JRA JOURNAL OF RANGELAND APPLICATIONS

Volume 1, 2014
pp. 58-77
ISSN: 2331-5512

Livestock Grazing and Sage-Grouse Habitat: Impacts and Opportunities

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Keywords: *Centrocercus urophasianus*, livestock grazing, mountain big sagebrush, Wyoming big sagebrush, sage-grouse, economics
AGROVOC terms: grouse, sagebrush, livestock, grazing

Abstract

Sage-grouse obtain resources for breeding, summer, and winter life stages from sagebrush communities. Grazing can change the productivity, composition, and structure of herbaceous plants in sagebrush communities, thus directly influencing the productivity of nesting and early brood-rearing habitats. Indirect influences of livestock grazing and ranching on sage-grouse habitat include fencing, watering facilities, treatments to increase livestock forage, and targeted grazing to reduce fine fuels. To illustrate the relative value of sagebrush habitats to sage-grouse on year-round and seasonal bases, we developed state and transition models to conceptualize the interactions between wildfire and grazing in mountain and Wyoming big sagebrush communities. In some sage-grouse habitats, targeted livestock grazing may be useful for reducing fine fuels produced by annual grasses. We provide economic scenarios for ranches that delay spring turnout on public lands to increase herbaceous cover for nesting sage-grouse. Proper rangeland management is critical to reduce potential negative effects of livestock grazing to sage-grouse habitats.

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Key Points

- *Livestock grazing can directly influence the composition and productivity of herbaceous plants in sagebrush communities; the greatest potential for livestock grazing to affect sage-grouse populations is by influencing nesting or early brood-rearing habitat productivity.*
- *Managed livestock grazing at moderate intensities can be compatible with maintaining sagebrush/bunchgrass plant communities.*
- *Sustained heavy grazing can reduce abundance of perennial grasses and lower suitability of habitat for most seasonal habitat needs of sage-grouse.*
- *Efforts to maximize herbaceous cover in areas frequented by nesting and brooding sage-grouse should be encouraged to increase sage-grouse concealment from nest and chick predators. Livestock grazing should be managed in breeding and brood-rearing habitats to maximize herbaceous growth and maintain functional bunchgrass understories where sagebrush cover exceeds 10%.*
- *Prescription grazing can be used as a tool to decrease continuity, amount, and potentially composition of fine fuels in areas prone to annual grass invasion.*
- *Economic impacts of sage-grouse management practices on ranches vary by both location and degree of change required in livestock management. Changes in season of use, stocking levels, or species grazed will cause changes in the yearlong production cycle of a ranch and differentially affect the economic sustainability of said ranch.*
- *Rangeland altering practices may or may not be economically feasible depending on cost-share arrangements, changes in production practices, or changes in rangeland and animal productivity. Each practice must be analyzed for the specific situation in which it will occur.*

Introduction

Sagebrush ecosystems once covered 1,090,000 km^2 (270,000,000 acres) of the western United States (Beetle, 1960; McArthur & Plummer, 1978) and support widely diverse wildlife species and land use practices. Greater sage-grouse (hereafter, sage-grouse) are a sagebrush obligate wildlife species that inhabits 11 western states and two Canadian provinces and has been experiencing a generalized range-wide decline since at least the 1960s (Connelly et al., 2004). This decline has prompted the US Fish and Wildlife Service to consider listing sage-grouse as a threatened or endangered species under provisions of the Endangered Species Act of 1973 (USFWS, 2010). The sage-grouse decline is associated with widespread loss or modification of sagebrush habitats (Aldridge et al., 2008; USFWS, 2010). These habitats have undergone large scale change in recent decades due to the introduction of exotic annual grass species at low elevations and altered fire regimes with associated expansion of native conifers (Utah, western, and Rocky Mountain Juniper; and piñon pine) at higher elevations (Davies et al., 2011a), as well as large-scale anthropogenic development, particularly in the eastern portion of their distribution (Naugle et al., 2011).

Livestock grazing occurs across much of the sagebrush biome and has the potential to impact both the composition and structure of sage-grouse habitat (Beck & Mitchell, 2000; Crawford et al., 2004). In this paper, we review the ecology of sagebrush habitats, the role of livestock grazing influencing that ecology, and the direct and indirect effects of livestock grazing to habitat quality for sage-grouse. We then develop an economic context for implementing sage-grouse habitat management practices within ranching operations.

