JOURNAL OF RANGELAND APPLICATIONS

Volume 1, 2014
pp. 14-34
ISSN: 2331-5512

Implications of Longer Term Rest from Grazing in the Sagebrush Steppe

K. W. Davies[1], M. Vavra[2], B. Schultz[3] & N. Rimbey[4]

Keywords: dormant season grazing, exclosures, herbivory, managed grazing
AGROVOC Terms: grazing management, sagebrush, rest

Abstract

Longer term grazing rest has occurred or been proposed in large portions of the sagebrush steppe based on the assumption that it will improve ecosystem properties. However, information regarding the influence of longer term rest from grazing is limited and has not been summarized. We synthesized the scientific literature on long-term rest in the sagebrush steppe to evaluate the potential ecosystem effects and identify factors that influence those effects. Longer term rest is clearly advantageous compared to detrimental grazing practices (i.e., repeated defoliation during the growing season without periodic deferment or short-term rest). Changing grazing management from detrimental use to modern recommended grazing practices or dormant season use will likely convey the same benefits as long-term grazing rest in most situations. In general, long-term rest and modern properly managed grazing produce few significant differences. However, some topic areas have not been adequately studied to accurately predict the influence of long-term rest compared to managed grazing. In some situations, long-term rest may cause negative ecological effects. Not grazing can cause an accumulation of fine fuels that increase fire risk and severity and, subsequently, the probability of sagebrush steppe rangelands converting to exotic annual grasslands. One common theme we found was that shifts in plant communities (i.e., exotic annual grass invasion and western juniper encroachment), caused in part from historical improper grazing, cannot be reversed by long-term rest. This synthesis suggests that land managers should carefully consider if long-term rest will actually achieve their management goals and if a change in grazing management would achieve similar results.

---

[1] Kirk W. Davies (Kirk.Davies@oregonstate.edu) – Rangeland Scientist, USDA-Agricultural Research Service, Eastern Oregon Agricultural Research Center, Burns, OR 97720, USA

[2] Martin Vavra – Emeritus Faculty, USDA-Forest Service, Pacific Northwest Research Station and Eastern Oregon Agricultural Research Center, Oregon State University, La Grande, OR 97850, USA

[3] Brad W. Shultz – Extension Educator, University of Nevada-Reno, Winnemucca, NV 89445, USA

[4] Neil Rimbey– Professor of Agricultural Economics, University of Idaho, Caldwell, ID 83605, USA

Table of Contents

Key Points

- *Long-term rest and grazing applied based on current recommended practices generally produce similar or indistinguishable results.*
- *Shifts in sagebrush steppe plant communities to undesirable states (i.e., exotic annual grass invasion and western juniper encroachment) generally cannot be reversed by long-term rest.*
- *Long-term rest likely benefits soil biological crust, though results are not consistent and other factors (e.g., soil chemistry, fire, exotic annual grasses) are more influential than livestock grazing.*
- *Long-term rest causes an accumulation of fine fuels that increases wildfire risk and potential severity and subsequently the cost of fire suppression efforts and the likelihood of conversion to exotic annual grasslands.*
- *Wildlife response to long-term rest is highly variable among species because of their different habitat needs. Some species may benefit and other species may be negatively impacted with long-term rest from livestock grazing.*
- *The loss of a forage base with long-term rest may result in livestock producers increasing grazing pressure on other land, converting sagebrush rangelands to introduced grasslands and irrigated forage to offset forage loss, or if ranching is no longer profitable, selling their private lands for development.*

Introduction

Rest from livestock grazing is traditionally applied to provide ecosystems time to recover from past grazing influences or other disturbances (e.g., fire), as well as to provide wildlife with areas free of livestock use. Rest is frequently applied for one year as part of many grazing systems; however, intermediate (five to ten years) to long-term (more than ten years) rest has occurred or been proposed in some areas based on the assumption that it will improve ecosystem properties. Information regarding the influence of intermediate to long-term rest is limited and has not been summarized. Because the separation between intermediate and long-term rest is arbitrary and information regarding intermediate rest is especially rare, we will be discussing intermediate and long-term rest together, hereafter referred to as long-term rest. The purpose of this synthesis is to evaluate the potential ecosystem effects of long-term rest and identify factors that influence those effects.

Livestock grazing has both individual plant and ecosystem level effects. At the individual plant level, grazing during the growing season immediately removes photosynthetic tissue and may, but not always, place grazed plants at a competitive disadvantage with ungrazed plants (Caldwell, 1984; Caldwell et al., 1987; Hartnett, 1989). Adverse ecosystem effects are typically observed when repeated grazing occurs during the growing season across consecutive years. Perennial grasses have many structural and physiological adaptations that permit them to be grazed on an annual or nearly annual basis. When the frequency, intensity and timing (growing vs. dormant season) of grazing exceeds the plant's ability to recover before the next grazing event, grazing can shift the composition of a plant community towards those species that are selected less often by grazing animals. Grazing by livestock may also have indirect influences on ecosystems (e.g., altering fuels). The ultimate ecological effect depends on the magnitude of change, and its duration and spatial extent.

Advocates for removing domestic livestock (permanent long-term rest) from large tracts of the western United States often claim grazing is degrading biodiversity and wildland ecosystems (e.g., Fleischner, 1994; Donahue, 1999; Beschta et al., 2013). These authors often select literature to support their call to remove livestock and ignore literature that contradicts their position (Brussard et al., 1994; Brown & McDonald, 1995; Curtin et al., 1995; Curtin 2002). Studies claiming wide-spread damage from livestock are often evaluating historical overgrazing, which does not equate to current managed grazing (Borman, 2005). For example, when comparing moderate grazing to long-term grazing exclusion in sagebrush communities, few differences have been detected (West et al., 1984; Rickard, 1985; Courtois et al., 2004; Manier & Hobbs, 2006). Modeling current grazing management and grazing exclusion over a 141,853 hectares (350,526 acres) landscape in eastern Nevada over a twenty year period predicted grazing only had minor effects (Provencher et al., 2007). Furthermore, well-managed grazing may have some indirect ecosystem benefits, like reducing wildfire risk and potential severity, and reducing post-fire exotic annual grass invasion (Davies et al., 2009; Davies et al., 2010).

Another issue when comparing the effects of grazing and rest is that the term *grazing* is often used generically, without a description of timing (stage of plant growth), intensity (amount of leaf and stem material removed), duration (an estimate of the probability of repeated defoliation), and kind and class of grazing animal (Borman, 2005). The effects of livestock grazing on western rangelands can differ substantially by variation in these factors (e.g., Rice & Westoby, 1978; West et al., 1984; Eckert & Spencer, 1986; Eckert & Spencer, 1987; Courtois et al., 2004; Manier & Hobbs, 2006). Therefore, the probability of shifts in vegetation and other effects depends on the grazing system applied (timing, intensity, duration, etc.), plant community composition, kind and class of grazing animals, site characteristics, and interactions between grazing and other disturbances.

Rest Effects Vary by Plant Community Composition

Sagebrush steppe rangelands exist in various vegetation states depending on past management and disturbances. These include exotic annual grass-invaded, western juniper-encroached, shrub-dominated, bunchgrass-dominated, and sagebrush/bunchgrass co-dominated plant communities. Long-term rest from livestock grazing effects may vary considerably depending on the composition of the plant community.

An exotic annual grass-dominated state is one of the most serious threats to sagebrush rangelands, and one of the most difficult to restore (Davies et al., 2011). Dominance by exotic annual grasses is favored by a reduction in large perennial bunchgrasses (Davies, 2008; James et al., 2008) and an increase in fire frequency (D'Antonio & Vitousek, 1992; Chambers et al., 2007). Heavy, repeated use by domestic livestock, without periodic annual rest or at least deferment from grazing during the growing season, reduces the ability of sagebrush plant communities, particularly the more arid (typically lower elevation and/or south aspects) communities, to resist exotic annual grass invasion (Daubenmire, 1970; Mack, 1981; Knapp, 1996). In essence, the bunchgrasses are grazed so often and/or so intensely they produce less leaf material. Their roots respond by reducing the volume of soil they occupy, leaving space, water and nutrients available to invasive annual grasses. However, Svejcar and Tausch (1991) and Davies et al. (2010) also found exotic annual grasses in sagebrush communities that had not been grazed by livestock. Though prolonged, improper grazing undoubtedly contributes to the exotic annual grass problem, long-term rest from grazing is unlikely to facilitate the conversion of annual grass-dominated plant communities back to native-dominated communities. This occurs for two primary reasons: 1) the positive feedback of the annual grass-fire cycle promotes the continued dominance by annual grasses (D'Antonio & Vitousek, 1992), and 2) the general inability of native perennial seedlings to compete with, and establish in the presence of, exotic annual grasses (Harris, 1967; Melgoza et al., 1990; Clausnitzer et al., 1999; Young & Mangold, 2008). Exotic annual grass invasion has increased fires across the arid western United States (Balch et al., 2013), largely due to an increase in fine fuels that dry out earlier than native bunchgrass communities (Davies & Nafus, 2013). Establishment and persistence of perennials in annual grass-invaded plant communities will require a break in the annual grass-fire cycle (Mata-González et al., 2007). Long-term grazing rest can cause substantial accumulations (two- to three-fold increases) of fine fuels and increase the probability of more frequent fires (Davies et al., 2010). Considering the scale of invasion by annual grasses, livestock grazing is probably the only practical fine fuels management tool for breaking the annual grass-fire cycle (Figure 1). The important management question on any specific management unit being impacted by exotic annual grass invasion becomes: what grazing strategy will best achieve a reduction in exotic annual grass fuels, and also provide desired perennial species the opportunity to increase?

