions were negative, one (3%) was positive, and 16 (47%) were neutral. We characterized three interactions as “unknown,” because due to other factors (e.g. coyotes) we could not confidently attribute pronghorn responses to the presence of horses. All negative interactions were costly because they either resulted in the pronghorn being prevented from drinking (this occurred in one interaction), or the pronghorn leaving the riparian area entirely (this occurred in the remaining 13 interactions).

16 interactions were horse-initiated, and 18 were pronghorn-initiated. Of the horse-initiated interactions, 12 (75%) were negative, three (19%) were neutral, and one (6%) was positive. Of the pronghorn-initiated interactions, two (11%) were negative, 13 (72%) were neutral, and none were positive. We observed horse aggression in six interactions, which was directed at pronghorn in three of those interactions. Five of the interactions involving horse aggression were negative. The sixth, ultimately neutral interaction involved horse aggression towards other horses. The pronghorn did spook and leave the riparian when the aggression was expressed, but she immediately returned to the riparian area.

In one interaction, a band of pronghorn approached the water where horses were present. About 50 m from the horses, the pronghorn broke into a run, circumvented the riparian area and the horses, and left our line of sight without entering the riparian area. We officially characterized this event as “unknown” because though the pronghorn could have avoided the

riparian area due to horse presence, we did not observe any horse aggression or horses approaching the pronghorn group to actively exclude pronghorn, and so cannot be positive of the cause of the pronghorn avoidance. On two other occasions, a band of pronghorn stayed in the uplands a few hundred meters from the water (out of interaction distance) while horses were present, and travelled to the water source shortly after the horses left. All three of these occurred when larger horse bands were using the riparian area (more than eight horses).

## DISCUSSION

We found that horses are having negative impacts on pronghorn water use and behavior. Costly behavior interactions can occur directly or indirectly: directly when aggression is involved, or indirectly when the result of the interaction is a reduction of intake via avoidance, or a change of behavior including increased levels of vigilance (Valeix et al., 2008, Ostermann-kelm, 2008). We observed 34 occurrences of pronghorn and horse interactions at water. Horse aggression towards pronghorn was rare (we observed it in only three cases), so horses do not appear to be directly competing with pronghorn. These results are consistent with Berger (1985), who observed few aggressive interactions between horses and pronghorn at water. However, we did observe evidence of indirect interference competition, in the form of negative (costly) interactions and changes in pronghorn behavior. These results are in contrast to the findings of Meeker (1979), who observed no evidence of competition for water between horses and pronghorn. The pronghorn we observed were vigilant more and foraged less when horses were nearby. Nearly half of all pronghorn/horse interactions we observed were negative, meaning in most cases that pronghorn left the riparian area completely at some point in the interaction due to horse activity (usually due to a horse directly approaching).

We did not find that horses had any significant affect on the length of time pronghorn stayed at water overall. However, we only measured the effects of horse presence on pronghorn groups, which were fluid with high turnover during some events. This could have obscured the effects of other variables on time stayed at water, as evinced by pronghorn group size being the only variable to significantly impact time stayed in our model. It is possible that the duration of time individual pronghorn remained at water could still have been affected by horse presence, though we could not detect this with our study design.

We found no evidence of spatial niche partitioning between pronghorn and horses from site to site. Within sites, we found a positive correlation between the daily water use of horses and the daily water use of pronghorn. However, daily water use was also positively correlated with average daily temperature. We consider it likely that this positive correlation suggests that both horse and pronghorn use is driven by temperature, rather than pronghorn use being driven by horse use. However, given the observational nature of our study, we do not have sufficient data to determine causality.

It does appear that temporal partitioning may be occurring on an hourly basis at sites with high horse use. Pronghorn activity patterns at water differed at sites with high and low horse use. At sites with more frequent horse use, peaks in pronghorn use often corresponded with lulls in horse activity. However, because of variability in horse and pronghorn hourly use patterns and the observational nature of this study, it is difficult to draw clear conclusions on hourly temporal partitioning.