Overview of Sage-Grouse Habitats

Breeding habitat

Sage-grouse must select habitats to ensure concealment from predators and to meet biological needs including food acquisition and thermoregulation (Hagen, 2011; Kirol et al., 2012). Breeding habitat for sage-grouse includes strutting grounds (leks), nesting habitat, and early brood-rearing habitat (Connelly et al., 2000). Conserving intact sagebrush habitat around leks is vital because >90% of nests are aggregated within 10 km (6.2 mi) of leks (Holloran & Anderson, 2005). Female sage-grouse tend to select nesting sites in areas with high cover and height of grasses and sagebrush (Connelly et al., 2000; Hagen et al., 2007), with this selection pattern possibly more pronounced in xeric (i.e., drier) sagebrush systems (receiving less than 25 cm [9.8 in] of precipitation annually; Kirol et al., 2012). Habitat attributes directly around nests and early brood-rearing locations are often very similar because brooding females spend their first two to three weeks after eggs hatch near their nests (Berry & Eng, 1985; Holloran & Anderson, 2005). The availability of insects, particularly ants and beetles, is a critical component of early brood-rearing habitat quality because sage-grouse chicks require high protein foods (i.e., insects and actively growing forbs) almost exclusively for the first two weeks after hatching (Peterson, 1970; Johnson & Boyce, 1990). Grasshoppers also form an increasingly important insect food for chick sage-grouse during late brood-rearing (Klebenow & Gray, 1968). Before nesting, sage-grouse hens also likely select habitats where they can obtain a higher nutritional status for reproduction (Barnett & Crawford, 1994; Gregg et al., 2008). Generally, breeding habitats are characterized by a well-developed sagebrush overstory and an abundant understory of herbaceous plants (Connelly et al., 2000). In sage-grouse breeding habitat, livestock grazing is of interest because of its potential effects on insect and forb abundance, shrub cover, and the herbaceous understory.

Late brood-rearing/summer habitat

As summer progresses, chick sage-grouse consume fewer insects and more forbs (Klebenow & Gray, 1968; Peterson, 1970). Consequently, late brood-rearing habitat is typically associated with mesic sites that produce forbs and insects eaten by hens and chicks (Schroeder et al., 1999; Connelly et al., 2000). There is a tendency for birds to move to more mesic sagebrush communities at higher elevation or to find sagebrush stands adjacent to wetlands, seeps, or riparian environments where forbs are more prominent (Fischer et al., 1996b). However, sage-grouse in drier sagebrush communities may still exhibit a close association with sagebrush and grass during the late brood-rearing period (Kirol et al., 2012).

Winter habitat

Sage-grouse use forbs in autumn until they senesce and become unavailable. At this time, grouse shift to feeding on sagebrush leaves and consume, almost exclusively, sagebrush throughout the winter (Wallestad & Eng, 1975). Thus, winter habitats must provide sagebrush that is tall enough to project above snow levels so grouse can forage. In general, wintering sage-grouse tend to select flatter topography in areas with large contiguous patches of dense sagebrush (Eng & Schadweiler, 1972; Doherty et al., 2008; Carpenter et al., 2010). Remington and Braun (1988) documented that all age and sex classes of sage-grouse wintering in North Park, Colorado gained or maintained weight and fat over winter. They concluded that the limited energy reserves that sage-grouse acquire are probably most important for breeding and nesting, not winter survival (Remington & Braun, 1988). In winter, sage-grouse may form flocks of only males or females, and restrict habitat use to small areas within the landscape (Beck, 1977). Sage-grouse are noted for their preference for sagebrush species or sub-species and individual plants in winter that are more palatable or nutritious. For example, Remington and Braun (1985) reported that sage-grouse in north-central Colorado selected individual big sagebrush plants having higher crude protein levels than random or unbrowsed plants. In an enclosed, uniform sagebrush garden in Utah stocked with six wild-caught birds, Welch et al. (1991) observed winter foraging preference for three subspecies and nine accessions of big sagebrush collected at various sites in Utah. These authors reported the order of foraging preference was mountain big sagebrush, Wyoming big sagebrush, and basin big sagebrush (Welch et al., 1991). Recently, sage-grouse were shown to make multi-hierarchical decisions in habitat selection by first selecting black sagebrush sites, which had lower plant secondary metabolites than Wyoming big sagebrush sites, then selecting patches and individual black sagebrush plants within those patches that had lower plant secondary metabolites and higher crude protein (Frye et al., 2013). It is therefore important to understand how grazing may influence the structure and chemical composition of individual plants and the sagebrush species composition on a site.

Ecology of Sagebrush Plant Communities

Impacts of historical livestock grazing and fire

Fire and herbivory are dominant disturbance factors influencing plant communities across the sagebrush biome. However, changes in grazing practices and fire regimes make it important to differentiate between the historic and present day impacts of these disturbances. European settlement and development of a livestock industry initiated dramatic changes in spatial and temporal patterns of grazing within sagebrush communities (Miller et al., 1994). Long periods of livestock use combined with high stocking rates resulted in decreased perennial grass and increased shrub abundance (Mack, 1981; Young & Sparks, 1985). At low elevations typified by Wyoming big sagebrush and low sagebrush, diminished perennial herbaceous vegetation and high levels of ground disturbance promoted the establishment of exotic annual grass species such as cheatgrass (Mack, 1981). Before the arrival of exotic annual grass species in the late 1800s, mean fire return interval (MFRI) in low elevation sagebrush steppe communities has been estimated at 50 to 100 years (Wright & Bailey, 1982). In higher elevation communities typified by mountain big sagebrush MFRI prior to European arrival was 12 to 25 years on mesic sites and up to 200 years on drier sites (Crawford et al., 2004). High livestock stocking rates likely reduced fine fuels and decreased fire frequency, resulting in expansion of fire-sensitive native conifer populations into areas previously dominated by sagebrush/bunchgrass plant communities at higher elevations (Riegel et al., 2006).