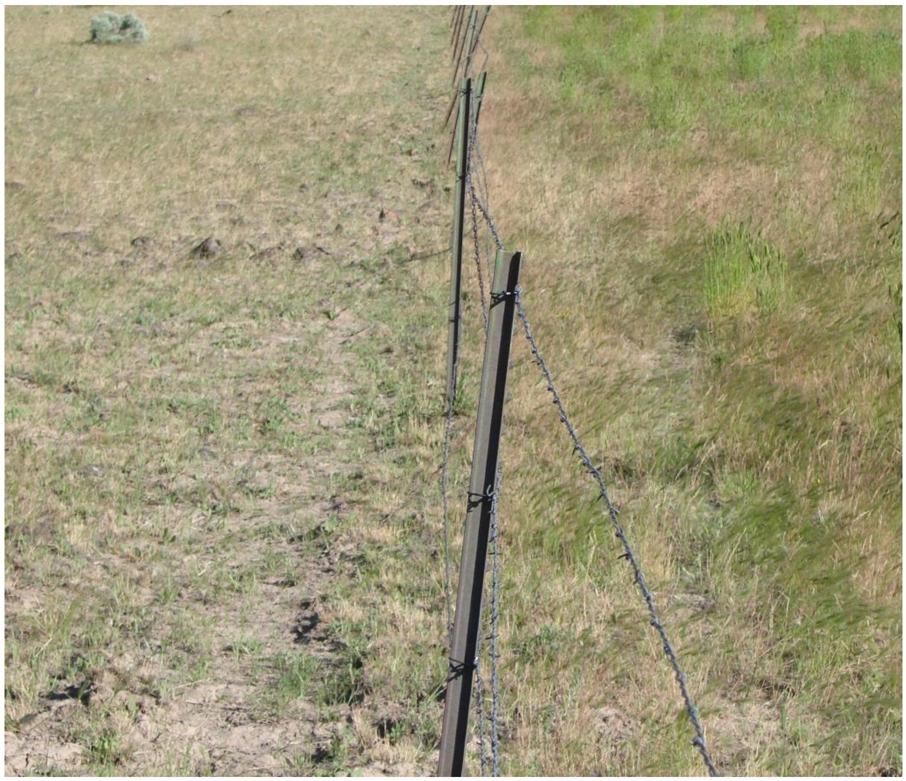

Figure 1. Photograph of livestock grazing used to reduce exotic annual grass fuels (left) and an ungrazed exotic annual grass rangeland (right). Photo by Kirk Davies.

Western juniper-dominated plant communities occupy large expanses of western rangelands. Western juniper encroachment into sagebrush communities has reduced herbaceous production, degraded wildlife habitat, and increased runoff and erosion risk (Miller et al., 2000; Bates et al., 2005; Pierson et al., 2007). The initial expansion of juniper was caused by a decline in fires due to the reduction in fine fuels from the nearly universal overstocking of western rangelands in the late 1800s (Burkhardt & Tisdale, 1969; Miller & Wigand, 1994). Concomitant with a decrease in fine fuels was the reduction of aboriginal burning practices (McAdoo et al., 2013). Subsequent encroachment by western juniper has been attributed to active fire suppression (Miller & Rose, 1995; Miller & Rose, 1999). Though historic overstocking of rangelands contributed to the juniper issue, long-term grazing rest will not restore sagebrush steppe that has been encroached upon by western juniper. Fox and Eddlemen (2003) found that juniper continued to increase with livestock exclusion in the absence of fire. During this 30-year period of livestock grazing exclusion, perennial grass cover declined 1.5% (Fox and Eddlemen 2003). Similarly, Knapp and Soulé (1998) reported that juniper cover increased 59% and perennial herbaceous cover declined 38% over a 23-year period in a sagebrush rangeland where livestock were excluded. Restoration of juniper-encroached sagebrush steppe towards roughly equal dominance of sagebrush and perennial herbaceous vegetation will require active juniper control (Miller et al., 2005). Thus, removal of livestock will neither be an effective treatment to restore the perennial herbaceous component of rangelands encroached by junipers, nor prevent further juniper encroachment.

Sagebrush-dominated plant communities with a depleted herbaceous understory may or may not recover with long-term rest from grazing. In Utah, during 45 years of rest from grazing, perennial grasses and forbs increased while mountain big sagebrush decreased (Austin & Urness, 1998). The influence of long-term rest from livestock grazing was confounded by browsing of the sagebrush by mule deer (Austin & Urness, 1998). In another study from the sagebrush semi-desert in Utah, West et al. (1984) found no significant increases in perennial grasses with long-term rest and cautioned that livestock exclusion will not result in a rapid improvement of native herbaceous plants on sites dominated by woody vegetation. Sneva et al. (1980) noted some slight increases in perennial grasses with 30 years of livestock exclusion in the sagebrush steppe, but this increase was less than what occurred on an adjacent grazed site, and after 35 years grass frequency had become slightly higher on the area outside the exclosure. Sneva et al. (1980) concluded that direct reductions in sagebrush would be required in order to greatly increase perennial grasses. In a long-term functional group removal study where grazing was excluded in southeastern Oregon, Boyd and Svejcar (2011) found that sagebrush dominance may limit perennial grass reestablishment. Though reducing sagebrush dominance may be needed to increase herbaceous vegetation, this often increases exotic annuals (Davies et al., 2012). Sagebrush communities in New Mexico rested for twenty-two years had minimal vegetation differences when compared to moderately grazed (30 to 50% use of current year's growth) areas, and what differences did appear included greater perennial grass cover in the grazed areas (Holechek & Stephenson, 1983). This suggests moderate grazing may have been beneficial. Thus, it remains unclear if long-term grazing rest will facilitate increases in the perennial herbaceous understory in communities with dense sagebrush overstories. Additional research is needed to determine the best methods to recover sagebrush communities with depleted understories and to determine how grazing interacts with those methods to influence recovery.

Most of these previously cited studies suggest that sagebrush-dominated plant communities with depleted perennial herbaceous understory will change little without a reduction in sagebrush. In contrast, Anderson and Inouye (2001) found that over a 45-year period in sagebrush rangelands in Idaho, vegetation was not static and suggested that this refuted the prediction of long-term stability with shrub dominance. Their data, however, showed a strong negative relationship between sagebrush cover and perennial grass cover in seven of the nine years sampling occurred. The data suggest negative relationships in the other two years, but lacked statistical significance. Reported differences may be due to environmental differences among sites, the level of herbaceous degradation and shrub dominance, and the interactions among these factors. Anderson and Inouye (2001) speculated that the most important factor contributing to the significant increases in herbaceous understory over the 45-year period was that viable populations of native grasses and forbs present in 1950 were able to take advantage of more favorable conditions for plant growth. In addition, shrubs may not have dominated the plant community to the point of limiting herbaceous vegetation recovery. In these areas, from 1950 to 1975, shrub cover increased 154% and perennial grass cover increased from 0.28% to 5.8% (Anderson & Holte, 1981), suggesting that the plant community was not dominated by shrubs when grazing ceased. The pattern changed from 1975 to 1995 when total shrub cover decreased from about 25% to 23% and sagebrush cover declined from 20% to 12%, while perennial grass basal cover declined from 5.8% to about 4.0% (Anderson & Inouye, 2001). Results from the second half of the 45-year study suggest that on this study area, once shrub cover reaches the 23% to 25% canopy cover, perennial grass cover is limited to a maximum range of 4% to 6%. Much of the recovery of these sites occurred before annual grasses were widespread in this area; how succession would have proceeded in these plant communities with exotic annual grass pressure remains unknown (Anderson & Inouye, 2001). Similarly, Robertson (1971) found that after 30 years of grazing exclusion, cover of most vegetation groups increased slightly. Sagebrush canopy cover increased from 4.4% to 7.8% and perennial grasses increased from 1.1% to 1.9%. Both studies suggest that once shrub cover reaches its upper limit for a specific site, perennial grass cover is unlikely to increase significantly with long-term livestock removal. An important point is that the response is often site-specific. These studies evaluated before and after measurements, and thus cannot conclusively determine if grazing exclusion was the catalyst for rangeland recovery. A change in one or more key components of grazing may well have produced a very similar response. For example, Laycock (1967) found that fall grazing (with sheep) and grazing exclusion resulted in a 30% increase in production of perennial grasses and perennial forbs compared to spring use. In this case, a change in the timing of grazing had the same effect as the long-term exclusion of grazing.

Rest may not be necessary to facilitate vegetation recovery, especially when a change in grazing management is being made to address the effects of a history of poor practices. Total live plant cover and perennial grass cover increased up to ten-fold in sagebrush and other shrub communities in Utah over the 50-year period after the passage of the Taylor Grazing Act changed livestock grazing from a year-round high intensity practice to a winter-only grazing season at substantially lower (specific amount not provided) stocking rate (Yorks et al., 1992). Exclusion of livestock and implementation of moderate grazing over a 70+ year period in sagebrush steppe plant communities resulted in essentially the same plant community, other than a buildup of fine fuels in the non-grazed areas (Davies et al. 2009). In the absence of fire, well-managed livestock grazing and long-term grazing exclusion often produce similar plant community composition, productivity, and densities.

Sagebrush/bunchgrass co-dominant plant communities (Figure 2) already have the desired vegetation composition from a resilience perspective; thus, long-term rest is unlikely to achieve any notable benefits in plant community composition. However, Beschta et al. (2013) argued that livestock grazing should be eliminated across western rangelands to

Figure 2. Photograph of relatively intact sagebrush-bunchgrass community in southeastern Oregon. Photo by Kirk Davies.

mediate for climate change based on the idea that climate change and grazing are both stressors and that two stressors are worse than one. Svejcar et al. (2014) reported that Beschta et al. (2013) was more of an opinion article and that its authors selected studies or parts of studies to support their statements instead of presenting a thorough synthesis. In addition, Beschta et al. (2013) ignored research suggesting that livestock grazing would mediate some of the impacts of climate change (e.g., Pyke & Marty, 2005; Davies et al., 2009).

Long-term rest in relatively intact plant communities may also have negative impacts. For example, Manier and Hobbs (2006) found that 42 years of grazing exclusion (both wild and domestic ungulates) decreased above-ground net primary production and biodiversity in mountain big sagebrush plant communities in Colorado.

After wildfire or other sagebrush-removing disturbances, the plant community may be dominated by perennial bunchgrasses for many decades. The length of time that sagebrush is absent from the plant community varies considerably by site environmental characteristics, distance to seed source, weather, seed bank, (Baker, 2006; Ziegenhagen & Miller, 2009) and probably livestock grazing. Livestock grazing may accelerate the recovery of sagebrush when it places herbaceous vegetation at a competitive disadvantage with sagebrush. Laycock (1967) reported that heavy spring grazing decreased herbaceous vegetation and increased sagebrush. Restoring sagebrush in areas dominated by perennial grass may require reductions in competing perennial grasses (Boyd & Svejcar, 2011). Thus, long-term rest in perennial bunchgrass-dominated communities likely prolongs the duration of the grassland state. In contrast, more intensive grazing may facilitate sagebrush reestablishment and growth by reducing competition from herbaceous plants. However, the effect of light to moderate grazing compared to long-term rest on sagebrush recovery remains relatively unknown. Long-term rest may be warranted if the management goal is to maintain sagebrush rangelands in a grass-dominated state after fire. This goal probably can also be achieved by dormant season grazing. If the goal, however, is to shift the community to a sagebrush-grass state, long-term grazing rest is likely to slow progression to this state.

Rest Influence on Soil Biological Crusts and Other Soil Characteristics

The response of soil biological crusts to long-term rest has been variable. Yeo (2005) found that grazing exclosures had higher cryptogram cover than grazed areas and that cover generally increased with the number of years of grazing exclusion. Similarly, Ponzetti and McCune (2001) reported greater crust cover and differences in composition in the grazing excluded areas compared to grazed areas. However, soil biological crusts were much more influenced by soil chemistry and climate than by grazing (Ponzetti & McCune 2001). Ponzetti et al. (2007) also reported that biological crust species richness and cover were also inversely correlated to cheatgrass cover. In contrast, biological crust cover did not differ between inside and outside 32 to 45 year-old grazing exclosures in Wyoming big sagebrush steppe (Muscha & Hild, 2006). In agreement, Manier and Hobbs (2006) found no difference in biotic crusts cover and frequency with 40-50 years of grazing exclusion compared to grazed areas. The differences in biological crusts responses to grazing exclusion are probably due to differences in grazing management and site characteristics. Though the response of soil biological crusts to long-term rest has varied, there are no direct adverse effects to soil biological crusts from long-term rest. However, soil biological crusts may be indirectly negatively impacted by long-term rest.

Long-term rest may have an adverse indirect effect on soil biological crusts because it can increase fuel loads and continuity, thereby increasing the potential for fire and cheatgrass invasion after fire (Davies et al., 2009, 2010). Soil biological crusts are known to be negatively influenced by fire (Johansen, 2001; Hilty et al., 2004) and have been reported to be negatively correlated with cheatgrass cover (Ponzetti et al. 2007). The influence of long-term rest on soil biological crusts is complicated by the potential for interactions with other disturbance, as well as site/community differences, which makes it difficult to predict the effects of long-term rest on soil biological crusts with any real certainty. However, in the absence of fire, long-term grazing rest will likely result either in no change or in increases in soil biological crusts.

Long-term grazing exclusion in sagebrush rangelands appears to have limited to no effect on soil characteristics such as soil organic matter content, carbon to nitrogen (C:N) ratio, and potential nitrogen (N) mineralization and nitrification in sagebrush rangelands. In sagebrush steppe plant communities, Shrestha and Stahl (2008) reported that grazed areas compared to areas where grazing had been excluded for 40 years had no significant differences in soil organic matter or C:N ratio. However, soil microbial carbon was greater in the grazing excluded areas, indicating that grazing may induce some differences in carbon and nutrient cycling in the soil (Shrestha & Stahl, 2008). Well-managed grazing probably results in stable accumulation and storage of soil organic carbon (Shrestha & Stahl, 2008). Manier and Hobbs (2006) found no difference in potential N mineralization and nitrification between grazed and long-term rested areas in mountain big sagebrush communities. In contrast, other soil characteristics may vary with grazing. In a literature synthesis comparing grazed and ungrazed rangelands, Jones (2000) reported lower infiltration rates and greater soil erosion in grazed areas. Jones's (2000) synthesis was not limited to sagebrush rangelands and did not account for differences in stocking rates and intensity, timing, or class of livestock, but may suggest that long-term grazing rest benefits some soil characteristics in some situations, most likely overused or mismanaged areas. We clearly do not have enough information on the influence of varying intensities, timing, stocking rates and the classes and kinds of livestock, and the interactions between these factors and disturbances on soil characteristics to fully comprehend the implications of long-term rest on soils. However, well-managed livestock grazing does not appear to have detrimental effects on soil characteristics, and thereby long-term rest from livestock grazing will probably have limited effects on soil characteristics compared to well-managed livestock grazing. In contrast, long-term rest may be quite beneficial to soils as compared to heavy livestock grazing.

Rest Effects Vary by Grazing Strategy

A compounding factor in determining the outcome of long-term rest compared to grazing is what type of grazing is occurring (i.e., what type of grazing is being compared to long-term rest). However, most literature comparing grazing to long-term rest does not adequately report details on stocking, timing, duration, and intensity of grazing (Jones, 2000). Grazing can be generally divided into two types: that which is improper and abusive, and that which is properly managed. Historic grazing in the late 1800s and early 1900s by cattle, sheep, and horses was improper, with use occurring year-round or at least during the entire growing season. During this era, many areas were grazed to degraded conditions (Mack & Thompson, 1982). Modern grazing systems incorporate periods of no grazing (deferment or short-term rest from grazing), which allows plants to periodically complete their life cycle without the physiological stress of defoliation, and also limited defoliation amounts during periods of use. This allows forage plants to maintain leaf and basal area, production potential, and to periodically reproduce (Hyder & Sawyer, 1951; Ratliff et al., 1972; Holechek et al., 1998).

For some time now range managers have understood the growth cycle of plants, the physiological states associated with growth (Hormay, 1970) and how different types of grazing may harm, benefit, or have no effect on plants. For many plant species, the most critical period for detrimental effects of grazing is floral initiation through the development of seed (Maschinski & Whitham, 1989). This period is critical because the plant's demand for photosynthetic products is high and the opportunity for regrowth is low due to declining soil moisture conditions in sagebrush communities. As a result of repeated grazing at this time, the capacity of forage plants to produce both root and shoot growth the next year may be diminished, especially if the plants are heavily grazed. Unfortunately, the best time to graze to maximize animal production is when the plant is green and growing (Vavra et al., 2014). The development of modern grazing systems incorporates this knowledge of plant physiology and animal nutritional needs so that physiological damage to the plant is minimized. Modern grazing systems use multiple management units (e.g., pastures, fields, allotments) that allow growing season use and short-term rest or deferment to be rotated among units across years to allow the plants to maintain their vigor and to reproduce. Livestock grazing in many management units is also often limited to only a portion of the growing season, further reducing the risk of repeated or intense use on most plants during that growing season.

In some regions season-long grazing is practiced effectively. These regions typically have a long grazing history whereby the plants have evolved with grazing and are tolerant of it, and have summer precipitation that allows for regrowth following grazing (Milchunas & Lauenroth, 1993). In regions with a short grazing history and therefore less tolerance to defoliation, and where summer drought occurs, forage plants are more susceptible to physiological damage from grazing (Milchunas & Lauenroth, 1993). The problem with season-long grazing in large landscape pastures is that animals have preferred areas for grazing and these patches may be heavily impacted by grazing animals (Teague & Dowhower, 2003). These areas typically occur near water and where forage is plentiful. Even under light stocking rates these areas may receive excessive use (Holechek et al., 1998; Teague & Dowhower, 2003; Reisner et al., 2013).

Critical to success of a rotation grazing system is stocking rate control (Kothman et al., 1971; Eckert & Spencer, 1987; Holechek et al., 1998). Depending on the number of pastures in the system, more animals are concentrated in one pasture than if the entire range was used season-long or continuously. Increases in stocking rate over season-long levels may not be practical. Failures of rotation grazing systems are usually related to heavy stocking rates (Holechek et al., 1998).

Though no experiments have compared a variety of different grazing management scenarios to long-term rest, it can be assumed that the outcome of long-term rest would have vastly different effects based on what grazing scenario is being replaced. Effects of modern grazing systems and long-term rest would be much more similar than either strategy compared to repeated, heavy use during the critical growing period as occurred historically.

Rest-Fire Interactions

The consumption of grasses and forbs by livestock in sagebrush communities can have substantial impact on fire risk and behavior. Comparing long-term grazing exclosures to adjacent moderately grazed areas, Davies et al. (2010) concluded that livestock grazing in the sagebrush steppe alters fine fuels, resulting in both reduced wildfire risk and potential severity. Grazing decreases fine fuel accumulations and reduces fuel continuity, subsequently reducing the likelihood of fire ignition and spread (Blackmore & Vitousek, 2000; Briggs et al., 2002; Waldram et al., 2008; Davies et al., 2010). Reducing wildfire risk is important because wildfires facilitate the conversion of invasion-prone sagebrush steppe to exotic annual grasslands (Chambers et al., 2007) and massive amounts of money and resources are spent on wildfires. Across the United States billions of dollars are expended annually on wildfire suppression, fuels management, and post-fire rehabilitation (Calkin et al., 2005; Liang et al., 2008). Since 2000, the US federal government has spent on average $1 billion or more annually on fire suppression (Liang et al., 2008; NIFC, 2013), with a significant portion of this being spent in sagebrush rangelands.

Livestock grazing may increase the effectiveness of fire suppression in sagebrush communities, though extreme fire weather and high shrub cover can limit or even eliminate this effect (Davies et al., 2010, Strand et al., 2014). The height and amount of fine fuels are positively correlated with the ability of fire to spread, especially across fuel gaps (Bradstock & Gill, 1993; Blackmore & Vitousek, 2000). Larger fuel gaps in moderately grazed sagebrush rangelands would require longer flames in order to be crossed. However, at the same time longer flame lengths are needed to carry fire across larger fuel gaps, grazing would be decreasing flame lengths by altering other fuel characteristics (Davies et al., 2010). Less fine fuel and shorter fuel height produces shorter flame lengths (Bradstock & Gill, 1993). Thus, moderate grazing affects several fuel characteristics to cumulatively decrease the flammability of sagebrush rangelands (Davies et al., 2010). The probability of burning and the continuity of the burn would be influenced by the rate of spread, which would be slower in the moderately grazed areas as compared to non-grazed areas. Blackmore and Vitousek (2000) reported that a reduction in fine fuel amounts and heights greatly suppressed the rate of fire spread. Shorter flame lengths and a reduced rate of spread in moderately grazed sagebrush rangelands would probably also increase the effectiveness of suppression efforts (Davies et al., 2010).

Long-term rest increases the likelihood of fire-induced mortality of perennial bunchgrasses because more fuel resides on the root crown of perennial bunchgrasses (Davies et al., 2009; Davies et al., 2010). Ongoing research at the Eastern Oregon Agricultural Research Center (Burns, OR), indicates that increasing fuel loads around perennial grass crowns generally increases maximum temperatures and the length of time that temperatures are elevated during a fire which cumulatively increase the potential for fire-induced mortality (work by A. Hulet et al.) Davies et al. (2009) found that post-fire exotic annual grass invasion was greater in sagebrush plant communities where livestock grazing had been excluded for more than half a century as compared to moderately grazed areas (Figure 3) because of increased fire-induced perennial grass mortality. Cattle grazing may also be used to break the exotic annual grass-fire cycle in some locations (Diamond et al., 2009). Diamond et al. (2012) also found that spring grazing can be used in combination with prescribed fall burning to reduce annual grass seed bank density and increase plant community diversity.

Large tracts of sagebrush steppe that experience long-term rest may promote more frequent and severe wildfires, which can facilitate the invasion and eventual ecological dominance of exotic annual grasses, which results in significant ecological deterioration. However, the effects of long-term rest and fire probably vary substantially with a variety of factors that include plant community composition, weather, fire behavior, and site characteristics. For example, more mesic sagebrush communities (typically higher elevation mountain big sagebrush) are much more resilient to disturbances and thus less prone to annual grass invasion (Chambers et al., 2007; Davies et al., 2011). The limited number of studies evaluating the interaction between fire and grazing on sagebrush plant communities equates to an insufficient knowledge base to adequately predict the outcome of long-term rest coupled with fire.

Figure 3. Photographs of a rangeland moderately grazed by livestock prior to fire (top) and a rangeland protected from livestock grazing (rested since 1936) (bottom) fourteen years post-fire. Treatments are adjacent to each other: note common ridge in background of photograph. Native perennial bunchgrasses dominate the rangeland grazed prior to fire, whereas cheatgrass dominates the rangeland protected from grazing prior to fire. Photos by Kirk Davies.

However, long-term rest may increase the likelihood that sagebrush rangelands will burn; this will result in fewer sagebrush-dominated areas. The loss of sagebrush rangelands due to long-term rest is likely to be detrimental to sage-grouse and other sagebrush obligate species of conservation concern.

Implications for Wildlife

Livestock grazing has often been viewed as detrimental to wildlife habitat. Historic continuous grazing that utilized most of the available forage was harmful to most wildlife species and was also detrimental to maintenance of desirable plant communities. However, on more arid ranges like the Intermountain West, seasonally controlled light or moderate livestock grazing typically has little impact on wildlife habitat (Payne & Bryant, 1994; Holechek et al., 1998). Payne and Bryant (1994) concluded that almost any grazing system was more beneficial to wildlife than continuous grazing. However, livestock grazing may still cause detrimental impacts to habitat for specific species or discrete locations on a landscape. For example, fall cattle use on deer winter range, where antelope bitterbrush is an important forage component to deer, can decrease antelope bitterbrush availability to deer. When grasses senesce and lose nutritive value cattle often switch consumption to antelope bitterbrush, which has a superior nutrient content (Lesperance et al., 1970; Ganskopp et al., 1999).

On salt desert communities in Nevada, Jones and Longland (1999) found that different levels of grazing were associated with differences in the relative abundance of some rodent species. Some species were more abundant in lightly grazed areas, but others were more abundant in heavily grazed areas. Also working with small mammals on semi-desert rangelands in Utah, Rosenstock (1996) found that treatment response, grazed versus ungrazed, varied among sites. Small mammal responses were only apparent at the macrohabitat scale. Small mammal reproductive activity and biomass were not affected by long-term rest (30+ years) from grazing at any scale. Rosenstock (1996) also reported that small mammal community composition varied greatly among sites and within treatments.

Nongame birds are a major component of the biodiversity of rangelands (Knopf, 1996). Because a large number of species potentially occur on a given landscape and have different responses to grazing or long-term exclusion, generalization for all species is not possible. Some species and populations may be favored while other are depressed (Knopf, 1996). Season of grazing can be more important than intensity of grazing: late-season grazing on dormant vegetation has little effect on bird communities (Knopf, 1996). A review of nest trampling studies by Schultz (2010) found that stocking rates on sagebrush steppe rangelands are too low for widespread nest trampling to occur. Moderate and low stocking rates of cattle grazing on bunchgrass communities in northeastern Oregon caused no negative impacts to ground-nesting songbirds (Johnson et al., 2011). These stocking rates generally provided suitable habitat for all species studied. However, high stocking rates did not provide suitable habitat for ground nesting birds.

Managed grazing systems designed for wildlife have the potential to develop and maintain habitat diversity and quality for wildlife. In cases where single-species management predominates (e.g., sage-grouse habitat or big game winter range), grazing systems specific to species' needs can be implemented. Managed grazing can have four general impacts on vegetation: 1) alter the composition of the plant community; 2) increase the productivity of selected species; 3) increase the nutritive quality of the forage; and, 4) increase the diversity of the habitat by altering its structure (Severson & Urness, 1994). Implementing a grazing management plan to enhance wildlife habitat requires an interdisciplinary approach. Knowledge of plant community dynamics, habitat requirements of affected wildlife species, and potential effects on livestock production are essential to designing a grazing plan to benefit wildlife. However, any habitat change made for one species may create adverse, neutral or beneficial changes for other species (Knopf, 1996; Vavra, 2005).

Composition and productivity of plant communities may be altered simply with a season of use change (Ganskopp et al., 1999). These authors found that moderate early season cattle grazing improved both the height and volume of antelope bitterbrush plants compared to ungrazed pastures. The nutritional quality of fall or winter forage can be improved with careful timing of spring use (Hyder & Sneva, 1963; Anderson & Scherzinger, 1975). Removing the current year's growth at the boot stage allows the plant to regrow if livestock are removed. Regrowth is interrupted by declining soil moisture that causes the plant to terminate physiological processes. The plant does not translocate nutrients back to the roots so nutrients are fixed in above ground parts providing high quality forage for ungulates. Evans (1986) demonstrated that properly timed cattle use on meadows provided regrowth of forbs that attracted sage-grouse.

Livestock do not graze rangelands uniformly; therefore, grazing can increase the structural diversity of the landscape (Vavra, 2005). Preferred foraging areas are selected for a variety of reasons and other areas are avoided for another set of characteristics. The size and extent of heavily grazed patches are primarily a function of animal numbers and duration of use. Thereby, long-term rest from grazing may also negatively impact the diversity of wildlife because the composition and structure of the vegetation of the ungrazed landscape can be rather homogeneous, particularly on landscapes that lack physiographic diversity. Anderson and Scherzinger (1975) stated that in some instances judicious grazing is essential to maintaining good wildlife habitat. Grazing modifies the vertical structure and canopy cover of the herbaceous layer, creating a patchy landscape of varying height and cover, attributes important to wildlife (Payne & Bryant, 1994). Likewise, Morrow et al. (1996) described grazing as a tool to increase habitat diversity (compared to landscapes rested from grazing) by the interspersion of open areas within grassland structure, and further suggested that recent declines in Attwater's prairie chicken were due to insufficient livestock grazing. On sagebrush-bunchgrass ranges that have burned and become perennial grasslands that cover tens to hundreds of thousands of hectares, managed grazing is one of the few practical tools available to create heterogeneity in the vegetation structure (Figure 4).

Figure 4. Former sagebrush-bunchgrass rangeland one-year after a 218,000 ha wildfire in the sagebrush steppe region (Owyhee Desert) of southeast Oregon. The lack of physiographic structure results in a relatively homogeneous bunchgrass-forb community across much of the burned area. Photo by Brad Schultz.

A word of caution is warranted here. Scientific evidence about grazing effects on wildlife has often been flawed by: 1) poor design of studies (i.e., inadequate controls or replications); 2) abusively grazed sites carelessly construed to represent proper grazing management; and, 3) investigator advocacy for a fisheries or wildlife resource (Knopf, 1996). The published literature on grazing effects on waterfowl and nongame birds are dominated by papers not subjected to critical review by peers (Knopf, 1996). In contrast, Johnson et al. (2011) serves as an example of a grazing study that provides cattle stocking rate levels and the impacts on both vegetation structure and songbird population and nesting.

The idea of eliminating livestock grazing to improve wildlife habitat ignores the complexity of ecosystem dynamics. Wildlife species vary greatly in their habitat needs, with some requirements varying temporally and by sex. This strongly suggests that some species would benefit while others species would be harmed by long-term grazing rest. The interaction between grazing and other disturbances also affects wildlife habitat values (Fuhlendorf & Engle, 2004; Davies et al., 2009). For example, livestock grazing can reduce the hiding cover for sage-grouse; however, long-term rest can increase the risk of wildfire which would eliminate sagebrush from the community, making the rangeland unsuitable for sage-grouse until sagebrush recovers (Davies et al., 2009; Davies et al. 2010). To ensure management goals will be achieved, careful consideration of various wildlife species habitat needs and the potential interactions of grazing rest with disturbances on habitat characteristics is needed before implementing long-term rest.

Dormant Season Use Compared to Long-Term Rest

Situations may arise where vegetation selected by grazers is reduced sufficiently to warrant long-term rest or long-term growing season grazing deferment. Mueggler (1975) reported that bluebunch wheatgrass and Idaho fescue, which were classified as being in moderately low vigor, required three and six years to recover, respectively. When categorized as very low in vigor, these same species required six and eight years, respectively, to recover (Mueggler, 1975). An alternative to complete rest from grazing is dormant season grazing (i.e., grazing when the desired forage plants are dormant). The dormant period is the least critical period for forage removal (Holechek et al., 1998) because the plant is photosynthetically inactive. Moderate grazing during this time period is likely a surrogate for complete rest. However, heavy grazing even during dormancy can have detrimental effects on plants and future forage production (Holechek et al., 1998). Hyder (1953) found that maintaining 224 kg/hectare (200 lbs/acre) of residual forage maintained or improved range conditions on most sites in southeastern Oregon. Also, dormant season forage generally does not meet the nutritional requirements of livestock (Vavra et al., 2014) and therefore, some form of feed supplement may be required.

Moderate dormant season use is in most instances an acceptable alternative to long-term rest. With dormant season use, herbaceous vegetation can recover from previous disturbance without eliminating the forage base. However, there are situations where dormant season use may not be a good alternative to long-term rest. If maintaining high amounts of the previous years' herbaceous growth is a management goal, then long-term rest would be more effective than dormant season use.

Potential Management Actions in Response to Long-Term Rest

The direct and indirect impact of long-term rest on public rangelands can extend beyond the area rested and include large tracts of private land that are linked to public rangelands. The effects of long-term rest must be looked at in the context of the entire complex of management units (often public grazing allotments and associated private ranches). Long-term rest on public lands may have some unintended consequences as livestock producers look for alternative means to compensate for the loss of forage. Some livestock producers may reduce their animal numbers to match their reduced forage base, but others may simply use their remaining forage base more intensively. Heavier utilization or longer seasons of use will likely degrade remaining grazed rangelands and encourage exotic plant invasions. Livestock producers may offset the reduction in their forage base by converting sagebrush rangelands to introduced grasslands or irrigated fields to increase forage production. This may further imperil sagebrush-associated wildlife species by degrading and fragmenting more of the sagebrush ecosystem (Davies et al., 2011). The effect of long-term rest on the entire complex of management units will vary considerably by the goals and values of the livestock producer(s), and the ratio of the amount of land being rested to available forage. Some livestock producers may go out of business if significant amounts of their forage base are rested long-term. The loss of profitable ranches increases the risk of anthropogenic development; unprofitable ranches will be sold and most likely developed (Wilkins et al., 2003). The conversion of ranches into ex-urban development lands degrades wildlife habitat and increases exotic species invasion (Knight et al., 1995; Maestas et al., 2003). Thus, the effects of long-term rest are complex (biological, economic and social) when evaluated across large landscapes, and what happens on one unit of land may significantly affect nearby land units.

Another issue regarding long-term rest, especially on public land, is the cost of ongoing maintenance of infrastructure that had been previously provided by the livestock producer. Fence maintenance and repair will still be required to meet management objectives. Water developments will need periodic checking and maintenance if they are to continue to be used by wildlife or by livestock at some future time. Livestock producers often spend considerably more time on the ground in their leases than do public land managers and producers are thus a valuable source of information regarding a suite of resource management issues. Livestock producers possess embedded knowledge from close contact with the land and from observing natural processes on a given site, often over several decades, and can provide insight and site-specific information about the lands used in their operations (Knapp & Fernandez-Gimenez, 2009).

Economic Implications of Long-Term Rest from Grazing

Estimating the economic impacts of management scenarios, feasibility of improvement practices, and policy alternatives has a long history in the range management profession. The benefits and costs of alternative management strategies must be considered by public and private land managers *(see* Torell et al., 2014*, for more detail on economic analysis associated rangeland issues)*. Rest from grazing carries numerous potential economic impacts to the rancher and land management entity.

These economic impacts are dependent upon a number of factors which vary based upon the financial situation of individual ranches, the period of rest, stocking rates, and alternative forage resources of the ranches. Short-term rest (e.g., 1-3 years) may be feasible on ranches with excess capacity in some of their other forage resources (e.g., private rangeland, pasture and hayland, leased forage sources). Short-term adjustments will be made by ranches, usually in an effort to maintain the cow herd at current or slightly reduced levels of production. As VanTassell and Richardson (1998) found, ranchers will do all that they can in the short run to maintain the cow herd and continue operation. Ranch operators are willing to increase costs in the short run to purchase additional hay, lease grazing grounds, and other alternatives, to maintain herd size. Maintaining an economical unit or herd size above what it takes to pay for fixed costs is essential for sustainable operations. This is also dependent upon the degree to which individual ranches are leveraged (relying upon borrowed capital for purchase of assets and/or operating funds). Lending institutions may view long-term rest as permanent retirement and choose to sell the ranch assets to minimize their losses and/or recoup their investment. In some cases, subdivision of the ranch base property may also occur (Sengupta & Osgood, 2003). Short-term rest is usually acceptable to private ranches (VanTassell & Richardson, 1998), with some assurances from the management agencies that the rested parcels will be part of the long-term management of the ranch's forage base.

Long-term rest is essentially a retirement of the grazing resource. If the ranch has to reduce herd size to adjust to the loss of public land allotments, this loss of forage resources erodes the asset value of the ranch. Public land grazing permits and some leases (e.g., state endowment land grazing leases) have value in the real estate market (Rimbey et al., 2007). These permits can be transferred as part of a sale of the ranch unit or as separate entities or holdings. Rimbey et al. (2007) specified numerous factors that influenced Great Basin permit values and found that the permits did not have a contributory value until about 25% of the year-round forage needs were derived from the permits. Numerous studies (summarized in Torell et al., 2014) have been done over the years estimating the economic impact of federal forage reductions. Generally, the ranch-level economic losses are in the range of $12-25/AUM (Torell et al., 2002; Rimbey et al., 2003; Taylor et al., 2005).

In many cases, the analysis of rest from grazing pressure involves the consideration of non-market benefits and costs. Critical environmental factors such as reduced sedimentation, streambank stability, protection of threatened and endangered species, and others are important, yet determining and measuring their economic impact is difficult (Torell et al., 2013).

Finally, maintenance of infrastructure (rangeland improvements such as fences, water developments, seedings and others) is an important consideration for land managers delving into the issue of rest from grazing. With the assumption of infrastructure maintenance by the public land permittees, continual maintenance is critical, even in the absence of grazing. In many cases, infrastructure provides economic benefits to other users of the public lands. Springs and water developments designed for livestock use may also provide water and habitat for wildlife. In many cases, protection of the investment in infrastructure through periodic maintenance includes a substantial cost. Torell et al. (1993) reported on non-fee costs of public and private land grazing activities in New Mexico, Wyoming and Idaho. These authors found the public land permittees invested $3.18/AUM in maintenance duties on their public land allotments during 1992. Private lessees of forage in the three states invested $1.84/AUM on infrastructure maintenance that same year. Rimbey and Torell (2011) updated these costs to 2011 figures and found that public land maintenance had risen to $5.48/AUM and private land maintenance increased to $3.38/AUM. These levels of cost indicate maintenance is a critical consideration for land managers, if protection of infrastructure investments is important.

Economic analysis of applying rest from grazing is critical and should be done in conjunction with the analysis of the physical aspects of these proposals and management strategies. From an economics perspective, it is critical to distinguish between short- and long-term rest. It is also critical to consider the non-market benefits and costs of alternative strategies, along with factors such as infrastructure maintenance.

Summary and Knowledge Gaps

Long-term rest can alter sagebrush communities; these changes may be beneficial to some organisms and detrimental to others. However, once sagebrush communities have shifted to undesirable states (i.e., annual grass-dominated, conifer-encroached, etc.), long-term rest is unlikely to reverse these shifts. Long-term rest is clearly advantageous compared to heavy, unmanaged grazing, but generally produces similar results as grazing applied based on current recommended practices. Thus, land managers need to carefully consider if long-term rest will achieve their management goals and if better management practices will achieve similar results. Long-term rest also comes with some risks. Long-term rest causes an accumulation of fine fuels that increases wildfire risk, potential severity, and subsequently the cost of fire suppression efforts and the likelihood of conversion to exotic annual grasslands. However, the interaction between long-term rest and wildfire is under-studied and needs to be further investigated. For example, information on the impacts of long-term grazing rest on wildfire risk and severity in exotic annual grass-invaded sagebrush rangelands is lacking. Wildlife species' responses to long-term rest vary because species have differing habitat needs. Thus, additional research is needed to determine species responses to long-term rest and how responses vary by the interaction between long-term rest and wildfire. Long-term grazing rest can have significant negative economic impacts, with the magnitude varying depending on the options livestock producers have to compensate for lost forage and the amount of area being rested. If ranches become unprofitable due to the loss of a forage base from long-term rest, then they will likely be sold and potentially developed. In conclusion, long-term rest can be beneficial, harmful or inconsequential depending on the response variable(s) of concern, the current state of the plant community, the interaction with wildfire, and what type of grazing management is being replaced with long-term rest.

Acknowledgements

This manuscript was requested and supported by the Owyhee Initiative (www.owyheeinitiative.org/). The work of these authors was also supported by the USDA-Agricultural Research Service, the Agricultural Experiments Stations of Idaho, and the University of Nevada Cooperative Extension.

Common and Scientific Names of Plants Listed in Text According to the USDA PLANTS Database (http://www.plants.usda.gov/).

Common Name	Scientific Name
Wyoming big sagebrush	*Artemisia tridentata Nutt.* ssp. *wyomingensis* Beetle & Young
Western juniper	*Juniperus occidentalis* Hook
Cheatgrass	*Bromus tectorum* L.
Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) Á. Löve
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Idaho fescue	*Festuca idahoensis* Elmer
Mountain big sagebrush	*Artemisia tridentata* Nutt*. spp. vaseyana* (Rydb.) Beetle
Antelope bitterbrush	*Purshia tridentata* (Pursh) DC.

Common and Scientific Names of Animals Listed in Text According to the Integrated Taxonomic Information System (www.itis.gov).

Common Name	Scientific Name
Attwater's prairie chicken	*Tympanuchus cupido attwateri*
Cattle, cow	*Bos Taurus*
Deer	*Odocoileaus* spp.
Horse	*Equus caballus*
Mule deer	*Odocoileus hemionus*
Sage grouse	*Centrocercus urophasianus*
Sheep	*Ovis aires*

Literature Cited

Anderson, E. W., & Scherzinger, R. J. (1975). Improving quality of winter forage for elk by cattle grazing. *Journal of Range Management, 28*(2), 120-125. doi:10.2307/3897442

Anderson, J. E., & Holte, K. E. (1981). Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *Journal of Range Management, 34*(1), 25-29. http://dx.doi.org/10.2307/3898446

Anderson, J. E., & Inouye, R. S. (2001). Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. *Ecological Monographs, 71*(4), 531-556. http://dx.doi.org/10.2307/3898446

Austin, D. D., & Urness, P. J. (1998). Vegetal change on a northern Utah foothill range in the absence of livestock grazing between 1948 and 1982. *Western North American Naturalist, 58*(2), 188-191.

Baker, W. L. (2006). Fire and restoration of sagebrush ecosystems. *Wildlife Society Bulletin, 34*(1), 177-185. doi:10.2193/0091-7648(2006)34[177:FAROSE]2.0.CO;2

Balch, J. K., Bradley, B. A., D'Antonio, C. M., & Gómez-Dans, J. (2013). Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). *Global Change Biology, 19*(1), 173-183. doi:10.1111/gcb.12046

Bates, J. D., Miller, R. F., & Svejcar, T. (2005). Long-term successional trends following western juniper cutting. *Rangeland Ecology & Management, 58*(5), 533-541. doi:10.2111/1551-5028(2005)58[533:LSTFWJ]2.0.CO;2

Beschta, R. L., Donahue, D. L., DellaSala, D. A., Rhodes, J. J., Karr, J. R., O'Brien, M. H., Fleischner, T. L., & Williams, C. D. (2013). Adapting to climate change on western public lands: Addressing the ecological effects of domestic, wild, and feral ungulates. *Environmental Management, 51*(2), 474-491. doi:10.1007/s00267-012-9964-9

Blackmore, M., & Vitousek, P. M. (2000). Cattle grazing, forest loss, and fuel loading in a dry forest ecosystem at Pu'u Wa'aWa'a Ranch, Hawai'i. *Biotropica, 32*(4a), 625-632. doi:10.1111/j.1744-7429.2000.tb00509.x

Borman, M. M. (2005). Forest stand dynamics and livestock grazing in historical context. *Conservation Biology, 19*(5), 1658-1662. doi:10.1111/j.1523-1739.2005.00115.x

Boyd, C. S., & Svejcar, T. J. (2011). The influence of plant removal on succession in Wyoming big sagebrush. *Journal of Arid Environments, 75*(8), 734-741. doi:10.1016/j.jaridenv.2011.03.008

Bradstock, R. A., & Gill, A. M. (1993). Fire in semiarid, mallee shrublands-size of flames from discrete fuel arrays and their role in the spread of fire. *International Journal of Wildland Fire, 3*(1), 3-12. doi:10.1071/WF9930003

Briggs, J. M., Hoch, G. A., & Johnson, L. C. (2002). Assessing the rate, mechanisms, and consequences of the conversion of tallgrass prairie to *Juniperus virginiana* forest. *Ecosystems, 5*(6), 578-586. doi:10.1007/s10021-002-0187-4

Brown, J. H., & McDonald, W. (1995). Livestock grazing and conservation on southwestern rangelands. *Conservation Biology, 9*(6), 1644-1647. doi:10.1046/j.1523-1739.1995.09061644.x

Brussard, P. F., Murphy, D. D., & Tracy, C. R. (1994). Cattle and conservation biology--another view. *Conservation Biology, 8*(4), 919-921. doi:10.1046/j.1523-1739.1994.08040919.x

Burkhardt, J. W., & Tisdale, E. W. (1969). Nature and successional status of western juniper vegetation in Idaho. *Journal of Range Management, 22*(4), 264-270. doi:10.2307/3895930

Caldwell, M. M. (1984). Plant requirements for prudent grazing. In National Research Council, & National Academy of Sciences, *Developing strategies for rangeland management* (pp. 117-152). Boulder, CO, USA: Westview Press.

Caldwell, M. M., Richards, J. H., Manwaring, J. H., & Eissenstat, D. M. (1987). Rapid shifts in phosphate acquisition show direct competition between neighboring plants. *Nature, 327*(6123), 615-616. doi:10.1038/327615a0

Calkin, D. E., Gebert, K. M., Jones, J. G., & Neilson, R. P. (2005). Forest Service large fire area burned and suppression expenditure trends, 1970-2002. *Journal of Forestry, 103*(4), 179-183.

Chambers, J. C., Roundy, B. A., Blank, R. R., Meyer, S. E., & Whittaker, A. (2007). What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*?. *Ecological Monographs, 77*(1), 117-145. doi:10.1890/05-1991

Clausnitzer, D. W., Borman, M. M., & Johnson, D. E. (1999). Competition between *Elymus elymoides* and *Taeniatherum caput-medusae*. *Weed Science, 47*(6), 720-728. Stable URL: http://www.jstor.org/stable/4046140

Courtois, D. R., Perryman, B. L., & Hussein, H. S. (2004). Vegetation change after 65 years of grazing and grazing exclusion. *Journal of Range Management, 57*(6), 574-582. doi:10.2307/4004011

Curtin, C. G. (2002). Livestock grazing, rest, and restoration in arid landscapes. *Conservation Biology, 16*(3), 840-842. doi:10.1046/j.1523-1739.2002.01212.x

Curtin, C. G., Fleischner, T. L., Haas, C. A., Fraser, J. D., Noss, R., Wuerthner, G., Belsky, J., Willers, B., Brussard, P. f., Murphy, D. D., & Tracy, C. R. (1995). Grazing and advocacy. *Conservation Biology, 9*(2), 233-239. doi:10.1046/j.1523-1739.1995.9020233.x

D'Antonio, C. M., & Vitousek, P. M. (1992). Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics, 23*, 63-87. doi:10.1146/annurev.es.23.110192.000431

Daubenmire, R. (1970). *Steppe vegetation of Washington* (Technical Bulletin No. 62). Pullman, WA, USA: Washington State University, Washington Agricultural Experiment Station.

Davies, K. W. (2008). Medusahead dispersal and establishment in sagebrush steppe plant communities. *Rangeland Ecology & Management, 61*(1), 110-115. doi:10.2111/07-041R2.1

Davies, K. W., & Nafus, A. M. (2013). Exotic annual grass invasion alters fuel amounts, continuity and moisture content. *International Journal of Wildland Fire*, *22*(3), 353-358. doi:10.1071/WF11161

Davies, K. W., Svejcar, T. J., & Bates, J. D. (2009). Interaction of historical and nonhistorical disturbances maintains native plant communities. *Ecological Applications, 19*(6), 1536-1545. doi:10.1890/09-0111.1

Davies, K. W., Bates, J. D., Svejcar, T. J., & Boyd, C. S. (2010). Effects of long-term livestock grazing on fuel characteristics in rangelands: An example from the sagebrush steppe. *Rangeland Ecology & Management, 63*(6), 662-669. doi:10.2111/REM-D-10-00006.1

Davies, K. W., Boyd, C. S., Beck, J. L., Bates, J. D., Svejcar, T. J., & Gregg, M. A. (2011). Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities. *Biological Conservation, 144*(11), 2573-2584. doi:10.1016/j.biocon.2011.07.016

Davies, K. W., Bates, J. D., & Nafus, A. M. (2012). Mowing Wyoming big sagebrush communities with degraded herbaceous understories: Has a threshold been crossed? *Rangeland Ecology & Management, 65*(5):498-505. doi:10.2111/REM-D-12-00026.1

Diamond, J. M., Call, C. A., & Devoe, N. (2009). Effects of targeted cattle grazing on fire behavior of cheatgrass-dominated rangeland in the northern Great Basin, USA. *International Journal of Wildland Fire, 18*(8), 944-950. doi:10.1071/WF08075

Diamond, J. M., Call, C. A., and Devoe, N. (2012). Effects of targeted grazing and prescribed burning on community and seed dynamics of downy brome (*Bromus tectorum*)-dominated landscapes. *Invasive Plant Science and Management, 5*(2), 259-269. doi:10.1614/IPSM-D-10-00065.1

Donahue, D.L. 1999. *The western range revisited: Removing livestock from public lands to conserve native biodiversity* (Vol 5). Norman, OK, USA: University of Oklahoma Press.

Eckert Jr, R. E., & Spencer, J. S. (1986). Vegetation response on allotments grazed under rest-rotation management. *Journal of Range Management, 39*(2), 166-174. doi:10.2307/3899292

Eckert Jr, R. E., & Spencer, J. S. (1987). Growth and reproduction of grasses heavily grazed under rest-rotation management. *Journal of Range Management, 40*(2), 156-159. doi:10.2307/3899210

Evans, C. C. (1986). *The relationship of cattle grazing to sage-grouse use of meadow habitat on the Sheldon National Wildlife Refuge* (Master's thesis). University of Nevada, Reno, NV, USA.

Fleischner, T. L. (1994). Ecological costs of livestock grazing in western North America. *Conservation Biology, 8*(3), 629-644. doi:10.1046/j.1523-1739.1994.08030629.x

Fox, M. A., & Eddleman, L. E. (2003). A time comparison study of vegetation on the Island Research Natural Area in central Oregon. *Northwest Science, 77*(3), 246-254.

Fuhlendorf, S. D., & Engle D. M. (2004). Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology, 41*(4), 604-614. doi:10.1111/j.0021-8901.2004.00937.x

Ganskopp, D., Svejcar, T., Taylor, F., Farstvedt, J., & Paintner, K. (1999). Seasonal cattle management in 3 to 5 year old bitterbrush stands. *Journal of Range Management, 52*(2), 166-173. doi:10.2307/4003512

Harris, G. A. (1967). Some competitive relationships between *Agropyron spicatum* and *Bromus tectorum*. *Ecological Monographs, 37*(2), 89-111. doi:10.2307/2937337

Hartnett, D. C. (1989). Density-and growth stage-dependent responses to defoliation in two rhizomatous grasses. *Oecologia, 80*(3), 414-420. doi:10.1007/BF00379045

Hilty, J. E., Eldridge, D. J., Rosentreter, R., Wicklow-Howard, M. C., & Pellant, P. (2004). Recovery of biological soil crust following wildfire in Idaho. *Journal of Range Management, 57*(1) 89-96. doi:10.2307/4003959

Holechek, J. L., & Stephenson, T. (1983). Comparison of big sagebrush vegetation in northcentral New Mexico under moderately grazed and grazing excluded conditions. *Journal of Range Management, 36*(4), 455-456. doi:10.2307/3897939

Holechek, J. L., Pieper, R. D., & Herbel, C. H. (1998). *Range management: Principles and pract*ices. Upper Saddle River, NJ, USA: Prentice-Hall.

Hormay, A.L. (1970). *Principles of rest-rotation grazing and multiple use land management* (Training Text No. 4[2200]). Washington, DC, USA: USDA, Forest Service.

Hyder, D. N. (1953). Grazing capacity as related to range condition. *Journal of Forestry, 51*(3), 206.

Hyder, D.N., & Sawyer, W.A. (1951) Rotation-deferred grazing as compared to season-long grazing on sagebrush-bunchgrass range in southeastern Oregon. *Journal of Range Management, 4*(1), 30-34. doi:10.2307/3894429

Hyder, D. N., & Sneva, F. A. (1963). Morphological and physiological factors affecting the grazing management of crested wheatgrass. *Crop Science, 3*(26), 267-271. doi:10.2135/cropsci1963.0011183X000300030030x

James, J. J., Davies, K. W., Sheley, R. L., & Aanderud, Z. T. (2008). Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. *Oecologia, 156*(3), 637-648. doi:10.1007/s00442-008-1015-0

Johansen, J. R. (2001). Impacts of fire on biological soil crusts. In J. Belnap & O. Lange (Eds.), *Biological soil crusts: Structure, function and management* (pp. 385-400). Ecological Studies, Vol. 150. Berlin, Heidlberg, Germany: Springer Verlag.

Johnson, T. N., Kennedy, P. L., DelCurto, T., & Taylor, R. V. (2011). Bird community responses to cattle stocking rates in a Pacific Northwest bunchgrass prairie. *Agriculture, Ecosystems & Environment, 144*(1), 338-346. doi:10.1016/j.agee.2011.10.003

Jones, A. (2000). Effects of cattle grazing on North American arid ecosystems: A quantitative review. *Western North American Naturalist, 60*(2), 155-164.

Jones, A. L., & Longland, W. S. (1999). Effects of cattle grazing on salt desert rodent communities. *The American Midland Naturalist, 141*(1), 1-11. doi:10.1674/0003-0031(1999)141[0001:EOCGOS]2.0.CO;2

Knapp, C. N., & Fernandez-Gimenez, M. E. (2009) Knowledge in practice: Documenting rancher local knowledge in northwestern Colorado. *Rangeland Ecology & Management*, *62*(6), 500-509. doi:10.2111/08-175.1

Knapp, P. A. (1996). Cheatgrass (*Bromus tectorum* L.) dominance in the Great Basin Desert: History, persistence, and influences to human activities. *Global Environmental Change, 6*(1), 37-52. doi:10.1016/0959-3780(95)00112-3

Knapp, P., & Soulé, P. T. (1998). Recent *Juniperus occidentalis* (western juniper) expansion on a protected site in central Oregon. *Global Change Biology, 4*(3), 347-357. doi:10.1046/j.1365-2486.1998.00160.x

Knight, R. L., Wallace, G. N., & Riebsame, W. E. (1995). Ranching the view: Subdivisions versus agriculture. *Conservation Biology, 9*(2), 459-461. doi:10.1046/j.1523-1739.1995.9020459.x

Knopf, F. L. (1996). Perspectives on grazing nongame bird habitats. In P. R. Krausman, (Ed.), *Rangeland wildlife* (pp. 51-58). Denver, CO, USA: Society for Range Management.

Kothman, M. M., Mathis, G. M., & Waldrip, W. J. (1971). Cow-calf response to stocking rates and grazing systems on native range. *Journal of Range Management, 24*(2), 100-105. doi: 10.2307/3896514

Laycock, W. A. (1967). How heavy grazing and protection affect sagebrush-grass ranges. *Journal of Range Management, 20*(4), 206-213. doi:10.2307/3896253

Lesperance, A. L., Tueller, P. T., & Bohman, V. R. (1970). Symposium on pasture methods for maximum production in beef cattle: Competitive use of the range forage resource. *Journal of Animal Science, 30*(1), 115-121.

Liang, J., Calkin, D. E., Gebert, K. M., Venn, T. J., & Silverstein, R. P. (2008). Factors influencing large wildland fire suppression expenditures. *International Journal of Wildland Fire, 17*(5), 650-659. doi:10.1071/WF07010

Mack, R. N. (1981). Invasion of *Bromus tectorum* L. into Western North America: An ecological chronicle. *Agro-ecosystems, 7*(2), 145-165. doi:10.1016/0304-3746(81)90027-5

Mack, R. N., & Thompson, J. N. (1982). Evolution in steppe with few large, hooved mammals. *American Naturalist*, *119*(6), 757-773. doi:10.1086/283953

Maestas, J. D., Knight, R. L., & Gilgert, W. C. (2003). Biodiversity across a rural land-use gradient. *Conservation Biology, 17*(5), 1425-1434. doi:10.1046/j.1523-1739.2003.02371.x

Manier, D. J., & Hobbs, N. T. (2006). Large herbivores influence the composition and diversity of shrub-steppe communities in the Rocky Mountains, USA. *Oecologia, 146*(4), 641-651. doi:10.1007/s00442-005-0065-9

Maschiniski, J., & Whitham, T. G. (1989). The continuum of plant responses to herbivory: The influence of plant association, nutrient availability, and timing. *American Naturalist 134*(1), 1-19. doi:10.1086/284962

Mata-Gonzalez, R. R. G. H., Hunter, R. G., Coldren, C. L., McLendon, T., & Paschke, M. W. (2007). Modelling plant growth dynamics in sagebrush steppe communities affected by fire. *Journal of Arid Environments, 69*(1), 144-157. doi:10.1016/j.jaridenv.2006.09.010

McAdoo, J. K., Schultz, B. W., & Swanson, S. R. (2013). Aboriginal precedent for active management of sagebrush-perennial grass communities in the Great Basin. *Rangeland Ecology & Management, 66*(3), 241-253. doi:10.2111/REM-D-11-00231.1

Melgoza, G., Nowak, R. S., & Tausch, R. J. (1990). Soil water exploitation after fire: Competition between *Bromus tectorum* (cheatgrass) and two native species. *Oecologia, 83*(1), 7-13. doi:10.1007/BF00324626

Milchunas, D. G., & Lauenroth, W. K. (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs, 63*(4), 327-366. doi:10.2307/2937150

Miller, R. F. & Rose, J. R. (1995). Historic expansion of *Juniperus occidentalis* southeastern Oregon. *Great Basin Naturalist, 55*(1), 37-45.

Miller, R. F., & Rose, J. A. (1999). Fire history and western juniper encroachment in sagebrush steppe. *Journal of Range Management, 52*(6), 550-559. doi:10.2307/4003623

Miller, R. F., & Wigand, P. E. (1994). Holocene changes in semiarid pinyon-juniper woodlands. *BioScience, 44*(7), 465-474. doi:10.2307/1312298

Miller, R. F., Svejcar, T. J., & Rose, J. A. (2000). Impacts of western juniper on plant community composition and structure. *Journal of Range Management, 53*(6), 574-585. doi:10.2307/4003150

Miller, R. F., Bates, J. D., Svejcar, A. J., Pierson Jr, F. B., & Eddleman, L. E. (2005*). Biology, ecology, and management of western juniper* (*Juniperus occidentalis*) (Bulletin No. 152). Corvallis, OR, USA: Oregon State University Agricultural Experiment Station.

Morrow, M. E., Adamcik, R. S., Friday, J. D., & McKinney, L. B. (1996). Factors affecting Attwater's prairie-chicken decline on the Attwater Prairie Chicken National Wildlife Refuge. *Wildlife Society Bulletin, 24*(4), 593-601.

Mueggler, W. F. (1975). Rate and pattern of vigor recovery in Idaho fescue and bluebunch wheatgrass. *Journal of Range Management, 28*(3), 198-204. doi:10.2307/3897525

Muscha, J. M., & Hild, A. L. (2006). Biological soil crusts in grazed and ungrazed Wyoming sagebrush steppe. *Journal* *of Arid Environments, 67*(2), 195-207. doi:10.1016/j.jaridenv.2006.02.010

NIFC [National Interagency Fire Center] (2013) Fire information –wildland fire statistics. http://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf

Payne, N. F., & Bryant, F. C. (1994). *Techniques for wildlife habitat management of uplands*. New York, NY, USA: McGraw-Hill, Inc.

Pierson, F. B., Bates, J. D., Svejcar, T. J., & Hardegree, S. P. (2007). Runoff and erosion after cutting western juniper. *Rangeland Ecology & Management, 60*(3), 285-292. doi:10.2111/1551-5028(2007)60[285:RAEACW]2.0.CO;2

Ponzetti, J. M., & McCune, B. P. (2001). Biotic soil crusts of Oregon's shrub steppe: Community composition in relation to soil chemistry, climate, and livestock activity. *The Bryologist, 104*(2), 212-225. doi:10.1639/0007-2745(2001)104[0212:BSCOOS]2.0.CO;2

Ponzetti, J. M., McCune, B., & Pyke, D. A. (2007). Biotic soil crusts in relation to topography, cheatgrass and fire in the Columbia Basin, Washington. *The Bryologist, 110*(4), 706-722. doi:10.1639/0007-2745(2007)110[706:BSCIRT]2.0.CO;2

Provencher, L., Forbis, T. A., Frid, L., & Medlyn, G. (2007). Comparing alternative management strategies of fire, grazing, and weed control using spatial modeling. *Ecological Modelling, 209*(2), 249-263. doi:10.1016/j.ecolmodel.2007.06.030

Pyke, C. R., & Marty, J. (2005). Cattle grazing mediates climate change impacts on ephemeral wetlands. *Conservation Biology, 19*(5), 1619-1625. doi:10.1111/j.1523-1739.2005.00233.x

Ratliff, R. D., Reppert, J. N., & McConnen, R. J. (1972). *Rest-rotation grazing at Harvey Valley: Range health, cattle gains, costs* (Research Paper No. 77). Berkeley, CA, USA: Pacific Southwest Forest and Range Experiment Station, Forest Service, US Department of Agriculture.

Reisner, M. D., Grace, J. B., Pyke, D. A., & Doescher, P. S. (2013) Conditions favoring *Bromus tectorum* dominance of endangered sagebrush steppe ecosystems. *Journal of Applied Ecology, 50*(4), 1039-1049. doi:10.1111/1365-2664.12097

Rice, B., & Westoby, M. (1978). Vegetative responses of some Great Basin shrub communities protected against jackrabbits or domestic stock. *Journal of Range Management, 31*(1), 28–34. doi:10.2307/3897627

Rickard, W. H. (1985). Experimental cattle grazing in a relatively undisturbed shrubsteppe community. *Northwest Science, 59*(1), 66-72.

Rimbey, N.R. & Torell, L.A. 2011. *Grazing costs: What's the current situation?* Moscow, ID, USA: University of Idaho, Department of Agricultural Economics & Rural Sociology. AEE series 2011-02. Available online at: http://web.cals.uidaho.edu/idahoagbiz/files/2013/01/GrazingCost2011.pdf

Rimbey, N. R., Darden, T. D., Torell, L. A., Tanaka, J. A., Van Tassell, L. W., & Wulfhorst, J. D. (2003). Ranch level economic impacts of public land grazing policy alternatives in the Bruneau Resource Area of Owyhee County, Idaho (Report No. 03-05). Moscow, ID, USA: University of Idaho, Department of Agricultural Economics and Rural Sociology, Agricultural Economic Extension Series.

Rimbey, N. R., Torell, L. A., & Tanaka, J. A. (2007). Why grazing permits have economic value. *Journal of Agricultural and Resource Economics, 32*(1), 20-40.

Robertson, J. H. (1971). Changes on a sagebrush-grass range in Nevada ungrazed for 30 years. *Journal of Range Management, 24*(5), 397–400. doi:10.2307/3896614

Rosenstock, S. S. (1996). Shrub-grassland small mammal and vegetation responses to rest from grazing. *Journal of Range Management, 49*(3), 199-203. doi:10.2307/4002878

Schultz, B. (2010). A review of nest trampling by livestock and the implications for nesting birds on shrub-grass rangelands in the western states. In Grazing Lands Conservation Initiative and Society for Range Management (Eds.), *Proceedings – Fourth National Conference on Grazing Lands December 13-16, 2009, Sparks, Nevada* (pp. 540-550). Ft. Worth, TX, USA: Grazing Lands Conservation Initiative.

Sengupta, S., & Osgood, D.E. (2003). The value of remoteness: A hedonic estimation of ranchette prices. *Ecological Economics*, *44*(1), 91-103. doi:10.1016/S0921-8009(02)00254-9

Severson, K. E., & Urness, P. J. (1994). Livestock grazing: A tool to improve wildlife habitat. In M. Vavra, W. A. Laycock, & R. D. Pieper (Eds.), *Ecological implications of livestock herbivory in the west* (pp. 232-249). Denver, CO, USA: Society for Range Management.

Shrestha, G., & Stahl, P. D. (2008). Carbon accumulation and storage in semi-arid sagebrush steppe: Effects of long-term grazing exclusion. *Agriculture, Ecosystems & Environment, 125*(1), 173-181. doi:10.1016/j.agee.2007.12.007

Sneva, F. A., Rittenhouse, L. R. & Tueller, P. T. (1980). Forty years - inside and out. In *Research in rangeland* *management* (Special Report No. 586; pp. 10-12). Corvallis, OR, USA: Oregon State University, Oregon Agricultural Experiment Station.

Strand, E. Launchbaugh, K.L., Limb, R., & Torell, L.A. (2014). Livestock grazing effects on fuel loads for wildland fire in sagebrush dominated ecosystems. *Journal of Rangeland Management, 1,* In Press.

Svejcar, T., & Tausch, R. (1991). Anaho Island, Nevada: A relict area dominated by annual invader species. *Rangelands, 13*(5), 233-236.

Svejcar, T., Boyd, C., Davies, K., Madsen, M., Bates, J., Sheley, R., Marlow, C., Bohnert, D., Borman, M., Mata-Gonzàlez, R., Buckhouse, J., Stringham, T., Perryman, B., Swanson, S., Tate, K., George, M., Ruyle, G., Roundy, B., Call, C., Jensen, K., Launchbaugh, K., Gearhart, A., Vermeire, L., Tanaka, J., Derner, J., Frasier, G.,& Havstad, K. (2014) Western land managers will need all available tools for adapting to climate change, including grazing: A critique of Beschta *et al*. *Environmental Management*, 1-4.doi:10.1007/s00267-013-0218-2

Taylor, D. T., Coupal, R. H., & Foulke, T. (2005). *The economic importance of Federal grazing on the economy of Park County, Wyoming*. Laramie, WY, USA: University of Wyoming, Department of Agricultural and Applied Economics. Retrieved from http://wyocre.uwagec.org/Publications/ParkGrazFinalRpt23Aug05.pdf

Teague, W. R., & Dowhower, S. L. (2003). Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. *Journal of Arid Environments, 53*(2), 211-229. doi:10.1006/jare.2002.1036

Torell, L.A., VanTassell, L.W., Rimbey, N.R., Bartlett, E.T., Bagwell, T., Burgener, P., & Coen, J. (1993). The value of public land forage in 1992: Implications for grazing fee policy (AES Bulletin No. 767). Las Cruces, NM, USA: New Mexico State University.

Torell, L. A., Tanaka, J. A., Rimbey, N., Darden, T., Van Tassell, L., & Harp, A. (2002). *Ranch-Level impacts of changing grazing policies onBLM land to protect the Greater Sage-Grouse: Evidence from Idaho, Nevada and Oregon* (Policy Paper SG-01-02). Caldwell, ID, USA: Policy Analysis Center for Western Public Lands.

Torell, L.A., Torell, G. L., Tanaka, J.A., & Rimbey, N.R. (2013). The potential for valuing ecosystem services on public rangelands. *Western Economics Forum, 12*(1), 40-46. Available on-line at: http://www.waeaonline.org/UserFiles/file/WEFSpring2013.pdf

Torell, L.A., Rimbey, N.R., Tanaka, J.A., Taylor, D.T., & Wulfhorst, J.D. (2014). Ranch level economic impact analysis for public lands: A guide to methods, issues, and applications. *Journal of Rangeland Applications, 1*, In Press.

Van Tassell, L. W., & Richardson, J. W. (1998). Impact of federal grazing reductions on Wyoming ranches. In *Stubble height and utilization measurements: Uses and misuses* (Research Bulletin No. 682; pp. 50-56). Corvallis, OR, USA: Oregon State University, Agricultural Experiment Station.

Vavra, M. (2005). Livestock grazing and wildlife: Developing compatibilities. *Rangeland Ecology & Management, 58*(2), 128-134. doi:10.2111/1551-5028(2005)58<128:LGAWDC>2.0.CO;2

Vavra, M., DelCurto T., Rimbey, N., & Kay, R. (2014) Ecological impacts of season of use on sagebrush-steppe grasslands. *Journal of Rangeland Applications, 1.* In Press.

Waldram, M. S., Bond, W. J., & Stock, W. D. (2008). Ecological engineering by a mega-grazer: White rhino impacts on a South African savanna. *Ecosystems, 11*(1), 101-112. doi:10.1007/s10021-007-9109-9

West, N. E., Provenza, F. D., Johnson, P. S., & Owens, M. K. (1984). Vegetation change after 13 years of livestock grazing exclusion on sagebrush semidesert in west central Utah. *Journal of Range Management, 37*(3), 262–264. doi:10.2307/3899152

Wilkins, N., Hays, A., Kubenka, D., Steinbach, D., Grant, W., Gonzalez, E., Kjelland, M. & Shackelford, J. (2003). *Texas rural lands: Trends and conservation implications for the 21st century*. College Station, TX, USA: Texas A&M University, Texas Agricultural Experiment Station.

Yeo, J. J. (2005). Effects of grazing exclusions on rangeland vegetation and soils, east central Idaho. *Western North American Naturalist, 65*(1), 91–102.

Yorks, T. P., West, N. E., & Capels, K. M. (1992). Vegetation differences in desert shrublands of western Utah's Pine Valley between 1933 and 1989. *Journal of Range Management, 45*(6), 569–578. doi:10.2307/4002574.

Young, K. R., & Mangold, J. M. (2008). Medusahead (*Taeniatherum caput-medusae*) outperforms squirreltail (*Elymus elymoides*) through interference and growth rate. *Journal of Invasive Plant Science and Management, 1*(1), 73-81. doi:10.1614/IPSM-07-021.1

Ziegenhagen, L. L., & Miller, R. F. (2009). Postfire recovery of two shrubs in the interiors of large burns in the Intermountain West, USA. *Western North American Naturalist, 69*(2), 195-205. doi:10.3398/064.069.0208.