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Spatial ecology observations from feral horses equipped with global positioning system transmitters

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Abstract: Our understanding of the spatial ecology of feral horses (*Equus ferus caballus*) and burros (*E. asinus*) in the United States is limited. Robust location data are needed to better understand the permeability of Bureau of Land Management Herd Management Area boundaries, relative to feral horse movement patterns and home ranges. To increase our understanding of feral horse movement, in February to March 2017, we deployed global positioning system (GPS) collars on 14 females ≥5 years old that were captured in the Adobe Town Herd Management Area (ATHMA) of southcentral Wyoming, USA. Herein, we report initial results from movement data collected during summer (May 15 to September 15) 2017 for 9 horses. We limited our focus to these 9 horses because we received at least 2 months of continuous GPS location data from them during summer 2017. Feral horse daily movement distances averaged 9.0 km (SE = 0.3), and mean summer total home range size was 40.4 km^2 (SE = 6.7). Of GPS location fixes obtained, 44.9% were outside ATHMA and 10.8% were on private land. Our results highlight the types of data that GPS collars can provide and illustrate the difficulties of managing free-roaming species such as horses and burros on landscapes with heterogeneous sociopolitical patterns. Expanded use of such technology on feral horses and burros in the United States will yield greater insight on spatial complexities constraining management.

Key words: *Equus ferus caballus*, home range, movement, utilization distribution, Wyoming

Global positioning system (GPS) technology allows for the collection of spatiotemporally robust location data used to answer a variety of complex questions (Cagnacci et al. 2010, Swain et al. 2011). Transmitters with GPS capability can record precise locations at short time intervals throughout the day and year, and they require little additional labor following deployment, such as manually relocating animals to obtain location fixes. In expansive landscapes or areas with limited access, GPS technology is often the only way to collect robust spatial data to answer important conservation and management questions. Furthermore, GPS-based animal tracking allows for minimal interference with wildlife compared to techniques requiring regular human presence, such as radio-telemetry or individual re-sighting.

Wildlife researchers have deployed GPS transmitters to answer a variety of spatially-related questions for numerous species, including large carnivores like African lions (*Panthera leo*; Loveridge et al. 2009), iconic ungulates such as American bison (*Bison bison*; Fortin et al. 2003), and species of conservation concern including greater sage-grouse (*Centrocercus urophasianus*; Smith et al. 2016). Considering the widespread use of this technology for other species, it is surprising that GPS technology has not been used more frequently for feral equids in the western United States. To date, GPS data on feral equids in the United States is entirely absent, even though the need for these data is clear.

The impacts of feral horses (*Equus ferus caballus*) and burros (*E. asinus*) on native flora and fauna has been a persistent management, conservation, and political issue in the western United States (Smith 1986, Danvir 2018, Garrott 2018, Norris 2018). Feral equids predominately occur on public lands managed by the Bureau of Land Management (BLM) in areas called Herd Management Areas (HMAs). As of March 1, 2017, the feral horse and burro populations within HMAs were estimated at >72,000 individuals, nearly 3 times higher than the BLM's stated Appropriate Management Level

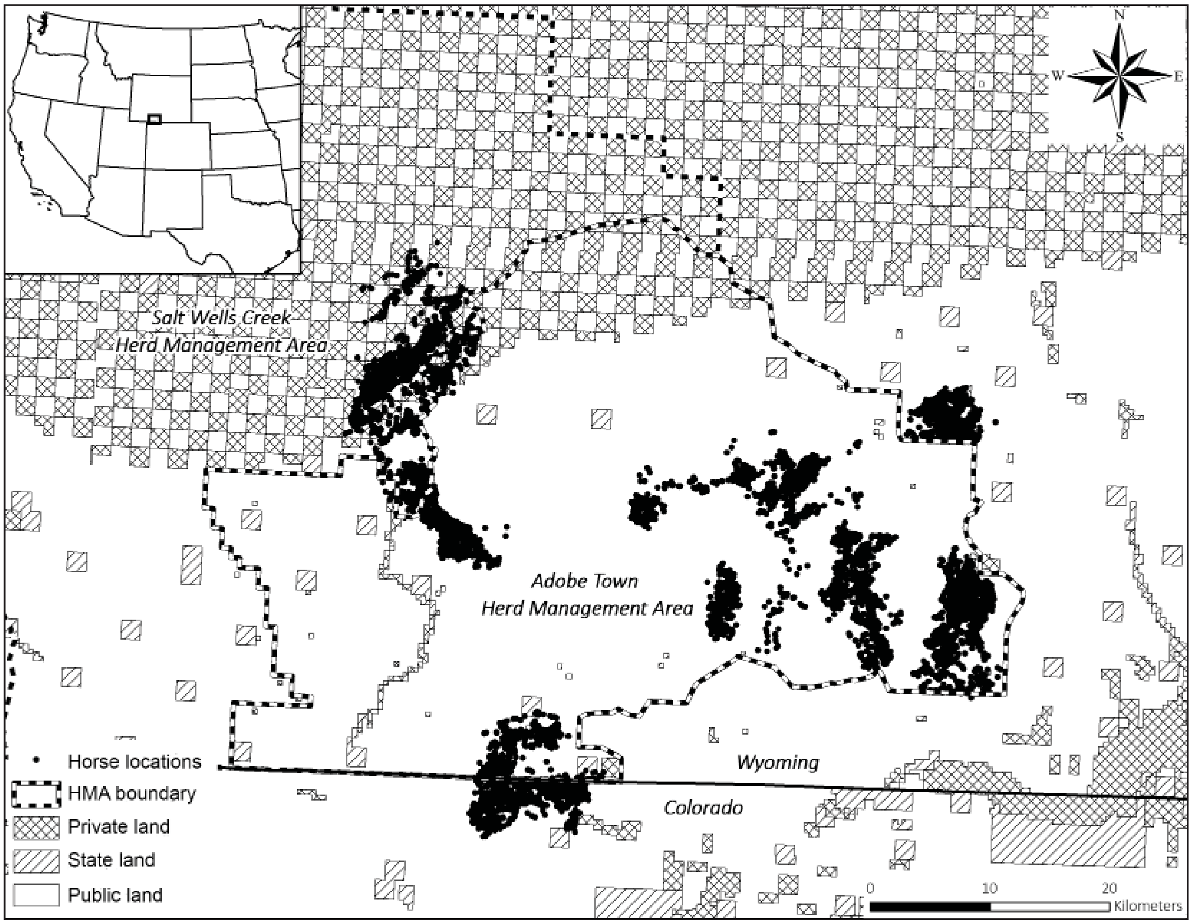

Figure 1. Location and land tenure of the Adobe Town Herd Management Area in southcentral Wyoming, USA, along with summer location fixes from 9 female feral horses (*Equus ferus caballus*) ≥5 years old, May 15 to September 15, 2017.

of 26,715 (BLM 2017*a*). These large populations of equids have the potential to negatively impact rangelands. For example, sites occupied by feral horses often exhibit lower native plant species diversity and plant height, along with higher soil compaction and lower soil aggregate stability (e.g., Beever and Brussard 2004, Beever et al. 2008, Davies et al. 2014, Boyd et al. 2017). Intensive burro herbivory can restrict growth of various plant functional groups (Hanley and Brady 1977).

While feral horse and burro impacts to rangelands are well documented, the spatial ecology of these species is poorly understood. Knowledge of movement patterns, home range sizes, and habitat selection is critical to appropriate management of these controversial feral species, as this information influences the allocation of HMA resources in landscapes that are heterogeneous mosaics of land tenure and surface ownership. Unfortunately, much of the existing literature on the spatial ecology of U.S. equids is >30 years old (e.g., Ganskopp and Vavra 1986) or does not employ high-resolution space-use data that GPS-enabled tracking devices can provide (e.g., Crane et al. 1997).

In the United States, concern regarding animal safety has been the primary driver behind the lack of use of GPS tracking technology on horses and burros. This anxiety is largely based on historic issues with its application (Collins et al. 2014). The main method of attaching a GPS device to a large mammal like a horse or burro is via collar. Radio-collaring of feral horses in Nevada during the late 1980s resulted in several injuries and even animal death due to poor collar fit and inappropriate horse selection (National Research Council 1991). In this specific situation, researchers placed rigid radio-telemetry collars too tightly on young and still-growing horses, or too loosely on others. The inflexible collar material combined with improper collar fit led to several injuries.

Figure 2. A ≥5-year-old female feral horse (*Equus ferus caballus*) fitted with a Lotek Wireless IridiumTrackM 3D global positioning system collar (Lotek Wireless, Inc., Newmarket, Ontario, Canada) at the Rock Springs Bureau of Land Management Wild Horse Holding Facility, Rock Springs, Wyoming, USA, 2017.

Subsequently, the BLM prohibited use of tracking collars to study horses and burros under their jurisdiction (Collins et al. 2014).

During the ensuing quarter of a century, tracking collar technology advanced considerably. Modern collars were fashioned with lighter and more flexible material made to better fit equid necks, and tracking devices and their associated batteries became considerably smaller and lighter (e.g., Collins et al. 2014, Johansson et al. 2016). Such advancements suggest that tracking collar use on wild equids might no longer present a safety concern. Furthermore, a bevy of published research exists, documenting successful use of GPS collars on wild equid species outside of the United States. The GPS collars placed on plains zebra (*E. quagga*; e.g., Cain et al. 2012, Bartlam-Brooks et al. 2013), Asiatic wild ass (*E. hemionus*; e.g., Kaczensky et al. 2010, Giotto et al. 2015), and endangered species like Grevy's zebra (*E. grevyi*; e.g., Sundaresan et al. 2007, Low et al. 2009), and Przewalski's horse (*E. f. przewalskii*; Kaczensky et al. 2007, 2008) resulted in few negative repercussions. Moreover, a recent study by Collins et al. (2014) indicated that GPS collars could be safely deployed on free-roaming horses.

Herein we present initial findings from a study employing GPS collars to study the spatial ecology of feral horses in Wyoming, USA. Our primary objective was to understand horse space use and movement across sociopolitical boundaries that included complex land tenure and surface ownership (public and private lands), areas designated for horses (i.e., HMAs), different sociopolitical jurisdiction (different states), and crucial ranges for important native ungulates.

Study area

We conducted our study in the Adobe Town Herd Management Area (ATHMA) located within Sweetwater and Carbon counties in southcentral Wyoming, USA (Figure 1). The ATHMA is 3,413 km^2 and bordered by the Salt Wells Creek HMA to the west and the state of Colorado to the south. The northern portion of the ATHMA includes a matrix of alternating 2.6-km^2 parcels of public and privately-owned land termed the "checkerboard" (Calef 1952). In total, private land makes up 5.5% of the area, state land 1.7%, and BLM-managed land 92.8%. The ATHMA is classified as cold-arid-steppe (Kottek et al. 2006) with annual 30-year normal precipitation ranging from 146–207 mm (PRISM Climate Group 2004) and elevation from 1,883–2,506 m (USGS

Table 1. Number of summer (May 15 to September 15) location fixes from 9 female feral horses (*Equus ferus caballus*) ≥5 years old within different sociopolitical boundaries in southcentral Wyoming and northcentral Colorado, USA, 2017.

	Locations (% of total locations)
Total	12,024
Adobe Town HMA	6,625 (55.1%)
Salt Wells Creek HMA	1,662 (13.8%)
Wyoming	9,742 (81.0%)
Colorado	2,282 (19.0%)
BLM land	10,502 (87.3%)
Private land	1,295 (10.8%)
State of Wyoming land	227 (1.9%)
Crucial mule deer habitat	485 (4.0%)
Crucial pronghorn habitat	430 (3.6%)
Greater sage-grouse Core Area	214 (1.8%)

2016). Dominant shrub species included Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young), Gardner's saltbush (*Atriplex gardneri* [Moq.] D. Dietr.), and greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.). Grass species were primarily cool-season bunch grasses including bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), prairie Junegrass (*Koeleria macrantha* [Ledeb.] Schult.), and Sandberg bluegrass (*Poa secunda* J. Presl).

We deployed GPS collars to adult females (≥5 years of age) between February 10 and March 18, 2017. Horses were bait-trapped within the ATHMA and transported to the Rock Springs Wild Horse Holding Facility in Rock Springs, Wyoming for collar attachment. We attached Lotek Wireless IridiumTrackM 3D GPS (Lotek Wireless, Inc., Newmarket, Ontario, Canada) collars to 14 adult females and observed them for least 24 hours to judge collar fit and position before releasing them back into ATHMA (Figure 2). A veterinarian was always on-site to oversee horse safety and welfare and to assess age and health of the horses. All animal handling and use was according to protocols approved by the Institutional Animal Care and Use Committee of the University of Wyoming (protocol #20160829DS00249) and applied within the criteria set forth in the DOI-BLM-WY-DO30_0104-EA Environmental Assessment.

We programmed collars to record GPS locations at 2-hour intervals for a duration of 2 years following deployment. Each collar included 2-way Iridium-based satellite communication, permitting daily download of horse locations. Additionally, we equipped collars with a very-high frequency (VHF) beacon to facilitate ground-based relocation. We furnished the collars with remote drop-off devices to remove collars without recapture. To determine quality of collar fit in the field, we followed a protocol to conduct monthly welfare checks and drop collars if they were found in a precarious position (i.e., over the horse's ears), or noticeable hair loss or chafing of the skin was present.

We defined the summer season as May15 to September 15. We downloaded location fixes from collars that lasted for at least 2 months during summer 2017 (n = 9). Of the 5 collars not used, 3 collars suffered battery failures, and 2 collars were dropped prematurely due to the collar being over the horse's ears. Before conducting analyses, we removed location fixes with position dilution of precision (PDOP) values >5 to account for imprecise locations (Lewis et al. 2007). To obtain estimates of home range sizes, we generated utilization distributions (UDs) using a dynamic Brownian Bridge model (Kranstauber et al. 2012) with a window size of 31 and a margin value of 11. The 95% contour of each UD was used as an estimate of the total home range, and the 50% contour was used as an estimate of core home range (Clapp and Beck 2015).

Results

We obtained 12,024 locations from 9 feral horses ≥5-year-old from May 15 to September 15, 2017 (Table 1). Of this total, 6,625 locations were within the ATHMA boundary (55.1%). The adjacent Salt Wells Creek HMA held 1,662 locations (13.8%). With respect to state boundaries, 81% of the locations were in Wyoming (n = 9,742), with the remaining 19% in Colorado (n = 2,282; Figure 1). We collected GPS horse locations from BLM-administered land (87.3%), privately-owned land (10.8%), and land owned by the state of Wyoming (1.9%). A closer examination of 1 individual's

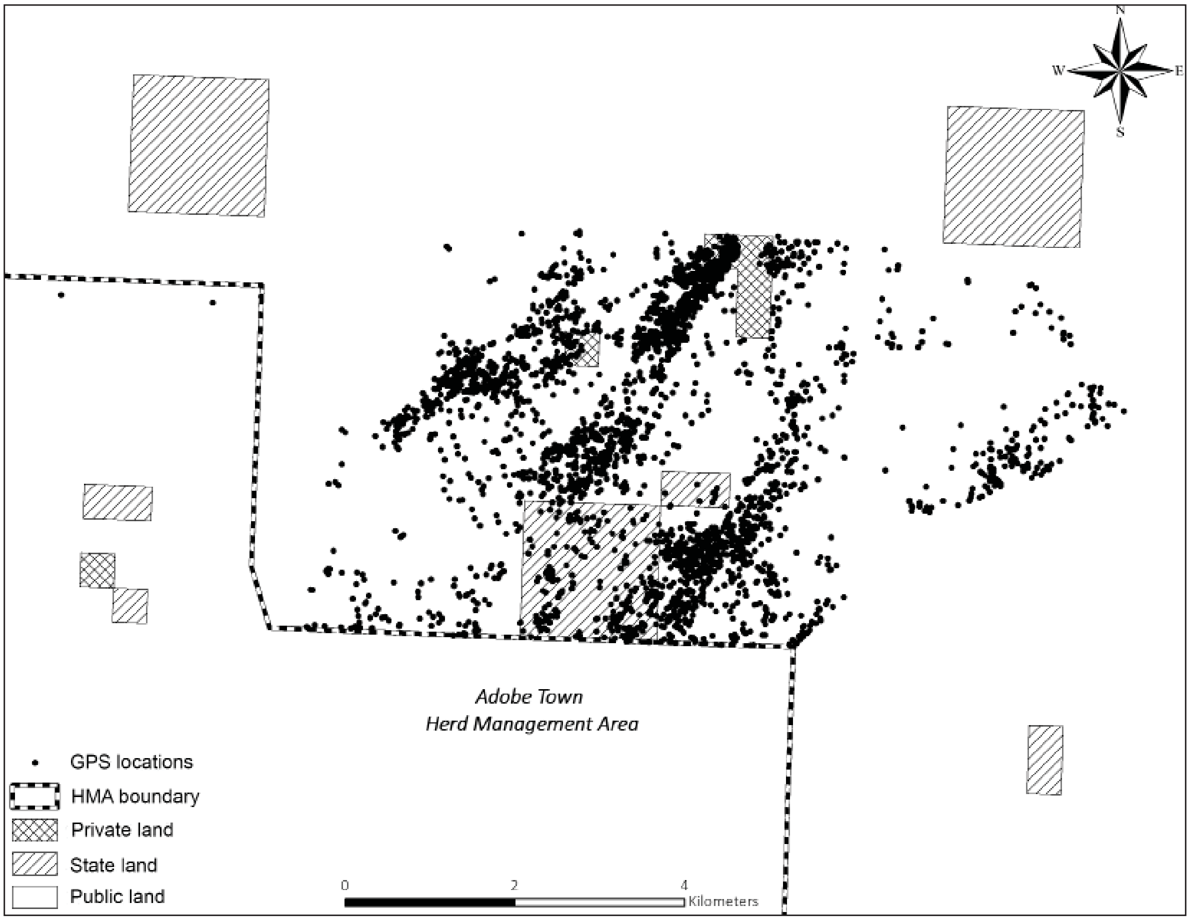

Figure 3. Global positioning system locations for a female horse (*Equus ferus caballus*) ≥5 years old illustrating distribution outside of Herd Management Area boundaries and across a complex surface ownership mosaic in southcentral Wyoming, USA, May 15 to September 15, 2017.

GPS locations illustrates her distribution across the complex mosaic of surface ownership and outside any HMA boundary (Figure 3). Figure 4 illustrates how another individual's summer home range overlapped land surface ownership and management boundaries.

Mean daily and weekly movement distances were 9.0 km and 62.1 km, respectively (Table 2). Mean summer total and core home ranges were 40.4 km^2 (SE = 6.7) and 7.4 km^2 (SE = 1.3), respectively (Table 2). We recorded 485 and 430 locations on mule deer (*Odocoileus hemionus*; 4.0%); and pronghorn (*Antilocapra americana*; 3.6%) yearlong and winter crucial ranges, respectively, and 214 locations in greater sage-grouse (1.8%) core areas (Wyoming Game and Fish Department 2017). To illustrate horse-use relative to important wildlife habitat, we present the summer total home range for 1 individual and the overlapping crucial yearlong and winter ranges for mule deer and pronghorn (Figure 5).

Discussion

Our study is the first to report space use and movements using GPS transmitters attached to feral horses in the western United States. With these preliminary data, we can begin to compare movement distances and home ranges of feral horses in the United States with those of feral and native equid species also equipped with GPS transmitters abroad. For example, the mean daily distance traveled in our study of 9 km was much lower than the 15.9 km reported for feral horses in the Australian outback (Hampson et al. 2010), higher than the 3.5 km of Przewalski's horses in Mongolia (Kaczensky et al. 2008), but similar to the 8.3 km reported for Asiatic wild asses, also in Mongolia (Kaczensky et al. 2008). Concerning home ranges, the mean summer 95% UD contour in our study of 40.4 km^2 was much smaller than mean 100% minimum convex polygon home ranges reported for Przewalski's horses (471 km^2) and Asiatic wild asses (5,860 km^2) in Mongolia

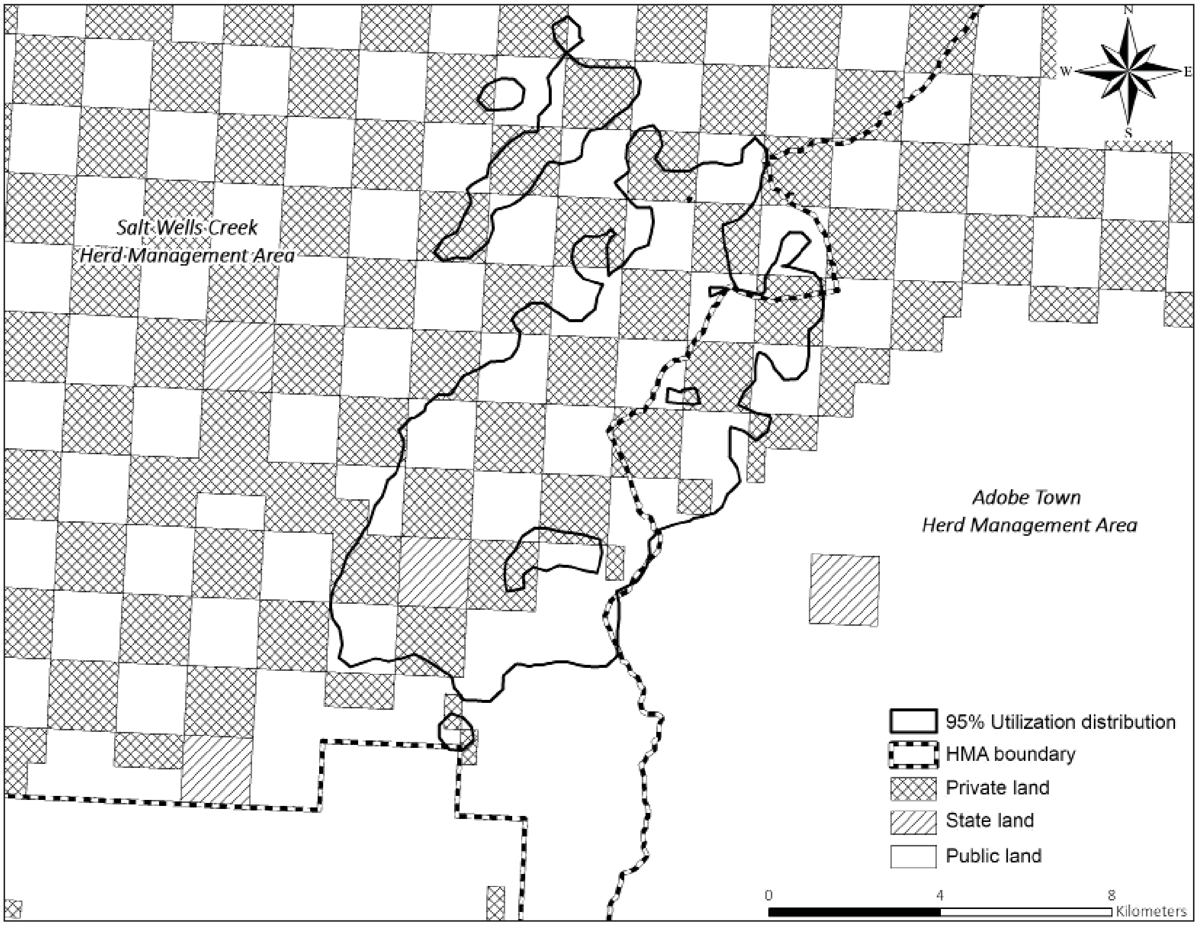

Figure 4. Summer 2017 (May 15 to September 15) 95% utilization distribution contour of global positioning system collared female feral horse (*Equus ferus caballus*) ≥5 years old in southcentral Wyoming, USA, illustrating use of complex land surface ownership and management boundaries.

(Kaczensky et al. 2008), but similar to the 95% kernel home ranges reported for feral horses in Alberta, Canada (48.4 km^2; Girard et al. 2013).

Our preliminary data also confirm that HMA boundaries can be permeable. Realization that horses reside outside managed areas is important regarding resource allocation to HMAs. The BLM conducts aerial surveys to obtain counts of adult horses and burros within HMA boundaries (U.S. Geological Survey [USGS] 2017). Population estimates from these surveys influence the number of animal unit months (AUMs) allotted to horses within an HMA, which subsequently affects the AUM limits set for livestock grazing (USGS 2017). As horse home ranges can encompass areas outside of HMA perimeters, aerial surveys likely do not produce accurate estimates of equids per HMA.

It was apparent from our data that horse herds may also occupy 2 separate HMAs. If an aerial survey assigns this herd to 1 HMA, but the herd actually spends most of its time in another, resource allocation to both HMAs would be inappropriate. The GPS data collected in our study allowed us to estimate utilization distributions, circumventing the lack of data available from aerial surveys. Perhaps even more insightful are the robust spatiotemporal maps and models that GPS data offer in

Table 2. Mean summer (May 15 to September 15) movement distances and home range estimates from 9 female feral horses (*Equus ferus caballus*) ≥5 years old in southcentral Wyoming and northcentral Colorado, USA, 2017. Total and core home ranges are 95% and 50% contours of utilization distributions, respectively.

	Estimate
Mean daily movement distance	9.0 km (SE = 0.3)
Mean weekly movement distance	62.1 km (SE = 3.7)
Mean total home range	40.4 km^2 (SE = 6.7)
Mean core home range	7.4 km^2 (SE = 1.3)

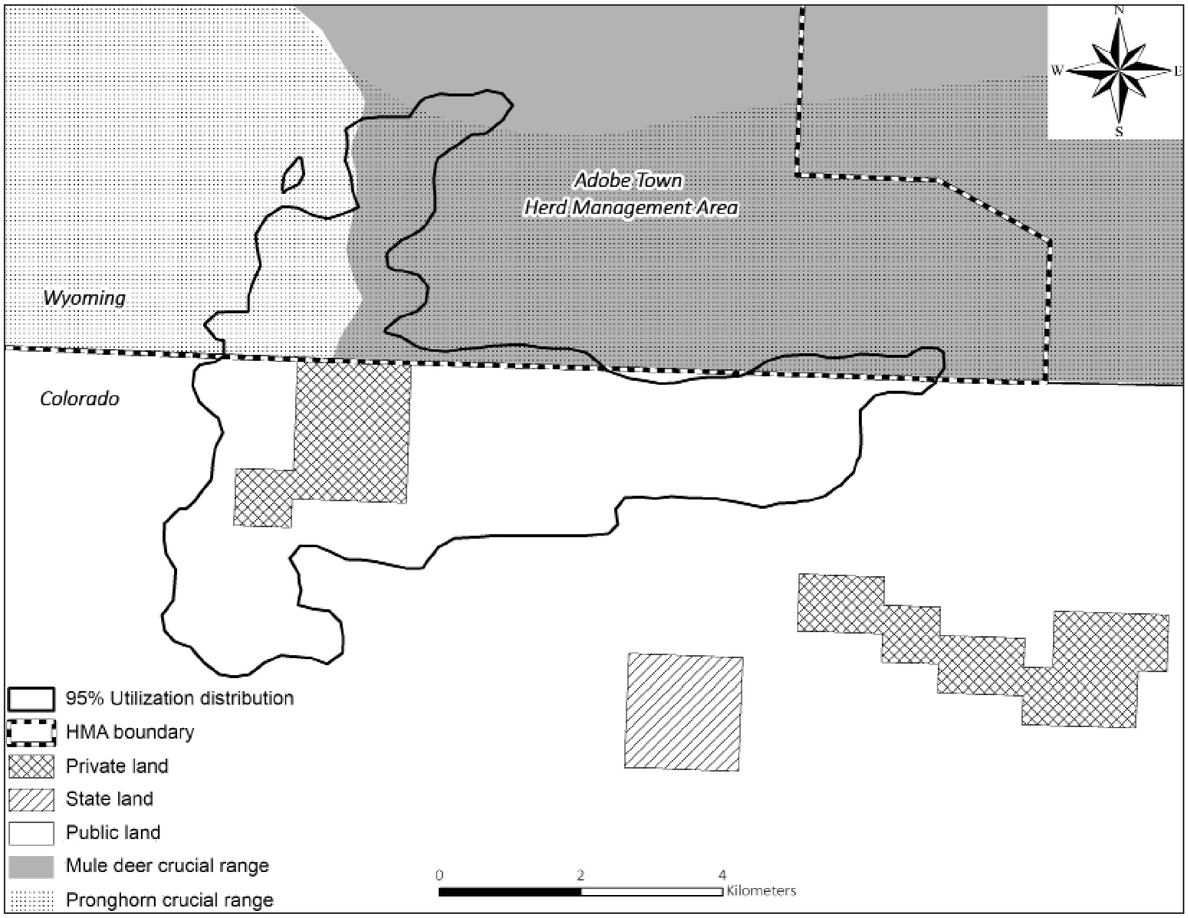

Figure 5. Summer 2017 (May 15 to September 15) 95% utilization distribution contour of a global positioning system collared female feral horse (*Equus ferus caballus*) ≥5 years old in southcentral Wyoming and northcentral Colorado, USA, and overlapping crucial yearlong and winter range for mule deer (*Odocoileus hemionus*) and pronghorn (*Antilocapra americana*).

comparison to single point-in-time and space information that aerial surveys provide.

Lastly, our initial data provide evidence of overlap with critical habitat for big game species. We lack systematic investigation of horse impacts on wildlife in extensive landscapes, but recent research documents the negative influences of horses on co-occurring species at watering sites. For example, horses impeded elk (*Cervus elaphus*) from sharing a watering hole in Colorado (Perry et al. 2015), and pronghorn were more vigilant near water sources with horses present (Gooch et al. 2017). These effects on native wildlife are not restricted to large, native ungulate use of discrete water sources, as they extend to broader aspects of biodiversity. Camera traps deployed in the Great Basin of western Utah at horse-occupied and horse-excluded watering sites found higher vertebrate species diversity on horse-excluded sites (Hall et al. 2016), providing another example of the adverse effects feral horses have on native wildlife.

Examination of broad-scale effects of horses on wildlife is an emerging research frontier, carried out through use of GPS collars. We can use this technology to examine interactions between equids and wildlife across the extensive rangelands they inhabit. Through collaring both horses and wildlife or livestock species in question, we can estimate indices of resource selection overlap (see Clapp and Beck 2015). Precise GPS data allow for habitat assessments carried out relative to UDs, used to determine if horses have degraded key wildlife habitat. Our preliminary results underscore the value of GPS technology for enhancing knowledge of feral equid ecology. This understanding is imperative in the western United States because management and conservation of these species has been a persistent issue. Management of wildlife species often directly relies on information obtained from GPS-based research (e.g., Sawyer et al. 2009, Clapp and Beck 2016, Smith et al. 2016). It is time to expand the use of this technology for feral equid research, so that it may guide management in the face of increasing horse and burro populations.

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