## MANAGEMENT IMPLICATIONS

Previous observations of horse and pronghorn interactions have suggested that interference competition at water in North America was unlikely (Meeker, 1979, Berger, 1985).

However, our study showed that indirect interference competition is occurring between these species. Similar results have been reported for horse interference with bighorn water use (Ostermann-kelm et al., 2008). This suggests that competition for water between horses and native ungulates is a cause for concern, and that managers of areas with high horse concentrations that overlap with pronghorn and other native ungulates need to consider the availability of accessible water for these populations.

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APPENDICES

*Appendix A. Site Maps*

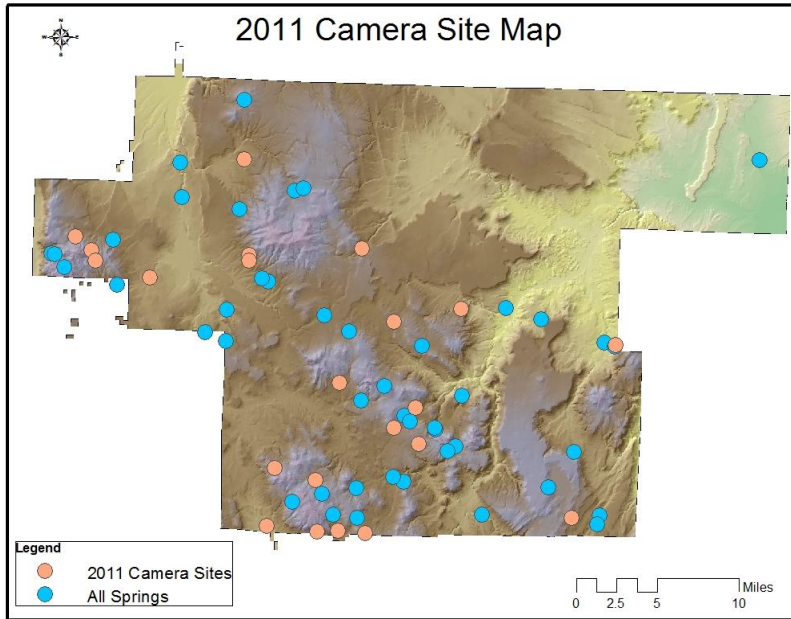


Figure 2 2011 camera sites

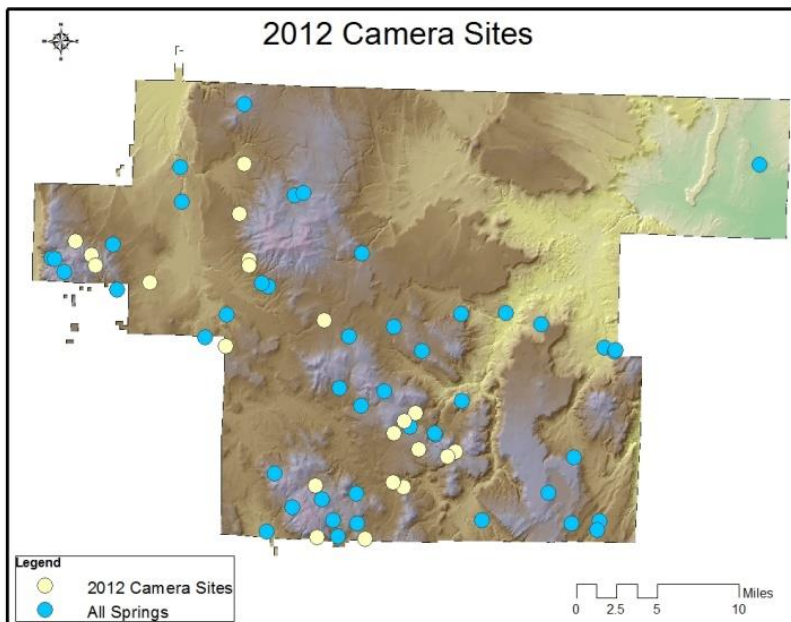


Figure 3 2012 camera sites

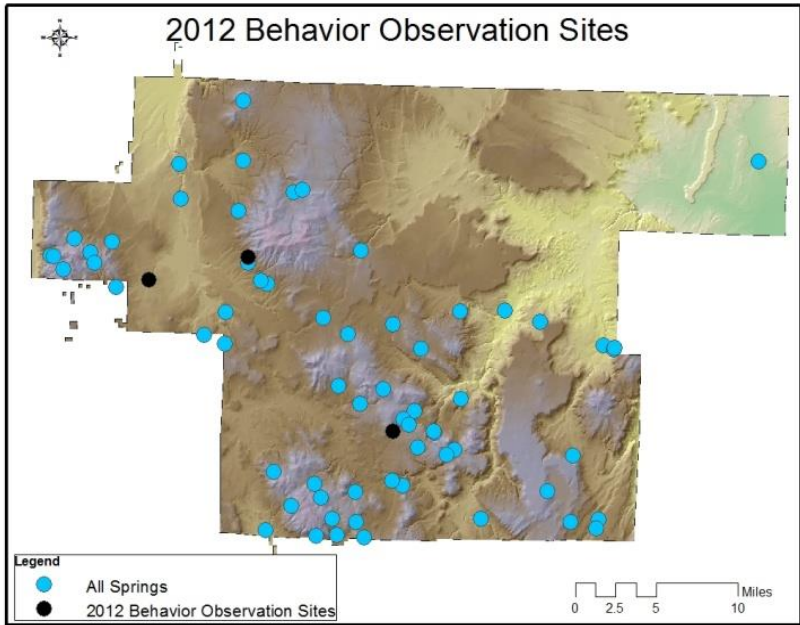


Figure 4 2012 behavior observation sites

## *Appendix B. Pronghorn Ethogram*

We composed a pronghorn ethogram, separating behaviors into primary and secondary categories, with mutually exclusive behaviors within each category. Primary behaviors described the activity state of a pronghorn: standing, walking, running, or bedding. Secondary behaviors described the specific activity of a pronghorn, each defined as follows:

- Vigilance was defined as “any time the pronghorn had its head above shoulder height while scanning the surroundings” (Childress and Lung, 2003).
- Foraging was defined as: “Any time an individual [was] consuming vegetation or searching with their head *below* shoulder height.” (Lipetz and Bekoff, 1982). Whether the animal was consuming forage or drinking could not always be distinguished, so these two behaviors were lumped.
- Linked urination-defecation was defined as a sequence of behaviors used by territorial bucks, with the sequence proceeding as follows: (1) Sniff and paw the ground, (2) Stretch and urinate in the scrape, and (3) Squat and defecate (Kitchen, 1974).
- Marking/thrashing was defined as when a “male rubs its cheek scent gland on vegetation or thrashes vegetation with its horns” (Maher, 1991).
- Travelling was defined as “walking, trotting, or running with head at shoulder level” (Childress and Lung, 2003).
- Chasing/following was defined as a dominance-oriented social interaction in which the dominant animal drives (at a walk) or chases (at a lope or run) the subordinate animal (Kitchen, 1974).

- Forcing up was defined as “A dominant pronghorn ... forcing up a bedded subordinate by approaching, lowering its head, and sniffing and/or butting the reclining individual” (Kitchen, 1974).
- Sparring was defined as any interaction between pronghorn individuals that involved touching horns, ranging from brief horn contact to actual fights.
- Herding was defined as males, positioned to the rear of females, with lowered heads walking towards the females, and/or blocking the flight path of the females in a broadside threat position (Kitchen, 1974).
- Courting was defined as the any of the progressive behaviors in the courtship sequence, which involves rump sniffing, chest touching, attempted mounting, and mounting (Kitchen, 1974)
- Other social behavior
- Other behavior.