Present day sagebrush ecology

Present day ecology and successional drivers of sagebrush plant community dynamics differ markedly along an elevation gradient. At low elevations, these communities can shift from co-dominance by shrubs with an understory of perennial grasses and forbs to grass-, shrub-, or annual grass-dominated plant communities (Davies et al., 2011b; Figure 1). Fire, even of low severity, can dramatically reduce sagebrush abundance because both big and low sagebrush plants are killed by fire and do not resprout following fire. Perennial grasses often recover from low severity fire, but may be killed under high severity fire, leading to dominance of the post-burn community by annual grasses (Miller & Eddleman, 2001).

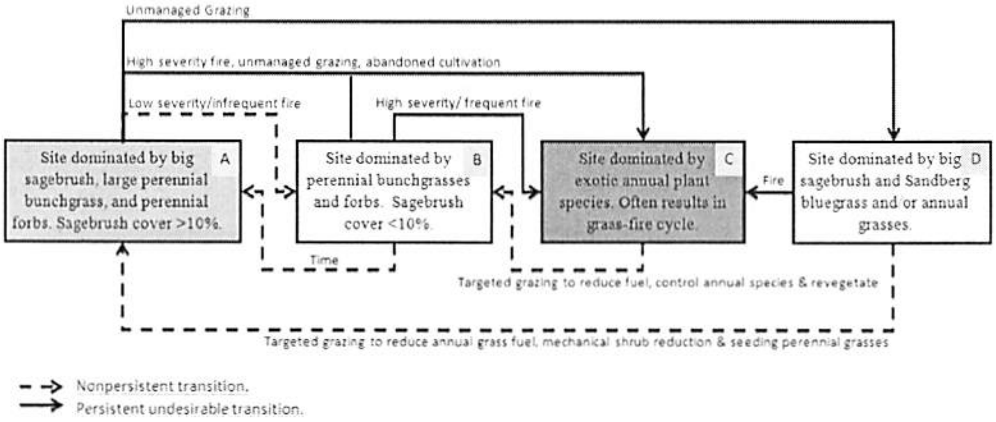

Figure 1. Successional model depicting present-day vegetation states and causes of transition between these states for low to mid-elevation sagebrush plant communities. This model generalizes characteristics for sites dominated by Wyoming big sagebrush. The green box denotes vegetation capable of providing year-around habitat for sage-grouse. Yellow boxes denote potential seasonal habitat and the red box indicates non-habitat. Targeted grazing to reduce annual grass fuel loading in states C or D may have indirect positive impacts at larger scales by reducing fire spread to intact plant communities (states A or B). Use of targeted grazing in state D should focus on reducing annual grass fuels to minimize probability of fire and subsequent transition to state C. Figure adapted from Crawford et al. (2004).

Moderate levels of grazing generally do not cause major shifts in relative abundance of plant functional groups (Miller et al., 1994), but sustained heavy grazing can reduce perennial bunchgrasses and promote sagebrush dominance with an annual grass understory (Strand et al., 2014). Defining specific levels of grazing that constitute moderate or heavy grazing is difficult because the effects of herbivory on plants vary strongly by species, site conditions, season, and year (Caldwell, 1984; Westoby, 1989; Crawford et al., 2004). Once annual grasses become dominant, wildland fire tends to become more frequent, which further promotes dominance of annual grasses (Miller et al. 1994). The continuous fine fuel bed created by annual grasses promotes easier ignition and MFRI can decrease to <10 years (Whisenant, 1990). Native perennial species are not adapted to frequent fire and are dramatically reduced or eliminated from the plant community. Exotic annual grasses now occupy or threaten to invade over 30 million hectares (74 million acres) of sagebrush rangelands (Meinke et al., 2009). These species promote large, frequent wildfires, reduce livestock forage quality, decrease biodiversity (D'Antonio & Vitousek, 1992; Davies, 2011) and reduce the quality of or eliminate habitat for sagebrush obligate wildlife species (Crawford et al., 2004).

At mid- to high-elevation, sagebrush plant community composition historically fluctuated in a fire-driven cycle between co-dominance by sagebrush, perennial grasses and forbs, and post-fire grass/forb communities (Figure 2). Sagebrush is reduced or eliminated by fire, but returns via post-fire regeneration from seed (Ziegenhagen & