

CHAPTER FOURTEEN

Influences of Free-Roaming Equids on Sagebrush Ecosystems, with a Focus on Greater Sage-Grouse

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Abstract. Free-roaming equids (horses [*Equus caballus*] and burros [*E. asinus*]) in the United States were introduced to North America at the end of the 15th century, and have unique management status among ungulates. Legislation demands that these animals are neither hunted nor actively managed with fences and rotation among pastures, but instead constitute an integral part of the natural system of the public lands. Past research has elaborated that free-roaming horses can exert notable direct influences in sagebrush (*Artemisia* spp.) communities on structure and composition of vegetation and soils, as well as indirect influences on numerous animal groups whose abundance collectively may indicate the ecological integrity of such communities. Alterations to vegetation attributes and invertebrates can most directly affect fitness of Greater Sage-Grouse (*Centrocercus urophasianus*) and other sagebrush-obligate species; alterations of soils and other ecosystem properties may also indirectly affect these species. Across 3.03 million ha of the western Great Basin, horse-occupied sites exhibited lower grass, shrub, and overall plant cover; higher cover of unpalatable forbs and abundance of cheatgrass; 2.2–10.0 times lower

densities of ant mounds; and 2.9–17.4 times greater penetration resistance in soil surfaces, compared to sites from which horses had been removed for 10–14 years. As is true for all herbivores, equid effects on ecosystems vary markedly with elevation, stocking density, and season and duration of use. However, they may be especially pronounced in periods of drought, which are forecasted to occur with increasing frequency in the southwestern United States under climate change, and when they interact synergistically with livestock-grazing effects. Equids' use of sagebrush landscapes will have different ecological consequences than will livestock grazing, at both local and landscape scales. Spatially, the addition of horses to sagebrush landscapes means more of the landscape receives use by nonnative grazers than if domestic cattle alone were present. In spite of recent advances in ecological understanding of equid synecology, much remains to be learned. Life-history characteristics of Greater Sage-Grouse and other sagebrush-obligate species suggest the great value in evaluating equid effects more broadly than through a horses-vs.-livestock perspective, and in monitoring ecosystem components such as soil-surface hardness

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and ant-mound density that have ecological and management relevance yet for which data are relatively inexpensive to collect.

Key Words: burros, *Centrocercus urophasianus*, direct and indirect effects, *Equus asinus*, *Equus caballus*, grazing, horses, sagebrush, sage-grouse.

Efecto de los Équidos de Vida Libre en los Ecosistemas de *Artemisia* spp., con Énfasis en el Greater Sage-Grouse

Resumen. Équidos de movimiento libre en los Estados Unidos (caballos [*Equus caballus*] y burros [*E. asinus*]) fueron introducidos a Norteamérica a fines del siglo XVI, y ellos han tenido un manejo único entre los ungulados. La legislación requiere que estos animales no sean cazados, ni manejados con cercas, ni tampoco dejados en un tipo de pastoreo rotacional pero en vez éstos constituyen una parte esencial del sistema natural de tierras públicas. Investigaciones previas han demostrado que estos caballos de movimiento libre pueden tener influencias directas sobre la estructura y composición de los suelos y vegetación en comunidades dominadas por *Artemisia* spp., así como también influencias indirectas en varios grupos de animales en donde su abundancia colectiva puede indicar la integridad ecológica de estas comunidades. Alteraciones a las características de la vegetación e invertebrados pueden afectar en forma directa al éxito reproductivo del Greater Sage-Grouse (*Centrocercus urophasianus*) y de otras especies obligadamente relacionadas a comunidades de *Artemisia* spp. También alteraciones a los suelos y a otras propiedades del ecosistema pueden afectar indirectamente a estas especies. Dentro de 3,030,00 hectáreas de la Gran Cuenca Occidental, áreas ocupadas por caballos han exhibido una menor cobertura de gramíneas, arbustos, y vegetación en general; una mayor cobertura de hierbas no comestibles y mayor abundancia de la gramínea exótica *Bromus tectorum*; una reducción de entre 2.2 a 10 veces en la densidad de los nidos de hormigas en montículo;

y un aumento de entre 2.9 y 17.4 veces en los niveles de resistencia a la penetración de la superficie en los suelos, todo esto si se compara con áreas en donde caballos han sido removidos por períodos de entre 10 a 14 años. Así como sucede con todos los herbívoros, los efectos de los équidos en ecosistemas varían de acuerdo a la densidad del ganado, duración y estación de pastoreo, y la elevación en el sitio. Sin embargo, estos efectos pueden ser especialmente dramáticos durante períodos de sequía, los cuales son previstos que ocurrirán en una mayor frecuencia en el suroeste de los Estados Unidos debido al cambio climático, y más aun cuando éstos interaccionan sinérgicamente con los efectos del pastoreo de la ganadería. El uso del paisaje en comunidades de *Artemisia* spp. por équidos tendrá consecuencias ecológicas muy distintas a las del pastoreo por medio del uso de ganado tanto a nivel local y del paisaje. En términos espaciales, la introducción de caballos a estos ecosistemas dominados por *Artemisia* significa que una mayor proporción de este ecosistema sea usado por herbívoros no nativos si este mismo fuese únicamente usado por el ganado doméstico. A pesar de los avances recientes en el entendimiento ecológico de la sinecología de équidos, todavía queda mucho que aprender. Las características naturales del *C. urophasianus* y de otras especies en estas comunidades sugieren que pueden ser de gran valor: 1) la evaluación del efecto de los caballos y que ésta debe ser tomada en forma más amplia que la simple perspectiva caballos vs. ganadería, y 2) el monitoreo de componentes del ecosistema tales como la dureza en la superficie de los suelos y la densidad de los nidos de hormigas en montículo, los cuales tienen relevancia ecológica y de manejo ya que la colección de datos es relativamente de bajo costo y factible de implementar en el campo.

Palabras Clave: *Artemisia*, burros, caballos, *Centrocercus urophasianus*, efectos directos e indirectos, *Equus asinus*, *Equus caballus*, pastoreo, sage-grouse.

Sagebrush (*Artemisia* spp.) habitats have undergone significant change during the last century because of conversion, degradation, and fragmentation (Knick et al. 2003, Connelly et al. 2004). Remaining sagebrush habitats continue to be threatened by direct loss of habitat due to agricultural conversion (West and Young 2000, Connelly et al. 2004), degradation or loss from energy exploration and extraction (Braun et al. 2002, Knick et al. 2003, Lyon and Anderson 2003, Aldridge and Boyce 2007), invasions of exotic plants (Knick et al. 2003, Connelly et al. 2004), intensive grazing practices (Beck and Mitchell 2000, Hayes and Holl 2003, Crawford

et al. 2004), fire (Connelly et al. 2000c, 2004), and climate change (Neilson et al. 2005). Grazing is often implicated in reducing sagebrush habitat quality (Beck and Mitchell 2000, Hayes and Holl 2003, Crawford et al. 2004) resulting in consequences for sagebrush-obligate species; however, these effects are rarely addressed quantitatively. This is due to the difficulties in accounting for legacy effects related to past management (Beever et al. 2006, Rowe 2007) and developing defined experimental treatments integrated with management actions that allow for testing of hypotheses within an adaptive-management framework (Aldridge et al. 2004).

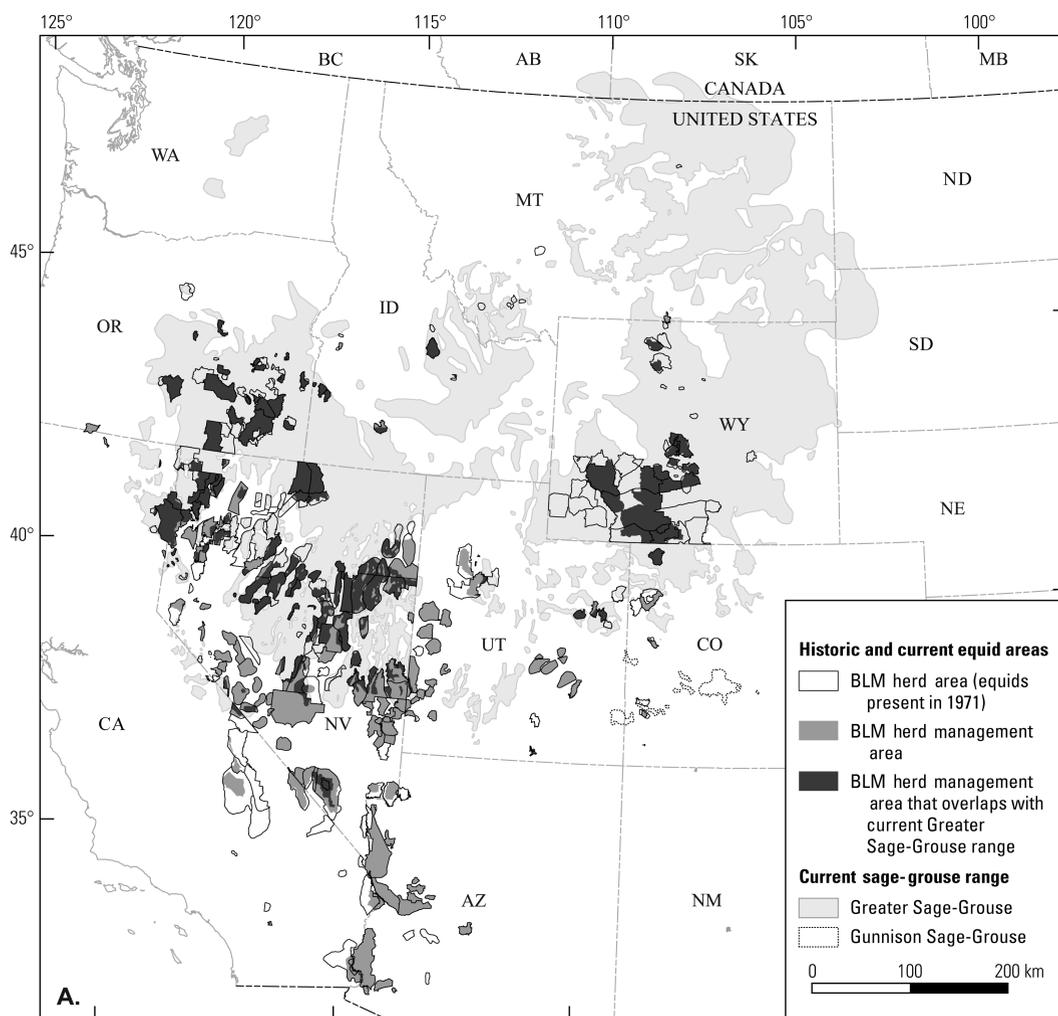


Figure 14.1. A) Distribution of Bureau of Land Management (BLM) free-roaming equid herd areas (equids historically present) and herd management areas (equids currently present), as well as B) U.S. Forest Service (USFS) wild horse and burro territories (equids currently present) across western North America. The current distributions (Schroeder et al. 2004) for both Greater Sage-Grouse and Gunnison Sage-Grouse are shown to illustrate the spatial overlap of equid landscape use with sage-grouse. Spatial data for equid ranges were compiled from state and local BLM and USFS offices.

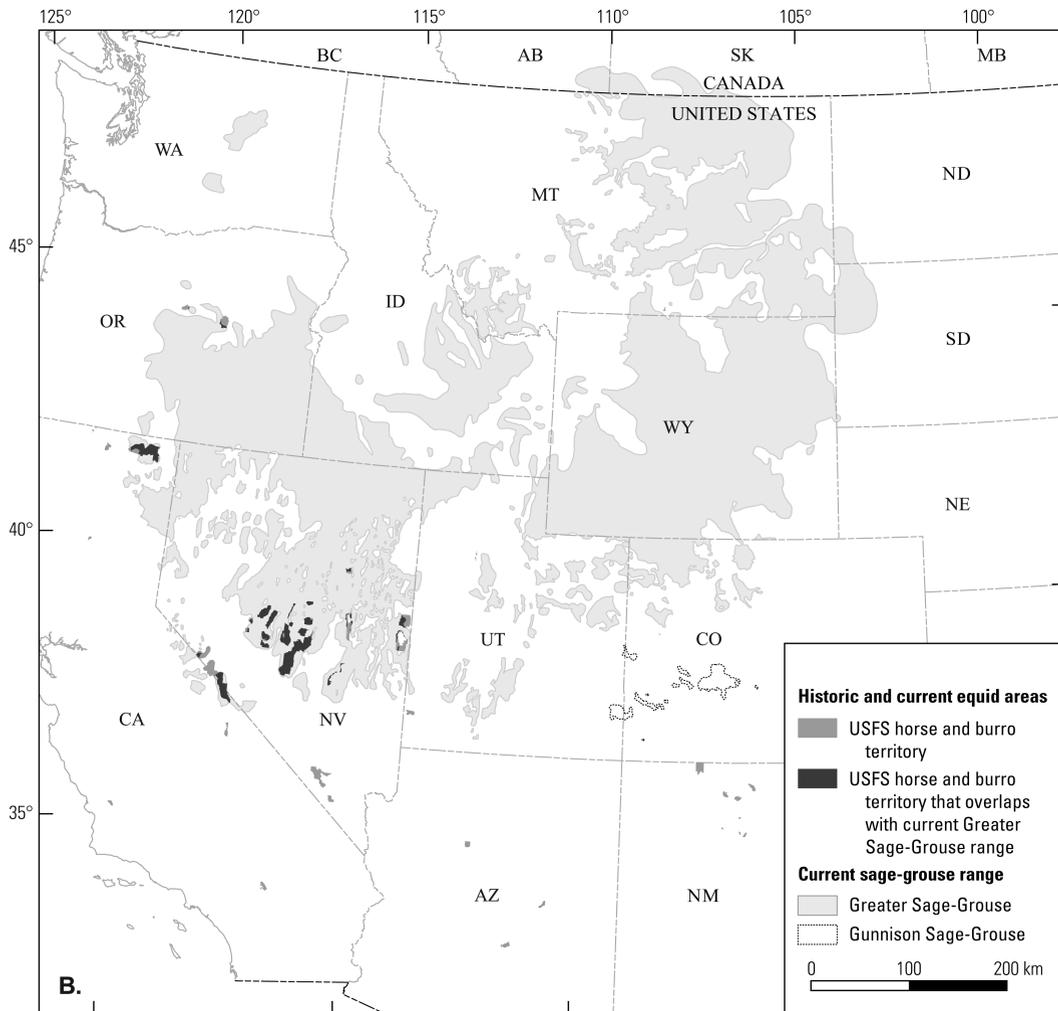


Figure 14.1. B. (continued)

Furthermore, relatively little consideration has been given to understanding links between the effects that free-roaming equids (hereafter, equids refer to horses [*Equus caballus*] and burros [*E. asinus*] in western North America; see distribution in Fig. 14.1) may have on sagebrush ecosystems and sagebrush-obligate species that these systems support.

Many wildlife species have been negatively affected by changes to sagebrush ecosystems. For example, many sagebrush-obligate birds have experienced population declines and range contractions over the past 40 years (Sauer et al. 2003, Connelly et al. 2004). Most monitored populations of Greater Sage-Grouse (*Centrocercus urophasianus*), for instance, have declined by ~2% or more per year since 1965 (Connelly and Braun 1997, Braun 1998, Connelly et al. 2004). Greater Sage-Grouse use a diversity of habitats across life

stages and encompass annual home ranges as large as 2,975 km² (Connelly et al. 2004). Large tracts of contiguous sagebrush habitat are required for their persistence (Aldridge et al. 2008), although heterogeneity within those patches may also be important (Aldridge and Boyce 2007).

A larger body of knowledge exists on Greater Sage-Grouse habitat requirements at local scales (Connelly et al. 2000c, Crawford et al. 2004, Hagen et al. 2007) compared to landscape-scale understanding (Connelly et al., this volume, chapter 4). Greater Sage-Grouse require habitat patches with extensive cover of sagebrush during breeding and nesting (15–25% cover), brood-rearing (10–25%), and winter (10–30%) (Connelly et al. 2000c, Hagen et al. 2007). In addition to the vegetation structure that Greater Sage-Grouse require from woody plants, grass cover is important for nest concealment and

as escape cover, and increased grass cover results in increased nest success (Connelly et al. 2000c, Crawford et al. 2004, Aldridge 2005, Hagen et al. 2007). Forb-rich mesic areas constitute important habitats during summer and brood-rearing; these areas provide forbs and insects as food resources that are required for chick survival (Johnson and Boyce 1990, Drut et al. 1994b, Sveum et al. 1998a). Greater Sage-grouse exhibit strong selection for greater cover (i.e., 14–40%) and greater diversity of forbs

(Klebenow and Gray 1968, Peterson 1970, Drut et al. 1994a, Sveum et al. 1998a).

Free-roaming equids within these sagebrush ecosystems, as is true for all large-bodied herbivores, can alter ecosystem components directly through any of several processes, including selective plant consumption, trampling of plants and surface soil horizons, and spatial redistribution of nutrients via ingestion and subsequent excretion (Fig. 14.2; Beaver et al. 2003, Beaver and Herrick 2006). These

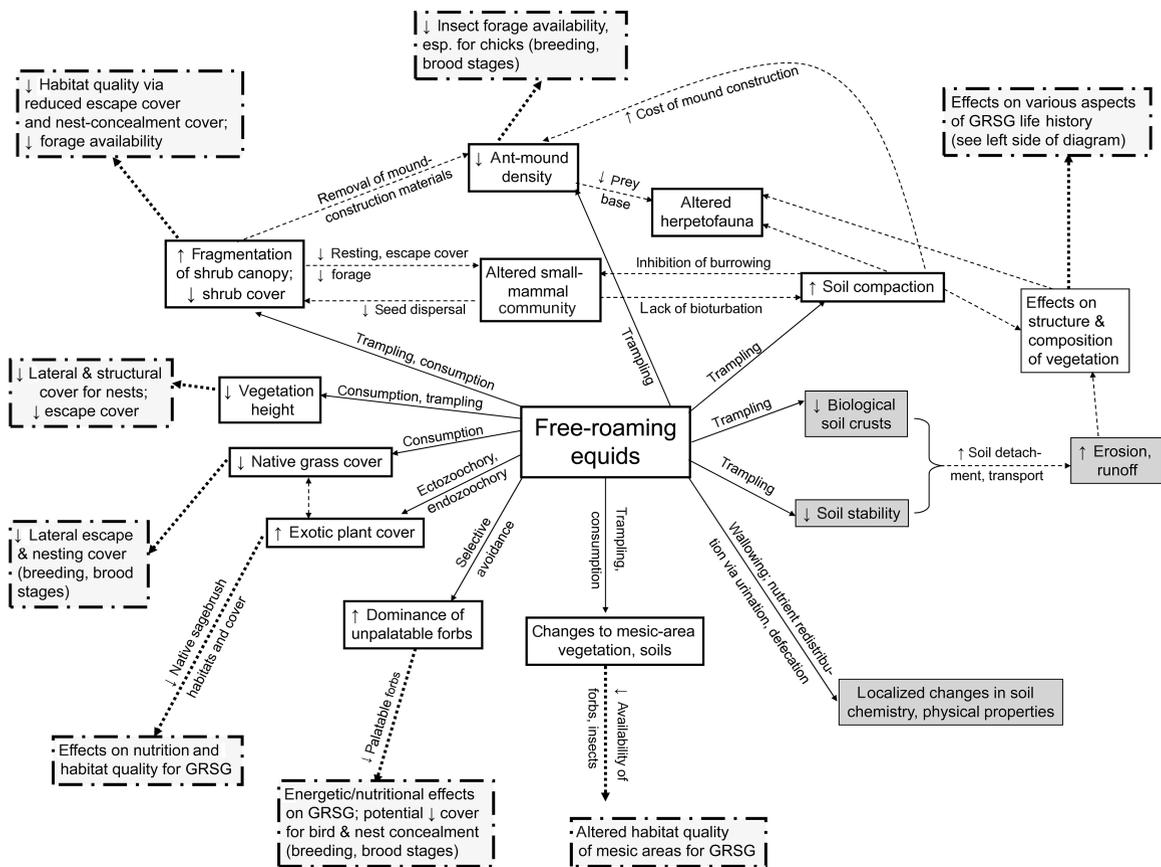


Figure 14.2. Conceptual model of relationships between free-roaming equids (center) and, in turn, between those aspects and life-history characteristics of Greater Sage-Grouse (GRSG) (outer ring of boxes: dash-dot border). Direct effects of equids are denoted by solid lines, whereas potential ecological cascades and indirect effects are denoted with dashed lines. Unless otherwise noted, alterations to habitat may affect Greater Sage-Grouse fitness during multiple important life stages, including at winter, brood-rearing, and breeding and nesting habitats. Thick inner boxes denote that horse-occupied sites have been found to differ significantly from horse-removed sites for these aspects of ecosystems (see text). Labels along arrows describe the likely mechanisms underlying these relationships. Arrows inside the boxes can be interpreted as increased or decreased. Equid influences likely interact with other drivers in their relationships with ecosystem components; such drivers include rapid climate change, wildfire and prescribed fire, western juniper dominance, off-highway vehicle use, native and domestic ungulates, other herbivores, and pests and disease invasions. For model clarity, potentially beneficial effects of free-roaming equids (e.g., reduction of site vulnerability to catastrophic fires due to brief removal of fine fuels, increase of pore spaces via chipping of soils at low equid densities, and creation of germination sites for new plants) were not included graphically. Note that whereas the relationships of equids to ecosystem components and the relationships of Greater Sage-Grouse to various habitat conditions have both been documented in some systems, the entire link of equids to Greater Sage-Grouse has not been demonstrated experimentally to date.

processes all occur at local through landscape scales, and thus can have relevance for life processes of Greater Sage-Grouse and other sagebrush-obligate species. Equids' rubbing against plant parts and creation of wallows are two examples of these disturbance processes at local scales. In addition to exerting these direct effects, equids can also affect sagebrush-inhabiting vertebrates indirectly through their influences on structure, composition, and chemistry of vegetation, as well as on the structure and local chemistry of soils (Beever and Herrick 2006, Beever et al. 2008). In turn, effects on vegetation can affect its value as hiding cover for terrestrial species. Collectively, these influences on both vegetation and soils can alter the competitive interactions among plants, alter soil-erosion patterns, create niches for colonizing or ruderal (early-successional, often disturbance-tolerant) species, and create feedback loops (Hobbs 1996, Beever and Herrick 2006) that could ultimately reduce the functionality of habitats for sagebrush-obligate species such as sage-grouse (includes Greater Sage-Grouse and Gunnison Sage-Grouse [*Centrocercus minimus*]).

Greater Sage-Grouse currently occupy ~668,412 km² of habitat across 11 states and two Canadian provinces, roughly 56% of their historic pre-settlement range in North America (Schroeder et al. 2004: Fig. 1). Based on extents of Bureau of Land Management (BLM) wild horse and burro herd areas (HAs) and herd management areas (HMAs), and United States Forest Service (USFS) wild horse and burro territories, we estimate that during at least some of the years since the establishment of the Wild Free-Roaming Horses and Burros Act of 1971, these equids have occupied 366,690 km² of semiarid ecosystems in western North America (Table 14.1). Areas that have been managed for horses and/or burros from 1971 to 2007 constitute ~18% (119,703 km²) of the currently occupied Greater Sage-Grouse range. This estimate excludes dispersal and extra-limital movements by equids (i.e., outside of management areas), which are difficult to quantify but may be widespread; considering these would appreciably increase the percentage of Greater Sage-Grouse habitats affected by equid grazing. About 12% (78,380 km²) of the current range of Greater Sage-Grouse is now managed for free-roaming equids (Table 14.1). Thus, there may be unmeasured consequences for a significant portion of sage-grouse habitat throughout the species' range because of the aforementioned ways in

which free-roaming equids can directly or indirectly impact sagebrush habitats.

Our goal is to critically consider the relationship between free-roaming equids and sage-grouse, focusing on Greater Sage-Grouse. Our objectives were to (1) synthesize the alterations to sagebrush and other communities that equids have been shown to exert in past research and (2) interpret these findings in view of the current body of knowledge of life-history and conservation requirements of Greater Sage-Grouse, as they pertain to continued persistence of the species.

A HISTORICAL REVIEW OF EQUID DYNAMICS IN NORTH AMERICA

Understanding relationships between free-roaming equids and sagebrush-obligate species such as sage-grouse requires a review over evolutionary and historical time. During the Eocene, equids (specifically, *Hyracotherium*) arose and began to diversify in North America (Simpson 1951, Zarn et al. 1977). Wild horses have occupied a variety of habitats worldwide throughout their evolutionary existence, but have generally favored cooler, more mesic habitats (e.g., grassland, open forest, and tundra), in contrast to the dry-steppe and desert habitats of burros and zebras such as *Equus burchellii* (Bennett 1992). After their long history in North America, however, horses were extirpated from the continent between 10,500 and >13,200 years ago, hypothesized to have resulted from overhunting by primitive peoples, climatic influences, or both (Martin 1984, Bennett and Hoffmann 1999). Equids were absent from North America until the end of the 15th century, when horses and burros were introduced by Spanish conquistadors into what is now the southwestern United States. Free-roaming horses spread rapidly across the Intermountain West, and populations reportedly peaked in the United States at 2,000,000–7,000,000 animals in the late 1700s to early 1800s (Ryden 1978, Thomas 1979). However, competing interests dictated that horses were captured in increasing numbers, a process that was accelerated by passage of the Taylor Grazing Act of 1934. These interests included using horses as saddle animals, breeding stock, or both; selling horses entrepreneurially for profit; and reducing suspected competition with livestock grazing. By 1934, numbers of free-roaming horses were reduced to ~150,000 animals (Thomas 1979).

TABLE 14.1
Area (km²) affected by free-roaming equids across western United States, by individual states overlapping the current range of Greater Sage-Grouse.

State ^a	BLM herd area ^b	BLM herd management area ^{c, d}	USFS wild horse and burro territories ^d	Area historically occupied by free-roaming equids ^e		Current area occupied by free-roaming equids	
				Within western North America	Within Greater Sage-Grouse current range	Within western North America	Within Greater Sage-Grouse current range
Arizona	14,722	12,480	303	27,505	—	12,783	—
California	28,184	9,787	2,640	40,611	8,720	12,427	6,981
Colorado	2,973	1,638	—	4,611	816	1,638	634
Idaho	1,933	1,692	—	3,625	1,594	1,692	1,440
Montana ^f	905	150	18	1,073	362	168	8
New Mexico	512	116	641	1,269	—	757	—
Nevada	1,788	70,716	6,881	169,384	48,281	77,596	38,229
Oregon ^f	17,584	11,991	414	29,990	16,904	12,405	11,775
Utah	15,885	11,482	133	27,501	1,870	11,616	1,023
Wyoming	41,795	19,326	—	61,121	41,156	19,326	19,290
Totals	216,282	139,378	11,029	366,690	119,703	150,408	78,380

SOURCE: Spatial data for equid ranges were compiled from a variety of state and local BLM and USFS offices; current area and equid numbers represent data as of 2007.

^a Indicates state that administers the federal land (not all land area reported is within the boundary of that state).

^b BLM wild herd areas represent areas historically occupied by free-roaming equids, but that are not currently managed to contain horses, unless currently contained within a BLM herd management area.

^c BLM herd management areas are contained within BLM herd areas.

^d BLM herd management areas and USFS wild horse and burro territories both historically were, and currently are, occupied by free-roaming equids.

^e During at least some period between 1971–2007.

^f Equid areas managed by the BLM within South Dakota and North Dakota are administered by Montana; areas in the state of Washington are administered by Oregon. Numbers are inclusive within those states.

Given burros' value to both Native Americans and Euro-Americans as work animals and as food after their introduction to western North America, burros probably did not become feral until the 19th century, likely the result of their escaping from loose confinement or being deliberately released and not rounded up (McKnight 1958, Carothers et al. 1976, Wagner 1983). Based on mail-survey and field estimates, McKnight (1958) reported that feral burros occurred in 10 western states in 1957. Burro movements overlap sage-grouse habitats in multiple areas across the southwestern United States, and although the overlap is less extensive than is the overlap with horse habitats, burros tend to spend more time in lower-elevation habitats, as do sage-grouse. Free-roaming burros are descended from the African wild ass (*Equus africanus*) native to northeastern Africa, and are more abundant in the warmer deserts south of the sagebrush distribution. Historically, horses have outnumbered burros in the historic range of Greater Sage-Grouse by 50 to 1 to well over 80 to 1. In addition, much of the scientific literature on burros in the western United States (1) comes from study areas outside the historic range of Greater Sage-Grouse; (2) focuses on potential competition between burros and bighorn sheep (*Ovis canadensis*), and only indirectly considers effects of burros on other ecosystem components; and (3) occurs in proceedings and other gray literature not

subject to the same level of scrutiny as other peer-reviewed sources (McKnight 1958, Carothers et al. 1976, Wagner 1983). We thus focus most of the remaining discussion on free-roaming horses and direct comparatively little attention to burros.

Legislative and Legal Mandates That Affect the Equid-Sagebrush Ecosystem Relationship

The legislation that established management policies for equids in western North America (Wild Free-Roaming Horses and Burros Act of 1971) deemed free-roaming equids an integral part of the natural system of public lands. Horse numbers rose sharply after enactment of the 1971 act that afforded horses and burros strong protection on BLM and USFS lands (Wagner 1983, United States Departments of Agriculture and the Interior 1997c). In the absence of any widespread, effective predator (but see Turner and Morrison 2001, Jeffress and Roush 2010 for a localized exception—mountain lions [*Felis concolor*]) and removal of any population constraint due to aridity because of human development of remote water sources such as guzzlers, humans became the strongest force regulating size of horse populations (Tables 14.2, 14.3). The Federal Land Policy and Management Act of 1976 and the Public Rangelands Improvement Act (PRIA) of 1978 amended the 1971 act and required record

TABLE 14.2

Criteria used by wild horse managers to set population goals reported in survey questionnaire from six states, administered in 1999.

Managers may have used more than one technique in Herd Management Areas (HMAs).

Technique used	No. of HMAs using technique	% of HMAs using technique
Grazing levels	31	55
Forage consumption rates	28	50
AUMs	16	29
Birth rates	3	5
Trend studies	3	5
Court order	2	4
Multiple-use decision (MUD)	2	4
Water availability	1	2
Genetics/ N_e	1	2

TABLE 14.3

Removal strategies used by managers in six states to maintain population numbers of wild horses, reported in survey questionnaires in 1999.

Some Herd Management Areas (HMAs) use more than one strategy.

Removal strategy	No. of HMAs using technique	% of HMAs using technique
Selective by age	48	86
Selective by phenotype	13	23
Emergency removal due to drought, mortality, or both	6	11
Entire harems removed	2	4
Contraception	2	4
No removals conducted	2	4
Selective by breeding needs	1	2
Nuisance animals only	1	2
Ranchers remove without legal authorization	1	2

SOURCE: K. A. Schoenecker (unpubl. data).

keeping of equid population sizes and distribution; required removal of excess animals from public lands once excess was identified, as well as disposition of animals through adoption; and allowed use of helicopters for capture and removals (Boyles 1986). The Public Rangelands Improvement Act also required research on the interrelationships with wildlife, water, and forage resources, and analysis of what constitutes “excess” animals. Currently, free-roaming equids have a unique management status in North America (Beever 2003). They must be managed according to the 1971 act at the minimal feasible level; thus, many free-roaming herds of horses and burros are neither fenced nor rotated among grazing areas. The act also stipulates that, in contrast to other wild ungulates, hunting of horses or burros is not permitted. Free-roaming horses on other jurisdictions—national wildlife refuges and national parks—are not governed by the same legislation as are lands administered by the BLM or the USFS. Collectively, these evolutionary, cultural, and management histories have set the stage for critically considering the current relationship of equids to Greater Sage-Grouse and other wildlife species dependent on sagebrush habitats.

REVIEW OF PAST RESEARCH

Overview

Influences of large-bodied herbivores on sage-grouse and other sagebrush obligates can occur directly, indirectly, and via feedback loops (Fig. 14.2). Equids can directly affect these by disturbance of lekking behavior and trampling of nests or altricial young, but these interactions have not been investigated. However, direct interactions have been anecdotally observed in the field for other native and nonnative herbivores, such as nest trampling and nest abandonment due to cattle activity <30 cm from the nest (C. L. Aldridge, unpubl. data). We thus discuss studies of equids’ effects on each of several components of sagebrush ecosystems and relate those effects to requirements of sagebrush-obligate species, focusing on Greater Sage-Grouse. The magnitude of grazing impacts will vary widely across the landscape, from areas minimally affected to areas used heavily (Coughenour 1999, Beever 2003), because of the nonuniform patterns of habitat use by horses and other ungulates (Hobbs 1996). However, the potential exists for these impacts to have consequences for Greater Sage-Grouse populations range-wide, given the

broad distribution of equids within the range of Greater Sage-Grouse (Fig. 14.1).

Possible Effects of Equids on Plants Within Sagebrush Ecosystems

Horse diets may contain >95% grasses in some seasons (Hubbard and Hansen 1976, Hanley and Hanley 1982, McInnis 1985). It is thus not surprising that across nine mountain ranges of the western Great Basin, horse-removed sites averaged 1.9–2.9 times more grass cover and significantly higher grass density than did horse-occupied sites in years that received 104–120% of the long-term average of precipitation (Beever et al. 2003, 2008). As was true for most other vegetative variables in that study, the magnitude of difference in grass cover and density was most pronounced on the more-productive and species-rich high-elevation sites (Beever et al. 2008). Grasses were similarly heavily used in Utah pastures grazed moderately by domestic horses, regardless of their phenology and thus fiber content (Reiner and Urness 1982).

Grass cover is important for Greater Sage-Grouse throughout the year (Crawford et al. 2004, Hagen et al. 2007). Grass provides escape cover and is particularly important for concealing nests, which are often in heterogeneous sagebrush habitats (Aldridge and Boyce 2007) that have greater residual and live cover of tall grasses (Sveum et al. 1998b, Connelly et al. 2004, Crawford et al. 2004, Hagen et al. 2007). Thus, removal of tall-grass cover in horse-occupied sites could negatively impact quality of habitat for Greater Sage-Grouse (Fig. 14.2).

Sites where horses were removed across the western Great Basin exhibited 1.1–1.9 times greater shrub cover than did horse-occupied sites ($P > 0.027$), although stem density of shrubs did not differ between the two types of sites ($P > 0.60$) (Beever et al. 2003, 2008). In particular, cover of sagebrush (*Artemisia* spp.) among high-elevation sites was 1.47–1.57 times higher at horse-removed than horse-occupied sites, but the difference among all sites was statistically significant ($P < 0.05$) in only the wetter of two years (Beever et al. 2008). This trend in sagebrush cover occurred in spite of a lack of difference in the stem count of sagebrush between the two types of sites (Beever et al. 2008). Horse-occupied sites also had a more fragmented shrub canopy, thought to be due to the combined effects of trampling, rubbing, and

consumption by horses. Specifically, randomly placed 50-m transects within horse-removed sites had significantly longer maximum intercepts of shrubs than did similar transects within horse-occupied sites (Beever et al. 2008). The relatively minor contribution of consumption to reductions in shrub cover was suggested by two studies from the Great Basin: (1) a study of the effects of domestic horses at different grazing intensities in northern Utah, which found that utilization of shrubs was usually $\leq 4.2\%$ (Reiner and Urness 1982), and (2) a study of food-resource partitioning among five sympatric ungulates in northeastern California and northwestern Nevada, which found that horse diets included an average of only 5.0% (range 1.0–11.8%) of browse—shrubs and trees combined—across seasons (Hanley and Hanley 1982).

Loss of sagebrush cover can directly affect food resources for Greater Sage-Grouse, given that they consume sagebrush throughout the year (Patterson 1952; Connelly et al. 2000c, 2004). In addition, loss of sagebrush and other shrubs could directly reduce the quantity and quality of nesting and winter habitat. Reduction in escape cover can result in increased predation pressure on both nests and birds (Connelly et al. 1991, Schroeder and Baydack 2001), which could be exacerbated in the presence of free-roaming equids.

Domestic horses in heavy-grazing regimes in Utah pastures primarily consumed grasses, but consumption of grass was increasingly replaced by forb consumption as duration of grazing lengthened. However, rates of forage removal per animal were lower than in moderately grazed pastures. The authors hypothesized that this diet-switching may have been due to the increased search time for preferred species, lower intake, or more frequent animal interactions (Reiner and Urness 1982). Horse diets in the northwestern portion of the Great Basin contained an average of only 5.5% forbs across seasons (range 2.1–9.4%; Hanley and Hanley 1982).

Sites across the western Great Basin occupied by free-roaming horses at higher elevations possessed greater cover and abundance of grazing-tolerant and unpalatable (to ungulate grazers) forbs such as mules' ears (*Wyethia* spp.) and lupine (*Lupinus* spp.) than did horse-removed sites (Beever et al. 2008), which Ruthven (2007) also reported for sites grazed by domestic livestock in south Texas. These forbs are not food items ingested by Greater Sage-Grouse. This trend was generally true for all forbs

combined, but was inconsistently and less strongly so than for other plant metrics. Furthermore, information-theoretic analyses suggested that variability in forb cover and frequency more strongly reflected precipitation, year, elevation, and site effects than the presence of horses (Beever et al. 2008). In spite of their greater (unpalatable) forb cover, horse-occupied sites were more depauperate floristically, averaging 4–12 fewer plant species per site; differences primarily reflected herbaceous species, particularly forbs (Beever et al. 2003). These site-level differences in plant species richness were evidenced in spite of a lack of statistical difference in average number of plants intercepted per transect, underscoring the greater heterogeneity within horse-removed sites (Beever et al. 2008) with which many vertebrates in sagebrush ecoregions are associated (Aldridge and Boyce 2007).

Cheatgrass (*Bromus tectorum*) tends to be more abundant at horse-occupied than horse-removed sites (1.6–2.6 times greater abundance; Beever et al. 2003, 2008). Dung piles of feral horses in montane natural grasslands of Argentina act as invasion windows for exotic plants: an invasive thistle was consistently associated with dung piles, and nonnative plant cover in abandoned dung piles was higher than in control plots (Loydi and Zalba 2009). From field-collected fecal samples in two research rangeland areas of the interior northwestern United States and subsequent studies of seed germination in greenhouses, Bartuszevige and Endress (2008) estimated that nonnative ungulates (domestic cattle) disperse 1,200,000 germinable exotic seeds/km²—about two orders of magnitude greater than that estimated for the native ungulates in the same area (elk [*Cervus elaphus*] and mule deer [*Odocoileus hemionus*]). Invasion of cheatgrass into lower-elevation, xeric sites and alteration of fire frequencies result in reduced plant diversity and habitat structure (Connelly et al. 2004, Crawford et al. 2004). Herbaceous components of the system are lost, resulting in reduced food resources for sage-grouse, and fire frequency is increased, directly eliminating native forbs, shrubs, and perennial grasses within sagebrush habitats (d'Antonio and Vitousek 1992, Miller et al. 1994, Crawford et al. 2004). All of these ecological cascades reduce habitat suitability for sage-grouse (Fig. 14.2; Connelly et al. 2004). Given the drastic changes in stable-state dynamics and management alternatives when cheatgrass invasions occur, possible changes to sagebrush ecosystems as a result of the presence of wild horses—

changes in vulnerability or resilience of communities to fire, mechanisms of spread or increase in nonnative plant density—may merit more consideration in light of concerns over the viability of Greater Sage-Grouse populations and other sagebrush-obligate bird species.

Within horse-occupied areas of the western Great Basin, transects adjacent to horse trails had less grass and shrub cover, equivalent or higher forb cover (primarily unpalatable species), and lower species richness than did randomly selected transects within the same site (Beever et al. 2008). That horse grazing affected ecosystem components similarly at both local and landscape scales is important because reports of home-range size in horses vary from 0.9 km² on Sable Island, Nova Scotia, to 303 km² in Wyoming (Pellegrini 1971, Welsh 1975, Green and Green 1977). We expect the most appropriate scale for analyses of interactions between equids and sage-grouse (or other species dependent on sagebrush habitats) will vary greatly across the geographic range of these sagebrush-associated species.

Insights from the Great Plains

Many of the longest-term and most intensive studies of free-roaming horses have occurred in the far northeastern corner of the current geographical extent of horses in the United States. The Pryor Mountain Wild Horse Range at the Montana-Wyoming border (Fig. 14.1) makes up <0.5% of the total extent of HMAs. Paleoevidence, coevolutionary arguments, and recent data all suggest that ecosystem response to equid grazing should be fundamentally different in grasslands and steppes of the Great Plains than in the lower-productivity communities of the Great Basin (Mack and Thompson 1982, Milchunas and Lauenroth 1993, Wilsey et al. 1997, Grayson 2006). Thus, extrapolating results from Pryor Mountain studies across the domain of free-roaming horses in North America should generally be avoided. However, long-term research in the Pryor Mountains suggests horse-grazing impacts on vegetation may vary by year (largely due to interannual variability in precipitation, especially precipitation during the growing season), short-term and especially long-term grazing history, life-form and species of plant, and, most commonly, site elevation and soil type (Coughenour 1999, Gerhardt and Detling 2000).

Insights from Research in Mesic Systems

Within sagebrush landscapes, streams and springs receive disproportionately heavy use by horses (Fig. 14.2; Crane et al. 1997, Beever and Brussard 2000). The extent to which these resources are negatively affected depends on timing, duration, and intensity of equid grazing; spring density in the area; and productivity and resilience of the habitats and soils adjacent to the water (Beever and Brussard 2000). Degradation of spring-associated resources in steeper terrain and higher-elevation areas by equids is of particular concern, given that these springs would be less likely to be accessible if domestic cattle were the only grazer in the area (Ganskopp and Vavra 1986, 1987; Beever 2003).

Research on ecosystem response to free-roaming horses in more mesic habitats such as salt marshes, oligotrophic bogs, pastures, and peatlands has a longer history and greater spatial replication at a global scale, but may contribute in only a limited manner to ecologists' understanding of grazing dynamics in semiarid landscapes and sagebrush communities. These ecosystems often have horses present in only limited numbers and over a limited area, and their response to horse grazing is likely to be fundamentally different from that expected in upland areas of semiarid ecosystems where thresholds and nonlinear dynamics dominate (Mack and Thompson 1982, Laycock 1991).

However, these studies may reveal how areas with wetted or hydric soils will respond to horse grazing, such as at springs and margins of riparian areas in the western United States; what plant attributes, portions of the plant community, or areas on the landscape may be particularly vulnerable to effects of horse grazing; and the mechanisms by which indirect effects are brought about by horse grazing. Collectively, these limitations in extrapolating results from other ecoregions to the Intermountain West, combined with the importance of springs and seeps for Greater Sage-Grouse and other sagebrush-obligate species, highlight equid relationships with mesic areas as a fruitful avenue for future research on conservation implications.

Possible Effects of Equids on Soils in Sagebrush Ecosystems

Soil hardness at horse-occupied sites averaged 2.9 times greater than at horse-removed

high-elevation sites in the western Great Basin, and 17.4 times greater among low-elevation sites (Beever et al. 2003, Beever and Herrick 2006). Strong within-year correlations ($r = 0.69$, $P = 0.001$) in these studies between average soil-surface penetration resistance and the number of horse defecations at each site suggested a direct effect of horses on penetration resistance (Beever and Herrick 2006). The correlation was stronger within each of the two elevational strata, including the low-elevation ($r = 0.77$) and high-elevation plots ($r = 0.71$). Alterations of soil properties such as bulk density, thickness of surface horizons, and soil chemistry have been implicated in catastrophic degradation of vegetation, invasion of exotic plant species, and desertification (Thurrow 1991, van de Koppel et al. 1997), all of which could reduce habitat availability and quality for Greater Sage-Grouse across all life stages (Fig. 14.2).

These alterations have been demonstrated for domestic-livestock grazing via compaction, hoof action and consequent erosion, and redistribution of nutrients such as nitrogen (Archer and Smeins 1991, van de Koppel et al. 1997). Surface soils are involved with numerous biotic and abiotic pathways (Thurrow 1991, Belsky and Blumenthal 1997, Beever and Herrick 2006). Consequently, further work on equid-soil relationships would increase ecological understanding and identify implications of and identify management strategies to minimize the influences of free-roaming equids on sagebrush habitats and, thus, on Greater Sage-Grouse populations. For example, two questions that have management significance are to what depths do increases in penetration resistance extend below the soil surface, and what factors (e.g., soil texture or percent clays, consistence, and strength of effervescence) most strongly modify these relationships and pathways?

Whole-Community Perspectives in Analyzing Effects of Equid Grazing

The question of whether horse-occupied and horse-removed sites differ across a broad region in a community or whole ecosystem sense needs to be addressed, in addition to examining grazing effects on individual ecosystem components. Beever et al. (2003) investigated the relative performance of five different data sets, all collected or estimated for long-term abiotic properties across the same 19 sites and two years of field

work, in detecting disturbance by free-roaming horses. Horse-occupied and horse-removed sites could not be clearly discriminated in multivariate ordination space using cover of key plant species consumed by horses (and measured by BLM horse specialists in horse-effects monitoring), cover or frequency of all plant species, or a full suite of abiotic site characteristics (Fig. 2 in Beever et al. 2003).

In contrast, the two types of sites were clearly distinguished by a suite of variables that were sensitive to grazing disturbance in prior ecological research. These diverse grazing-sensitive ecosystem attributes included density of ant (Formicidae) mounds, penetration resistance of the soil surface, percentage of hypothetically possible granivorous small mammals that were actually trapped, species richness of plants, grass cover, forb cover, shrub cover, and abundance of cheatgrass (Beever et al. 2003). This may be important for Greater Sage-Grouse and other sagebrush-obligate species because although neither cover of the species that free-roaming horses eat nor abiotic site properties differed between horse-removed and horse-occupied sites in a collective (multivariate) sense, community-level differences between the two types of sites clearly existed (Beever et al. 2003). These differences may be important to differing degrees, depending on the species, but effects of these ecosystem alterations have not been addressed for Greater Sage-Grouse. Greater Sage-Grouse have been shown to choose more complex vegetation structure (Crawford et al. 2004, Aldridge 2005). Changes at the community level could result in a reduction in visual obstruction barriers for Greater Sage-Grouse and increase predation on nests and individual birds (Martin 1993, Schroeder and Baydack 2001, Crawford et al. 2004, Aldridge 2005).

Habitat-Use Patterns by Equids and Potential Synergies with Livestock-Grazing Effects

One of the more important challenges in interpreting equids' role in the ecological integrity of sagebrush communities for the future of sage-grouse and other species of concern involves understanding how equids' effects are distributed across the landscape. Spatially explicit quantitative assessment of habitat-use patterns does not translate directly into equivalent understanding of how shorter- and longer-term grazing effects are distributed across

semiarid landscapes. This is because of the differential vulnerability of various soil types and plant communities to equid grazing. However, habitat-use analyses provide a foundation that can be focused with emerging scientific information.

Several authors have noted particularly heavy use of the more mesic portions of semiarid landscapes—meadows, grasslands, springs, and riparian zones—by free-roaming horses, especially during the warmest, driest portions of the year (Feist 1971, Pellegrini 1971, Ganskopp and Vavra 1986). Beever and Brussard (2000) concluded local spring density was one of the strongest factors explaining differences in magnitude of impacts at springs across multiple mountain ranges. McKnight (1958) reported that feral burros may remain at watering locations for several hours, and roll and defecate in the water.

Mesic habitats are important for Greater Sage-Grouse survival, providing an abundance of forbs and insects as food resources from pre-laying in early spring (Crawford et al. 2004) through brood-rearing and into the fall (Klebenow and Gray 1968, Drut et al. 1994b, Sveum et al. 1998a, Aldridge 2005). Loss of productive mesic habitats can result in low productivity for Greater Sage-Grouse, which has been linked to population declines throughout the species' range (Connelly et al. 2004, Aldridge and Boyce 2007). Heavy use of these sites by equids could increase conflicts and reduce the availability and quality of important Greater Sage-Grouse habitats. Especially in arid and semiarid ecosystems, springs and riparian ecosystems are of paramount importance to maintaining regional biodiversity because of their facultative or obligate use by $\geq 70\%$ of a region's species (Naiman et al. 1992). The extent to which free-roaming equids in sagebrush communities directly or indirectly alter the availability of insects important to Greater Sage-Grouse broods at these mesic sites is currently unknown.

Most ungulate species are known to move in response to local and seasonal shifts in distribution of forage abundance, availability, and nutrient quality (Talbot and Talbot 1963, Kitchen 1974). Horses in many of the Great Basin HMAs (Fig. 14.1) tend to move to higher elevations from late spring until early fall, and descend to lower habitats during colder months, when snow may persist at higher elevations (Pellegrini 1971, McInnis 1985). Seasonal shifts in habitat use by Greater Sage-Grouse occur during the late brood-rearing period (July and August) and are driven by the availability of forbs,

which are required by chicks and adults (Patterson 1952, Klebenow and Gray 1968, Peterson 1970). Similar to the shift in habitat use by equids, Greater Sage-Grouse often move to higher-elevation mountain-shrub communities, spatially tracking the phenology of plant communities to ensure access to more mesic habitats with forbs throughout summer (Fischer et al. 1996a, Connelly et al. 2004). The seasonality of equids' use of the landscape may have important implications for Greater Sage-Grouse habitats and populations, given the varying requirements of Greater Sage-Grouse throughout the year.

Horses use plant communities and landscapes differently than do cattle and native ungulates, across both time and space. Within seasons, horses often segregate by elevation from cattle by using steeper slopes and occupying higher-elevation habitats (Pellegrini 1971; Ganskopp and Vavra 1986, 1987). Both cattle and horses most commonly used the sagebrush-grass vegetation type when averaged across the year in the Red Desert of Wyoming, but peak use by horses occurred in fall and winter, whereas use by cattle peaked in summer and fall (Miller 1980). Horses also spend considerably less time at watering locations than do cattle (Meeker 1979, Ganskopp and Vavra 1986) and range farther from watering sources throughout the year (up to 49.2 km in eastern Nevada; Feist 1971, Pellegrini 1971, Welsh 1975, Green and Green 1977). Horses graze an average of six hours per day longer than cows (Arnold and Dudzinski 1978, Rittenhouse et al. 1982, Duncan et al. 1990) and consume 20–65% more forage than would a cow of equivalent body mass because of their cecal digestion and rapid passage rate of food (Hanley 1982, Wagner 1983, Duncan et al. 1990, Menard et al. 2002). Horses can crop vegetation closer to the ground than can other ungulates due to their sensitive, flexible lips and possession of both upper and lower incisors (Stoddart et al. 1975, Symanski 1994). This cropping sometimes delays the recovery of plants (Symanski 1994, Menard et al. 2002). Furthermore, native ungulates such as mule deer and pronghorn (*Antilocapra americana*) can range farther from water than can horses, are browsers, and have much smaller body mass and hoof area relative to horses (Symanski 1994).

Taken collectively, these broader-scale differences in grazing ecology indicate that a larger proportion of the landscape experiences nonnative grazing when horses and cattle are present sympatrically,

compared to when only cattle are present (Symanski 1994, Beever 2003). Domestic livestock consume an estimated 7,100,000 animal-unit months (AUMs) of forage annually (Table 14.4) within the current range of Greater Sage-Grouse. We estimate that free-roaming equids consume an additional 315,000–433,000 AUMs annually within the current range of sage-grouse (Table 14.4). It is unknown whether effects of cattle grazing, horse grazing, and native-ungulate browsing are synergistic or simply additive. However, the significance of the aforementioned differences is underscored by the importance that both patch dynamics and landscape patterns have been shown to have for several species, including Greater Sage-Grouse, which use the landscape at multiple spatial scales (Connelly et al. 2004, Aldridge 2005, Aldridge and Boyce 2007). The peak spatial overlap in use of sagebrush habitat with sage-grouse may thus occur during the breeding or late brood-rearing periods.

In addition to these contemporary additive or synergistic effects, large-mammal researchers and managers often struggle to separate the legacies of past mismanagement or poor implementation of livestock grazing strategies (especially during 1890–1920) from effects of current disturbances (Foster et al. 2003, Rowe 2007). Domestic livestock grazing is nearly ubiquitous across public lands of western North America, and the ratio of livestock to equid AUMs in this region averaged 23 to 1 in 1982 (Wagner 1983). However, within Nevada—the state with over half of the continent's free-roaming equids—this ratio averaged only 4.8 to 1 livestock-to-equid AUMs in 1982, and varied from 23 to 1 in the Elko BLM District to 2 to 1 in the Las Vegas BLM District (Wagner 1983).

FUTURE APPROACHES TO INVESTIGATE EQUID–SAGE-GROUSE RELATIONSHIPS

Several methods can quantitatively assess the influence of equids on the biotic integrity of sagebrush communities within the historic range of sage-grouse. The most informative for managers and perhaps most powerful statistically would be to regress an index of biotic integrity (Angermeier and Karr 1986) obtained from remotely sensed data against equid density using points from across the region. Unfortunately, this approach is currently untenable for several reasons. First, although the use of light detection and ranging (LiDAR) and satellite-based imagery to remotely

TABLE 14.4

Animal unit months (AUMs) permitted for domestic livestock and free-roaming equids by state, across the current distribution of Greater Sage-Grouse within the United States.

Domestic livestock and equid estimates are based on BLM-administered lands within the current range of Greater Sage-Grouse.

State	Domestic livestock AUMs (2007) ^a	Range of equid AUMs ^b	
		Lower (1.2 times)	Higher (1.65 times)
California	150,228	30,874	42,451
Colorado	326,393	5,875	8,078
Idaho	855,131	10,541	14,494
Montana	1,334,208	2,218	3,049
North Dakota	9,268	0	0
Nevada	1,436,771	159,869	219,820
Oregon	866,194	29,722	40,867
South Dakota	36,958	0	0
Utah	261,075	19,224	26,433
Washington	10,307	0	0
Wyoming	1,894,034	56,693	77,953
Totals	7,118,989	315,014	433,145

^a Livestock estimates are based on 2007 allocations, as summarized by the BLM Rangeland Administration System, <http://www.blm.gov/ras/>, 24 October 2009.

^b Permitted AUMs does not necessarily mean all AUMs were used, but the BLM system does not track used AUMs. Range of AUMs used by equids was estimated using numbers obtained from the National Wild Horse and Burro Program (<http://www.wildhorseandburro.blm.gov/statistics/2007/index.htm>, 24 October 2009), assuming 12 mo of use at 1.2–1.65 times greater forage consumption for equids (both horses and burros) compared to cattle (Hanley 1982, Wagner 1983, Menard et al. 2002).

map and monitor habitats across large landscapes is developing rapidly, indices that would be meaningful for Greater Sage-Grouse and other sagebrush obligates are not yet broadly available at sufficiently fine resolution to permit quantitative analysis.

Second, it is unclear whether maximum equid density or average density within AUMs would be a more logical predictor of current sagebrush conditions (Ellison 1960, van de Koppel et al. 1997). Third, except in the Pryor Mountain Wild Horse Range in Montana, the finest scale for which equid density estimates are available is the entire HMA, which is often an entire mountain range(s). This is critical because, as evidenced by the example that ~40% of the Pryor Mountain Wild Horse Range was unsuitable for horse grazing due to steep topography or large extents of rock or bare ground (Fahnestock and Detling 1999b), estimates

of entire HMA equid density can be off by a factor of at least 1.7. This error factor for any given location could be even higher, because the conservative assumption that every remaining “suitable” location is grazed at the same intensity is clearly not true.

Fourth, high increase rates observed in populations of wild horses (to >20% annually; Eberhardt et al. 1982) indicate that the number of horses in a given fall or spring census period will not necessarily correspond either to the population size in the management unit at a given time in the future or to an average number of AUMs on the landscape during the entire year. This would only be problematic if error magnitudes were distributed nonrandomly, but this seems feasible (e.g., higher error in larger populations). Fifth, differences in precision of equid censuses across the sagebrush

range due to differences in aircraft, observer experience, tree cover that reduces animal detectability, and other factors would reduce the power of the analysis (Caughley 1974, Ohmart et al. 1978).

Finally, and perhaps most seriously, the way in which equid, cattle, sheep, and native-ungulate AUMs are allocated to HMAs would confound the analysis if lower levels of equid AUMs are correspondingly or randomly replaced by increased cattle AUMs. Livestock grazing intensity could be incorporated as a covariate, but intensity is known only at the spatially coarse level of allotments, and historical records of density are not widely available, thus crippling this potential analysis.

A second analytical approach would compare a metric of sagebrush biotic integrity—such as cover of sagebrush from remotely sensed data—in management areas with and without equids. In addition to the aforementioned lack of alternative indicators, a problem for this analysis is the fact that because HMAs often correspond to entire mountain ranges, lower sagebrush cover within an HMA may be a consequence of that range's vicariance history rather than a reflection of greater disturbance. A new challenge created by this approach is that HMAs where equids have been removed are not allocated in a random, dispersed manner, but instead are driven by sociopolitical concerns (e.g., conflicts with railroad property rights). Thus, equid-removed herd areas are at times spatially clumped, a hindrance to landscape-scale analyses.

This second approach circumvents the second through fifth problems in the first analytical approach, but with the sixth, effects of other ungulates would remain—a serious confounding factor. Horse specialists realize it is difficult to separate effects of other sympatric ungulates, such as domestic livestock and native ungulates such as mule deer, elk, and pronghorn, from equid effects.

A final analytical approach would involve assessment of the possible direct interactions between equids and Greater Sage-Grouse or other sagebrush-obligate species. In this approach, radio transmitters placed on individuals of both grouse and equids would provide the raw data needed to develop habitat-selection maps for both species. In turn, these maps would indicate the factors driving habitat selection for the two taxa in regions where they are sympatric and allow investigation of overlap of use for the two species in

different seasons that correspond to critical life-stages for Greater Sage-Grouse.

CONCLUSIONS

Conservation challenges posed by sage-grouse and other sagebrush-obligate species provide a timely impetus to consider the role free-roaming equids might play in ecoregional-scale conservation strategies. From a practical standpoint, such challenges may be an avenue by which the limiting horses versus cows debate that has dominated discussions and popular perception of equid management for decades may be broadened to include other resource values. Free-roaming burros and especially horses are undeniably charismatic and enigmatic, and have been used to symbolize power, freedom, wildness, and toughness. Given the multiple stresses that interact to influence ecosystem dynamics across western North America, however, the benefits these nonnative herbivores provide for various publics within society must be weighed against actual and potential ecological costs.

As with any large-bodied herbivore, the magnitude and permanence of impact that free-roaming horses and burros will have on sagebrush ecosystems depend upon a host of factors, including the plant-animal coevolutionary history, soil development, climate, recent weather, effects of other sympatric herbivores, site elevation, amount of recent and long-term precipitation, and the seasonality, duration, and intensity of grazing (Milchunas et al. 1988, Fahnestock and Detling 1999a, Beever et al. 2008). In turn, intensity of landscape use by equids is influenced by a host of biotic factors, including vegetation and soil types, vegetation physiognomy, proximity to water, presence and recency of wildfire, spatial and temporal distribution of plant defenses against herbivory, behavior of conspecifics or competitors, and past, current, and future nutritional states of animals, among other factors. Abiotic factors such as elevation, aspect and slope, snow depth, thermoregulatory constraints, and proximity to roads and other disturbances also affect habitat use of free-roaming equids.

Equid-induced changes in sagebrush and other communities that may most strongly affect sagebrush-obligate birds and have been observed to date include reduction in grass abundance and cover, alterations to the structure and composition

of the shrub mosaic (e.g., lower cover and greater fragmentation of shrubs, and lower sagebrush cover), increases in compaction in surface soil horizons, and increased dominance of forbs unpalatable to livestock and Greater Sage-Grouse (Fig. 14.2). Collectively, these effects represent a nontrivial contribution to ecosystem integrity across the sagebrush range. All of these ecosystem alterations may increase the vulnerability of Greater Sage-Grouse and other species to predation, parasites, or disease; increase energetic costs and stress levels required to locate suitable habitat or resources; and negatively affect nest success, chick survival, or other aspects of fitness and survival, all of which could ultimately affect the viability of some populations.

CONSERVATION IMPLICATIONS

Multidisciplinary teams of managers and researchers comprising leading experts on various aspects of equid biology have long considered investigation of grazing impacts to be of highest priority (Blaisdell and Thomas 1977, Kitchen et al. 1977, Zarn et al. 1977, Wagner et al. 1980, Singer 2004), but understanding how feral horses may affect the nonungulate components of sagebrush ecosystems is only beginning (Crane et al. 1997, Fahnestock 1998, Peterson 1999, Beever and Brussard 2004, Beever and Herrick 2006). Recent research suggests that equid use of a landscape can indirectly affect a wide array of taxa in a community through numerous pathways (Fig. 14.2) (Levin et al. 2002). For example, compared to ecologically similar horse-removed sites in the western Great Basin, horse-occupied sites differ in numerous aspects of ecosystem structure, such as lower shrub cover, higher compaction of soil surfaces, and a more fragmented shrub canopy, composition (e.g., lower grass cover, lower total vegetative cover, lower plant species richness), and function (e.g., lower density of ant mounds). In spite of the increasing attention in recent research to synecological relationships of equid grazing in arid and semiarid landscapes of western North America, many basic questions remain unanswered.

Nearly all of the research on equids in western North America has been performed at spatially limited scales due to the advantages in terms of logistics, costs, and research design. Unfortunately, these focused investigations are difficult to

amalgamate into a landscape- or regional-level understanding of equid biology. This is especially true given that horse behavior can be plastic across ecoregional scales (Bennett and Hoffmann 1999). Furthermore, most studies have usually used only two treatment levels for equid grazing—present and absent. If, instead, investigators were to select equid-occupied sites across a range of grazing intensities, this would allow clarification of the shape of the dose-response curves of various ecosystem indicators. This has importance for monitoring, because monitored indicators should ideally be sufficiently sensitive to grazing disturbance to act as early-warning indicators of system degradation.

Results from past research across 3,030,000 ha of the western Great Basin may help in forecasting how Greater Sage-Grouse and other sagebrush-obligate species may be affected by free-roaming equids. For example, community completeness may be lower in horse-grazed than in horse-free areas (e.g., for granivorous small mammals) as a result of the absence of rarer species from horse-grazed sites (Beever and Brussard 2004). In that work, community completeness was defined as the percentage of species detected during a standardized trapping effort, compared to the full suite of species predicted to exist at a site given the elevation, geographic location, and microhabitats of the site. Differences in grass cover are likely to have a biologically meaningful effect for some grass-specialist animals, as was illustrated by two to four times higher capture rates of the western harvest mouse (*Reithrodontomys megalotis*) at horse-removed compared to horse-occupied sites (Beever and Brussard 2004). Equid-influenced areas may be more dominated by disturbance-tolerant generalists like deer mice (*Peromyscus maniculatus*) and species that specialize in open areas without vegetation, such as western whiptails (*Cnemidophorus tigris*) (Beever and Brussard 2004). Greater density of ant mounds at horse-free sites than at horse-occupied sites suggests that at least a portion of the invertebrate community is more robust at horse-removed sites, and may also reflect differences in level of ecological function (Beever and Herrick 2006). Collectively, these responses not only illustrate the types of community restructuring that can occur in areas heavily influenced by equids, but also suggest indicators and mechanisms that may be important for further investigating equids'

effects on Greater Sage-Grouse and other sagebrush-obligate species.

Given current knowledge, however, and the fact that recovery can be protracted and uncertain in arid and semiarid ecosystems within the geographic range of Greater Sage-Grouse—due to their low-productivity, event-driven, threshold state-and-transition dynamics (Laycock 1991, Tausch et al. 1993)—several conservation considerations appear warranted. First, arid land health and ecosystem integrity are important considerations for long-term conservation of sagebrush systems, along with minimum viable population sizes and other genetic concerns for free-roaming equid populations. Long-term conservation objectives should consider the appropriate management levels of horses and burros that can be maintained (Tables 14.2, 14.3) because free-roaming equids can influence the structure and function of sagebrush ecosystems. Fencing and rotational grazing can be used to limit spatial and temporal effects of domestic livestock grazing, but few options outside of controlling population levels are available to land managers for managing horse and burro distributions and grazing effects. Consequently, the primary mechanisms for managing equids will center on approaches that reduce herd levels or limit population growth.

Second, it remains important within this context to have explicit management goals to justify

and reinforce decisions of where and how many free-roaming equids will occupy public lands. Third, extensive research into immunocontraception as a potential method to limit equid populations should be accompanied by synecological investigations that not only support adaptive management of equid herds but also provide insights into additional ecological indicators of grazing disturbance as it relates to ecosystem integrity. Finally, herd reductions during drought periods that managing agencies currently use may be important in sustaining sagebrush ecosystems during ecological stresses. Such emergency reductions not only avoid the pronounced grazing-induced ecosystem degradation that can accompany drought (Jardine and Forsling 1922, Archer and Smeins 1991) but also avoid conditions that can be stressful or lethal for equids.

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