*Appendix C. Full (Significant) Behavior Results*

Table 2 Significant results from the differences of least squares means from \*all variables included in the foraging and vigilance behavior models. Adjustment for multiple comparisons: Tukey-Kramer

Foraging						
Variable Type	Variable 1	Variable 2	Estimate	SE	t-value	Adj p-value
Cohort	Female with Young	Mixed	-0.1243	0.04548	-2.73	0.0493
Time of Day	Afternoon	Day	0.1957	0.08395	2.33	0.0517
Time of Day	Day	Morning	-0.231	0.03962	-5.83	<.0001
Pronghorn Age/Sex	Adult	Male	0.2921	0.09225	3.17	0.0084
Pronghorn Age/Sex	Adult	Young	0.2425	0.08715	2.78	0.0277
Pronghorn Age/Sex	Female	Male	0.1705	0.05402	3.16	0.0087
Pronghorn Age/Sex	Female	Young	0.121	0.0415	2.91	0.0187
Vigilance						
Variable Type	Variable 1	Variable 2	Estimate	SE	t-value	Adj p-value
Cohort	All Female	Female with Young	0.204	0.07416	2.75	0.0469
Cohort	All Male	Female with Young	0.4591	0.128	3.59	0.0031
Cohort	Female with Young	Mixed	-0.1574	0.04485	-3.51	0.0041
Cohort	Female with Young	Solitary	-0.2588	0.06887	-3.76	0.0016
Time of Day	Afternoon	Morning	-0.4194	0.08417	-4.98	<.0001
Time of Day	Day	Morning	-0.362	0.03942	-9.18	<.0001
Pronghorn Age/Sex	Adult	Female	-0.4601	0.09292	-4.95	<.0001
Pronghorn Age/Sex	Adult	Male	-0.5474	0.09813	-5.58	<.0001
Pronghorn Age/Sex	Female	Young	0.4399	0.04158	10.58	<.0001
Pronghorn Age/Sex	Male	Young	0.5272	0.05379	9.8	<.0001

\*See Table 1 for horse distance and horse group size results

*Appendix D. Survival Analysis Full Results*

Table 3 Full results of the Cox proportional hazards model.

Time <sup>a</sup>	N.risk <sup>b</sup>	N.event <sup>c</sup>	Survival <sup>d</sup>	Std.err <sup>e</sup>	Lower 95% CI	Upper 95% CI
2.0	171	8	9.95e-01	2.23e-03	9.91e-01	1.000
2.5	160	1	9.94e-01	2.49e-03	9.90e-01	0.999
3.0	160	7	9.89e-01	4.21e-03	9.81e-01	0.997
3.5	153	1	9.88e-01	4.48e-03	9.79e-01	0.997
4.0	150	8	9.81e-01	6.69e-03	9.68e-01	0.994
4.5	143	2	9.79e-01	7.29e-03	9.64e-01	0.993
5.0	140	22	9.52e-01	1.47e-02	9.24e-01	0.981
5.5	119	2	9.50e-01	1.54e-02	9.20e-01	0.980
6.0	118	9	9.37e-01	1.87e-02	9.01e-01	0.974
6.5	108	1	9.35e-01	1.91e-02	8.99e-01	0.974
7.0	107	17	9.05e-01	2.66e-02	8.55e-01	0.959
7.5	92	1	9.04e-01	2.71e-02	8.52e-01	0.958
8.0	90	4	8.96e-01	2.89e-02	8.41e-01	0.955
8.5	85	3	8.90e-01	3.03e-02	8.33e-01	0.952
9.0	86	9	8.73e-01	3.45e-02	8.08e-01	0.943
10.0	73	12	8.47e-01	4.06e-02	7.71e-01	0.931
11.0	63	6	8.33e-01	4.39e-02	7.51e-01	0.923
12.0	55	10	8.02e-01	5.07e-02	7.09e-01	0.908
12.5	44	1	7.99e-01	5.15e-02	7.04e-01	0.906
13.0	45	4	7.84e-01	5.47e-02	6.84e-01	0.899
13.5	41	1	7.80e-01	5.55e-02	6.79e-01	0.897
14.0	39	5	7.56e-01	6.06e-02	6.46e-01	0.884
15.0	35	3	7.38e-01	6.40e-02	6.22e-01	0.875
16.0	31	3	7.20e-01	6.77e-02	5.98e-01	0.865



