Ecological Effects of Free-Roaming Horses in North American Rangelands

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Free-roaming horses are a widespread conservation challenge. Horse use (grazing and related impacts) is largely unmanaged, leading to concerns about its impact on native plant communities and ecosystem function. We synthesized the literature to determine the ecological effects of free-roaming horses in North American rangelands. Largely unmanaged horse use can alter plant community composition, diversity, and structure and can increase bare ground and erosion potential. Free-roaming-horse use has also been linked to negative impacts on native fauna. Horses have repeatedly been shown to limit and even exclude native wildlife's use of water sources. These effects would likely be greatly reduced if the horse populations were better managed, but sociopolitical factors often preclude improved management. Using rigorous ecological research to educate politicians and the general public may facilitate the development of science-based management of free-roaming horses; however, ecological effects may have to become more severe before such changes can be realized.

Keywords: conservation, grazing, herbivory, trampling, wild horses, wildlife

Free-roaming horses in North America are a management challenge and conservation concern (Turner 1987, Beever 2003, Girard et al. 2013, Beever et al. 2018). Wild horses (*Equus* sp.) went extinct in North America approximately 10,500 (Guthrie 2003, 2006) to 13,000 (Grayson 2006) years ago. Self-sustaining populations of free-roaming domestic horses (*Equus caballus*) in North America established in the sixteenth and seventeenth centuries from domestic stock introduced by Spanish explorers (Haines 1938). Both accidental and intentional releases of domestic horses associated with the agricultural industry also augmented free-roaming horse populations and genetics (Young and Sparks 2002). At times, livestock producers used nearby free-roaming-horse populations as brood stock and would occasionally release stallions to alter the free-roaming-horse genetics for their purposes (Bowling 1994, Hyslop 2017, Idaho BLM 2018). These practices largely ended with the passage of the Wild Free-Roaming Horses and Burros Act (WFRHBA) of 1971, although the abandonment of domestic horses in free-roaming-horse-occupied areas still occurs, particularly during economic downturns or when feed costs increase substantially.

The management of free-roaming horses is a contentious topic, with pressure from multiple special interest groups (e.g., wildlife enthusiasts, hunters, animal-rights groups, ranchers, conservationists, environmental groups, and horse advocates and enthusiasts) with divergent demands. A large part of the challenge is that humans often have a strong emotional connection to horses, because horses have been ingrained in human cultures for centuries (Beever et al. 2019). Free-roaming horses are viewed as a symbol of freedom and strength, as well as an icon of the American West (Beever 2003), but the modern free-roaming horse is also an exotic species in North America that may influence ecosystem function and integrity if the population is left unmanaged. An additional concern is that most of the free-roaming horses on public lands in the United States occur in the driest state, Nevada (BLM 2018), which, similar to other arid and semiarid environments, is composed of plant communities and ecological sites that are sensitive to disturbance and mismanagement. The management of free-roaming horses, however, is often challenged and criticized by special interest groups (Symanski 1996, Linklater et al. 2002).

Free-roaming horses are a serious conservation concern, because the use (grazing and related impacts) by this species is largely unmanaged and continuous, suggesting that its effects may be large, even in areas with low animal populations (Beever 2003). In contrast, domestic livestock are more intensively managed through planned periods of grazing deferment and rest; herding; and salt, mineral, and water placement (Beever 2003). Therefore, unlike domestic species under managed grazing, free-roaming horses have the potential to continuously graze preferred plants and locations, such as riparian areas. The ecological effects of free-roaming horses would likely be similar to the effects that have been documented for largely unmanaged use by other large herbivores, such as historic livestock grazing in the western United States (Davies et al. 2014b) or free-roaming

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camels in Australia (Edwards et al. 2010). Therefore, free-roaming horses may pose a threat to the sustainability of these ecosystems and the services they provide, including wildlife habitat, ecohydrologic function, and forage production.

Free-roaming horses have the potential to affect large tracts of rangeland. They occupy 31.6 million acres of federal land in the United States (BLM 2018). The population estimate of free-roaming horses and burros ranging on Bureau of Land Management (BLM)–administered lands was 81,951 animals and exceeded the appropriate management level (AML) by more than 55,000 animals in 2018 (BLM 2018). The BLM is required to determine the AML by the 1971 WFRHBA, and AML reflects the number of horses allowable, given consideration of ecological factors and other uses and values, including wilderness, wildlife, recreation, and livestock grazing. The number of horses on US rangelands will likely continue to grow; free-roaming horse populations are estimated to increase at a mean annual rate approaching 20% (National Research Council of the National Academies 2013), and the federal government has been unable to remove even a substantial portion of this increase in recent years (BLM 2018). Free-roaming-horse–occupied areas also overlap with habitat for many species of conservation concern, including sage-grouse and other sagebrush obligate species. There is a critical need to determine the ecological effects of free-roaming horses on North American rangelands.

However, determining the ecological effects of free-roaming horses has proven difficult, because domestic livestock frequently uses the same landscapes as free-roaming horses. Domestic livestock, particularly cattle, and free-roaming-horse diets overlap substantially (Krysl et al. 1984, Scasta et al. 2016). Therefore, domestic livestock grazing often confounds the ecological effects of free-roaming-horse grazing, giving rise to considerable uncertainty regarding the full extent and degree of impact of horses on rangeland ecological processes.

A synthesis of the literature is needed to more fully comprehend the ecological effects of free-roaming horses and to separate their effects from those of domestic livestock. Our objective in this article is to synthesize the ecological effects of free-roaming horses on North American rangelands and to provide science-based suggestions for minimizing those effects. We will determine the state of the science and its application potential in the management of free-roaming horses.

Free-roaming-horse effects on vegetation

Unrestricted free-roaming-horse use affects vegetation in uplands and riparian areas. In general, horse use alters the structural characteristics and, at times, the abundance of native vegetation (figure 1). Areas from which horses had been excluded compared with horse-occupied areas in Great Basin uplands had two to three times greater native grass cover and frequency (Beever et al. 2008). In riparian areas, free-roaming-horse use decreased herbaceous vegetation cover and height (Beever and Brussard 2000, Boyd et al. 2017). Grass cover was lower in areas occupied by horses over a long term than those from which horses had been excluded for short or long terms in Montana and Wyoming (Fahnestock and Detling 1999). In contrast, Davies and colleagues (2014a) found greater native perennial grass cover in sagebrush communities from which horses had been excluded than in those with heavy horse use but found no difference between areas from which horses had been excluded and those that showed light to moderate use by horses. One limitation with the Davies and colleagues (2014a) study was that the horses were only excluded for 4–5 years, and therefore, the exclusion areas may have still been recovering from prior horse use. Sagebrush communities often require several decades for recovery to become detectable after the removal of a disturbing agent (Sneva et al. 1980, West et al. 1984, Anderson and Inouye 2001). Beever and colleagues (2008) found that horse use can shift plant community composition toward greater abundance and cover of grazing-tolerant and unpalatable herbaceous species, but others have not detected an effect on composition (with a small sample size and confounding grazing effects from other large herbivores; Baur et al. 2017).

In shrub-occupied riparian and upland habitats, the exclusion of free-roaming horses increased shrub density (Beever and Brussard 2000, Davies et al. 2014a, Boyd et al. 2017). Horses also consumed riparian shrubs and thereby greatly decreased the shrubs' height. Although the difference was not significant, the juvenile sagebrush density in areas from which horses had been excluded was 7.8 times greater than that in horse-occupied areas (Davies et al. 2014a). Juvenile sagebrush density was not significantly different between occupied and unoccupied areas because of large variability, and one of the replicates essentially had no juveniles because it was fully occupied by mature sagebrush. The results from Davies and colleagues (2014a) and Boyd and colleagues (2017) suggest that free-roaming horses limit the recruitment of shrubs and thereby prevent their recovery. Mature sagebrush was twice as dense in areas from which horses had been excluded than in those horses occupied (Davies et al. 2014a). Shrub cover was also generally greater in areas from which horses had been excluded than in those horses occupied (Beever et al. 2008, Davies et al. 2014a). The exclusion of unmanaged use by other large herbivores also increased shrub cover in shrub-steppe communities in the Rocky Mountains (Manier and Hobbs 2006).

Free-roaming-horse use may also decrease plant species diversity and richness in Intermountain West plant communities. Species richness was lower in free-roaming-horse–occupied sites than in those from which the horses had been removed in the Great Basin and declined as grazing disturbance increased (Beever et al. 2008). Diversity increased with free-roaming-horse exclusion in sagebrush communities in northern Nevada (Davies et al. 2014a). In riparian

Figure 1. Free-roaming-horse–grazed upland on the right and horse excluded upland on the left on Sheldon National Wildlife Refuge, in Nevada, in early June 2012. Horse use at this location was heavy and should not be interpreted to represent horse use across the entire area occupied by horses, because their forage use is highly heterogeneous.

areas, species richness increased with free-roaming-horse exclusion (Beever and Brussard 2000). However, plant diversity declined in Montana and Wyoming with free-roaming-horse exclusion (Fahnestock and Detling 1999). The reduced cover of dominant grasses probably allowed subordinate species to increase in horse-occupied areas (Fahnestock and Detling 1999). No difference in diversity or species richness was detected across five study sites spanning a wide diversity of ecosystems (from the Great Basin Desert to mixed-grass prairie; Baur et al. 2017). The effects of herbivory on diversity and richness likely vary with use levels and frequency (de Villalobos and Zalba 2010), plant community composition, environmental characteristics (Olff and Ricthie 1998), and the degree to which plant communities evolved with herbivory. Therefore, limited free-roaming-horse use likely increases diversity when it reduces dominant vegetation where light competition is a driving force in the composition of the plant community. However, when horse use is heavy or in a moisture-limited system, it likely reduces diversity and richness.

Postfire restoration is likely hampered by free-roaming-horse use. In southeast Oregon, free-roaming-horse use was a major factor leading to the failure of a postfire seeding project. The free-roaming horses pulled first-year grass seedlings out of the ground, resulting in high mortality of perennial bunchgrass and, subsequently, much lower grass density than in adjacent areas that did not have horses. Compounding this problem is the reality that grazing animals may preferentially use burned areas in larger landscapes (Clark et al. 2014). Similar issues have been observed with domestic livestock use of grass seedlings (Salihi and Norton 1987), and it is therefore a standard practice to defer grazing until after grass seedlings are of sufficient maturity to not be readily pulled from the ground. Grazing is also not recommended immediately after fire in areas that are not seeded, because it will likely decrease recovery by adding more stress to already stressed plants (Bates et al. 2009). Therefore, free-roaming horses are an added challenge to postfire restoration of rangelands.

The effects of free-roaming-horse use on exotic plant abundance are not clear. Cheatgrass (*Bromus tectorum* L.), an exotic annual grass causing ecological damage across the western United States, was generally more frequent in horse-occupied sites, but its cover was not significantly greater on these sites (Beever et al. 2008). Short-term horse exclusion did not decrease annual grasses (largely composed of exotic species) relative to those in horse-occupied sites (Davies et al. 2014a), although it's unlikely that short-term grazing cessation would allow native vegetation to recover to a high enough abundance to limit exotic annual grasses (Davies et al. 2014b). However, because free-roaming-horse grazing can decrease native perennial grasses (Beever et al. 2008), it may increase the risk of exotic annual grass invasion. Perennial grasses are a plant functional group crucial to limiting exotic annual grasses in the Great Basin (Chambers et al. 2007, Davies 2010). In other systems, feral-horse-driven changes in the abundance of native plant functional groups have decreased biotic resistance to exotic plant invasion (de Villalobos and Schwerdt 2017). Better knowledge of the effects of free-roaming horses on exotic plants would improve the understanding of their ecological effects and potentially improve resource management in horse occupied areas.

Free-roaming-horse effects on soils

One of the more concerning impacts of unmanaged horse use may be its effects on soils and erosion potential, because these affect site productivity and ecosystem function. Unrestricted free-roaming-horse use can result in high levels of bare ground, particularly in areas they repeatedly select (figure 2). Similar impacts were observed with other large herbivores when they were allowed to repeatedly use preferred areas (Dobkin et al. 1998, Bescta and Ripple 2009, Batchelor et al. 2015). Bare ground was approximately seven times greater in riparian areas occupied by free-roaming horses than in areas from which horses were excluded (Boyd et al. 2017). Bare ground was quantitatively greater in horse-occupied sagebrush communities than in those from which horses had been excluded; however, the difference was not statistically significant (Davies et al. 2014a). Combined, these results suggest the potential for free-roaming horses to increase bare ground.

The trampling effect of horses on soils is a destructive component of unmanaged use by free-roaming horses (Turner 1987). Horse use decreased soil aggregate stability and increased soil surface penetration resistance (i.e., an index of compaction) in uplands (Beever and Herrick 2006, Davies et al. 2014a), likely largely because of trampling and unrestricted grazing. In some instances, the effects of compaction may be limited to established trails; however, the area covered by such trails can be extensive (Ostermann-Kelm et al. 2009). Water infiltration rates decrease with increased soil penetration resistance, leading to increased runoff risk (Maestre et al. 2002, Aksakal et al. 2011). Declines in aggregate stability increase the risk of soil movement with wind and water (Herrick et al. 2001). Bare ground is also more exposed to erosional forces than ground covered by litter or vegetation and can increase the probability of exotic plant invasion. The combined effect of these alterations to soils from unmanaged horse use is an elevated risk of soil erosion, potentially affecting ecohydrologic function. Furthermore, soil erosion has the potential to cause irreversible declines in plant community productivity and stability (Pimentel et al. 1995); therefore, free-roaming-horse use over time could permanently affect the productivity and function of some areas.

Free-roaming horse effects on wildlife

It is well established that free-roaming horses can alter vegetation and soils in rangeland ecosystems (e.g., Beaver and Herrick 2006, Beever et al. 2008, Davies et al. 2014a), and this can negatively affect wildlife habitat (Beever and Aldridge 2011). Free-roaming-horse use has also been linked to negative impacts on insects (Beever and Herrick 2006), small mammals (Beever and Brussard 2004), birds (Zalba and Conzzani 2004), and estuarine fauna (Levin et al. 2002).

Shrubs are a critical habitat component for many wildlife species, and therefore, horse use limiting the recovery of shrubs could negatively affect these species. In particular, unmanaged horse use may negatively affect sagebrush-associated wildlife. The results from recent horse-exclusion studies (Davies et al. 2014a, Boyd et al. 2017) support the prior conclusions that free-roaming-horse effects may negatively influence sagebrush-associated wildlife (Beever and Brussard 2004, Beever and Aldridge 2011). Altered vegetation structure and composition in riparian areas can affect the availability and suitability of habitat for a variety of wildlife species. Avian species often select particular vegetation characteristics in riparian habitats (Ammon and Stacey 1997); therefore, horse effects may negatively influence some species and positively influence other species, depending on their habitat requirements.

In moisture-limited ecosystems, horses may cause additional stress on native wildlife through competition for water. Free-roaming horses frequently prevented water acquisition by elk at a natural water source in Colorado (Perry et al. 2015) and pronghorn in Nevada (Gooch et al. 2017). Pronghorn and mule deer also used water sources less often where horse activity was high (Hall et al. 2018). Free-roaming-horse use of water sources was also associated with decreased native wildlife species richness and diversity (Hall et al. 2016). Native wildlife also visit and spend less time at water sources used by free-roaming horses, indicating that horses further constrain access to a limited resource (Hall et al. 2016, 2018). Clearly, free-roaming horses displace native wildlife at water sources. How this affects wildlife populations, demographics, and fitness is unknown (Berger 1985), but further loss of water in these water-limited environments from competition with free-roaming horses could amplify conservation challenges for native wildlife.

Figure 2. Free-roaming-horse–grazed riparian area on Sheldon National Wildlife Refuge, in Nevada, in September of 2009. Note the high degree of trampling. Domestic livestock have been excluded from the Sheldon National Wildlife Refuge since the mid-1990s, and wild ungulates were not abundant. Unrestricted use by other large herbivores in areas that have a similar disparity in the timing between riparian vegetation and upland vegetation senescence will produce similar results.

We agree with Beever and Aldridge (2011) that the effects of free-roaming-horse use in sagebrush uplands and riparian areas (Beever and Brussard 2000, Beever et al. 2008, Davies et al. 2014, Boyd et al. 2017) on the conservation of sage-grouse and other sagebrush-associated wildlife need to be considered in developing wildlife management plans and conservation strategies. Free-roaming horses are an additional stressor on the wildlife species of conservation concern in North America, particularly in water-limited ecosystems. Therefore, horse effects likely need to be considered when developing wildlife plans and conservations strategies for any species with a range that substantially overlaps with horse-occupied areas.

Management implications

The management of free-roaming horses is a complicated social and legal issue. It is controversial, with many special interest groups issuing competing demands. Furthermore, management is constrained by the WFRHBA and politicians with faulty or incomplete knowledge of the issue (Beever 2003). In particular, the "minimal management strategy" set forth by the act restricts the application of scientifically validated management options.

Managing free-roaming horse populations is needed, because most herd management areas are over AML (BLM 2018). The overpopulation of free-roaming horses is a widely recognized problem, and limitations to resolving this issue are largely sociopolitical, because there are well-defined strategies for animal population management (Gaillard et al. 1998, Garrott 2018, Norris 2018). Unmanaged herbivores will repeatedly defoliate preferred vegetation, causing ecological damage over time (Engle and Schimmel 1984, Launchbaugh and Howery 2005, di Virgilio and Morales 2016). Repeated defoliation that continuously removes photosynthetic tissue can place grazed plants at a competitive disadvantage with ungrazed plants and prevents the grazed plants from completing their life cycle (Caldwell et al. 1987, Briske and Richards 1995, Holechek et al. 1998). Dissimilar to free-roaming-horse use, use by domestic livestock is managed so that defoliation only occurs for a set period of time; defoliation is limited during the periods of use; and periods of no use (deferment or short-term rest from herbivory) occur, which allows plants to periodically complete their life cycle without the physiological stress of defoliation (Davies et al. 2014b). Ecological damage is exacerbated with increasing free-roaming-horse populations, because larger areas experience repeated use. Therefore, purposeful management to reduce horse populations should be practiced, because the management strategies often used for domestic livestock (e.g., rotational grazing, periodic rest) are generally not allowed under the WFRHBA or are not feasible with horses.

Where competition for water from horses negatively affects native wildlife access to water, the full or partial exclusion of horses from water sources may be needed, perhaps with a concomitant development of off-site water sources. Horses may also need to be excluded from sensitive areas, such as riparian areas, or other areas they overuse. However, the exclusion of horses from any resources will need to be carefully applied, because exclusion may increase horse use in other areas. This, again, points to the need for diligent management of horse populations.

A reevaluation of AMLs is needed, because climate change, invasive plants, and woody plant encroachment have potentially altered forage production, plant community composition, and water availability since the WFRHBA was written. Reevaluating AMLs is particularly needed in areas in which federal agencies have frequently had to supplement forage or water or have had to conduct emergency gathers to prevent horse deaths. Clearly, AMLs need to be reevaluated if herd management areas cannot meet the needs of horses year-round. AMLs may need to be lowered in areas in which free-roaming-horse use causes substantial ecological damage or negatively affects species of conservation concern.

Conclusions

Unmanaged free-roaming-horse use can cause changes in plant community structure, composition, and diversity, which can affect both ecological processes and the quality and availability of wildlife habitat. When they are largely unmanaged, other animals, including camels, cattle, and pigs cause similar ecological degradation (Gallacher and Hill 2006, Cole and Litton 2014, Davies et al. 2014b). Free-roaming horses also appear to directly affect other wild species by potentially limiting their access to water sources. Providing wildlife with access to water without the presence of free-roaming horses may entail excluding the horses from at least a portion of the water sources in water-limited environments. Unmanaged horse use increases the risk of soil erosion in both riparian and upland plant communities (Davies et al. 2014a, Boyd et al. 2017) and may, at some sites, decrease ecosystem productivity and function. Unrestricted use over time may cause stream channel incision and a drop in the water table in riparian areas, particularly if the banks were made unstable by a loss of deep-rooted plant species (e.g., *Carex* spp.). Soil compaction from unrestricted free-roaming-horse use likely limits herbaceous vegetation, because soil compaction can restrict water infiltration and root growth (Ehlers et al. 1983, Bengough and Mullin 1991, Villamil et al. 2001). Collectively, the body of literature on unrestricted free-roaming-horse grazing demonstrates that horses have a substantial ecological impact in native upland and riparian plant communities. The ecological effects are probably greater than these studies suggest, because ecosystem recovery can be slow and because most exclusion studies are short term relative to the speed at which ecological properties are recovered following a disturbance (e.g., Davies et al. 2014a, Boyd et al. 2017). Longer-term evaluation of the response of soil, vegetation, and wildlife to free-roaming-horse exclusion is needed in order to better understand the magnitude of these effects. However, the magnitude of horse effects will likely vary substantially across the landscape, because horse use intensity and frequency is variable. The ecological effects of free-roaming horses need to be considered in restoration efforts and conservation plans for native fauna and flora. Some restoration and conservation goals may not be achievable in areas that free-roaming horses occupy and should therefore not be attempted, because resources would be wasted.

Limiting the ecological effects of free-roaming-horse use will require the successful navigation of a complex and emotionally charged sociopolitical environment. We currently have sufficient ecological literature to inform management decisions regarding free-roaming horses. However, science-based ecosystem conservation is confounded by human psychology and the politics and sociology of horse advocacy groups (Sysmanski 1996).

We would like to believe that change in the sociopolitical arena around free-roaming horses can be stimulated by rigorous ecological research and using that research to inform scientifically sound management of free-roaming horses, as well as educating politicians and the public. However, we recognized that science is often ignored and, in some cases, blatantly discounted because of people's emotional connection to horses. People's emotional connections to other animals cause similar issues around the world. In Dubai, camel use is unrestricted because of a cultural reverence for them, even though it is the single greatest threat to inland deserts (Gallacher and Hill 2006). Introduced feral pigs cause ecosystem degradation in Hawaii, but eliminating them is strongly opposed by native Hawaiians because of their cultural tradition of pig hunting (Cole and Litton 2014, Beever et al. 2019). The ecological impacts of free-roaming horses will likely have to become more severe before the sociopolitical environment surrounding this issue changes sufficiently to alter management. That said, the status quo of largely not managing free-roaming-horse populations is neither ecologically tenable nor compatible with the conservation of North American rangelands and their native fauna.

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