Time <sup>a</sup>	N.risk <sup>b</sup>	N.event <sup>c</sup>	Survival <sup>d</sup>	Std.err <sup>e</sup>	Lower 95% CI	Upper 95% CI
17.0	28	2	7.06e-01	7.02e-02	5.81e-01	0.858
18.0	26	2	6.91e-01	7.30e-02	5.62e-01	0.850
19.0	24	2	6.72e-01	7.63e-02	5.38e-01	0.839
21.0	23	1	6.60e-01	7.83e-02	5.23e-01	0.833
23.0	20	2	6.44e-01	8.10e-02	5.03e-01	0.824
26.0	19	1	6.35e-01	8.25e-02	4.92e-01	0.819
27.0	18	1	6.24e-01	8.42e-02	4.79e-01	0.813
28.0	15	1	6.11e-01	8.60e-02	4.64e-01	0.805
29.0	16	2	5.82e-01	8.99e-02	4.30e-01	0.788
30.0	14	2	5.57e-01	9.33e-02	4.01e-01	0.774
31.0	11	1	5.41e-01	9.56e-02	3.83e-01	0.765
34.0	10	1	5.16e-01	9.95e-02	3.53e-01	0.753
37.0	10	1	4.96e-01	1.02e-01	3.32e-01	0.741
43.0	9	1	4.53e-01	1.05e-01	2.88e-01	0.714
45.0	8	1	4.24e-01	1.08e-01	2.58e-01	0.698
47.0	7	1	3.67e-01	1.11e-01	2.02e-01	0.664
52.0	6	1	3.34e-01	1.09e-01	1.76e-01	0.635
57.0	5	1	3.12e-01	1.08e-01	1.59e-01	0.614
87.0	4	1	2.26e-01	1.08e-01	8.88e-02	0.575
119.0	3	1	8.41e-03	2.80e-02	1.24e-05	1.000
150.0	1	1	7.25e-03	2.41e-02	1.07e-05	1.000
236.5	1	1	7.21e-08	9.04e-07	1.52e-18	1.000

<sup>a</sup>Time indicates the length of the stay.

<sup>b</sup>N.risk indicates how many different pronghorn stayed longer than the corresponding time.

<sup>c</sup>N.event indicates how many times an event occurred at that time.

<sup>d</sup>Survival indicates the percent of pronghorn that made it to the given length.

<sup>e</sup>Std.rr gives the standard deviation connected to the survival estimate. This error is used to give a

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confidence interval on the survival estimate. For example for time 2.0, the estimate is 99.5% of pronghorn stay longer than 2 minutes at a watering site. However, we are 95% confident this estimate falls in the range of 99.1% of pronghorn to 100%.

Appendix E. Temporal Partitioning

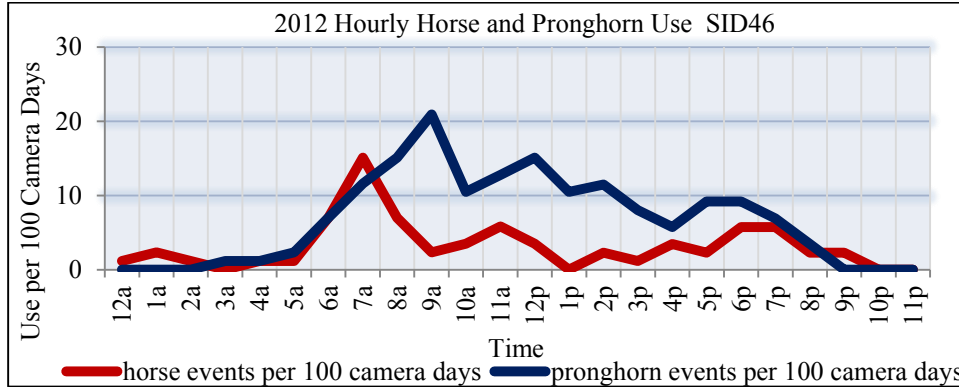


Figure 5 Temporal use of site WRB\_46, site identification number (SID) 46. At this site we observed 66 horse and 140 pronghorn events, for an average of 0.76 horse and 1.61 pronghorn events per day.

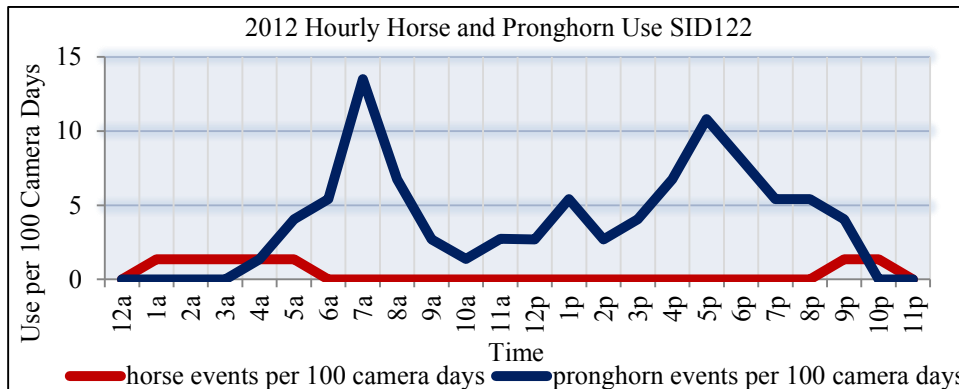


Figure 6 Temporal use of site WRB\_122, SID122. At this site we observed 7 horse and 69 pronghorn events, for an average of 0.09 horse and 0.92 pronghorn events per day.

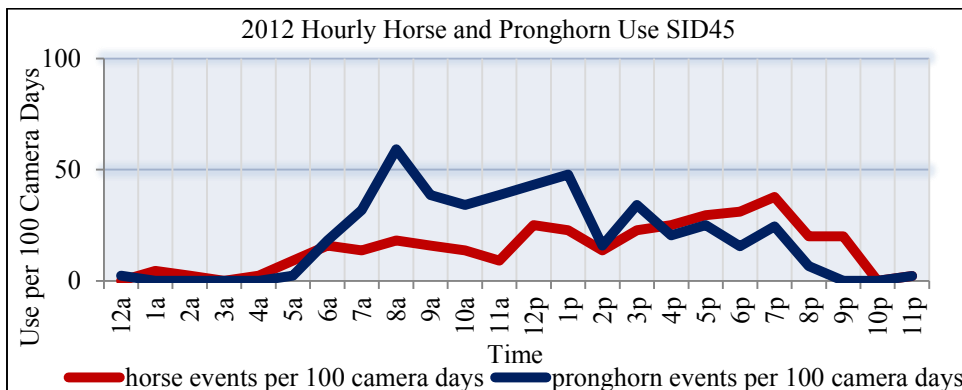


Figure 7 Temporal use of site Martinez, SID45. At this site we observed 157 horse and 203 pronghorn events, for an average of 3.49 horse and 4.51 pronghorn events per day.

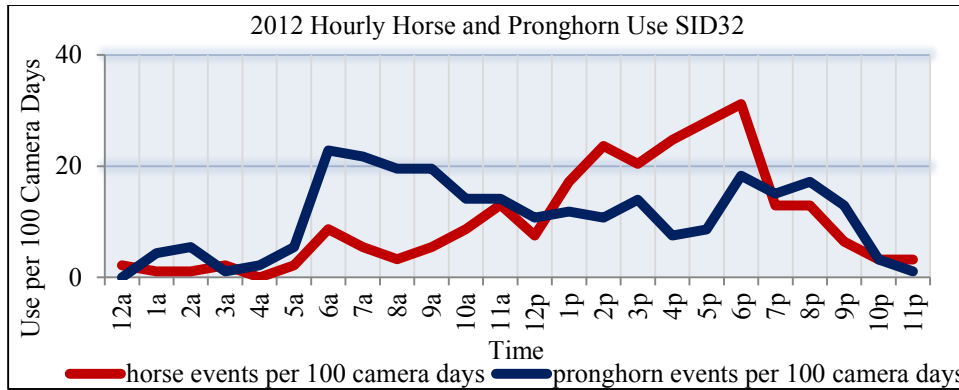


Figure 8 Temporal use of site Little Buckaroo, SID32. At this site we observed 227 horse and 242 pronghorn events, for an average of 2.44 horse and 2.60 pronghorn events per day.

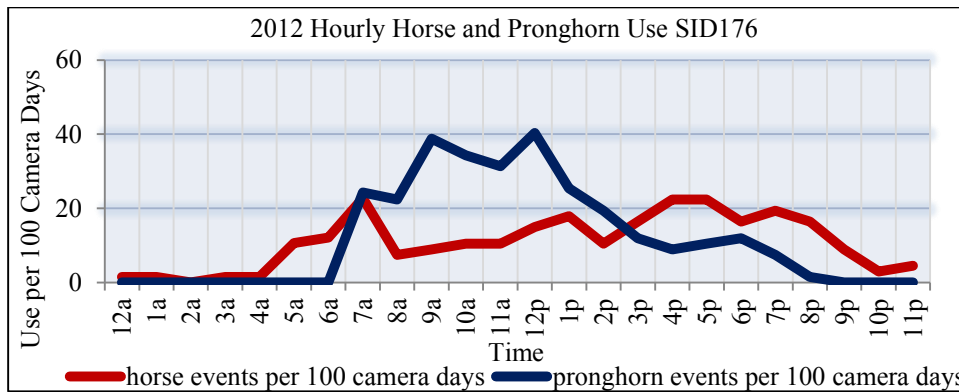


Figure 9 Temporal use of site East Spring South, SID176. At this site we observed 175 horse and 193 pronghorn events, for an average of 2.61 horse and 2.88 pronghorn events per day.

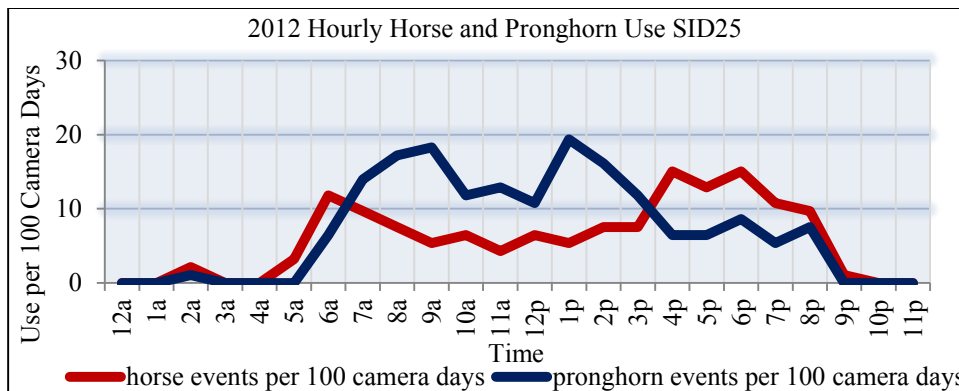


Figure 10 Temporal use of site Porcupine, SID25. At this site we observed 132 horse and 162 pronghorn events, for an average of 1.42 horse and 1.74 pronghorn events per day.

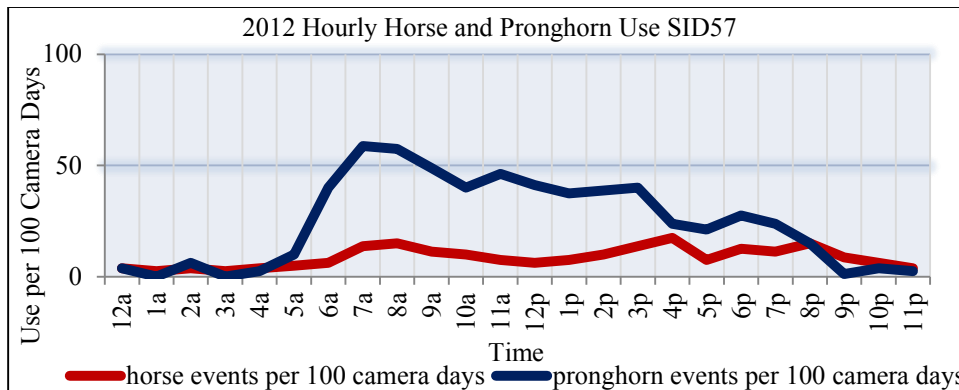


Figure 11 Temporal use of site McClusky, SID57. At this site we observed 164 horse and 472 pronghorn events, for an average of 1.05 horse and 5.9 pronghorn events per day.

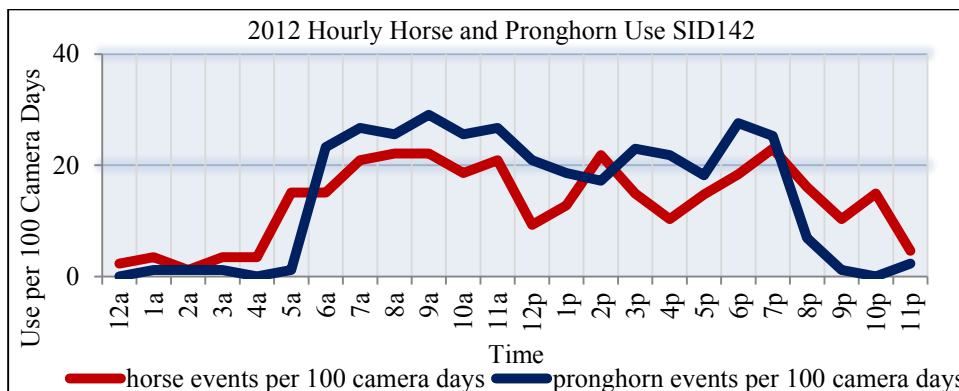


Figure 12 Temporal use of site WRB\_142, SID142. At this site we observed 277 horse and 298 pronghorn events, for an average of 3.15 horse and 3.39 pronghorn events per day.

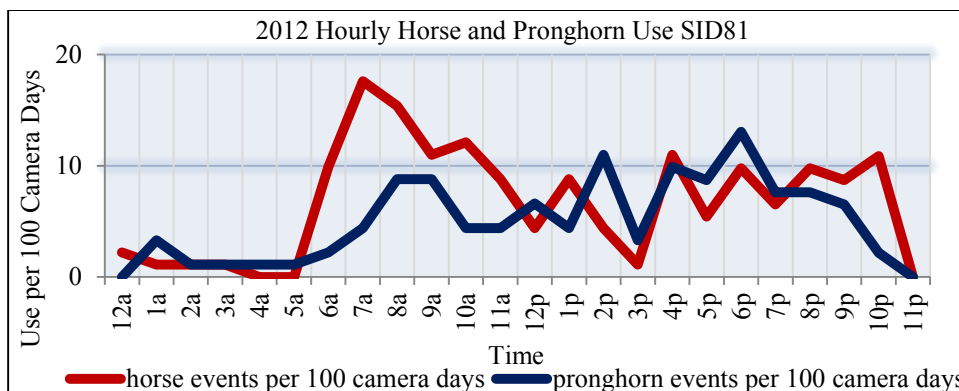


Figure 13 Temporal use of site Little Cottonwood Spring South, SID81. At this site we observed 147 horse and 111 pronghorn events, for an average of 1.60 horse and 1.21 pronghorn events per day.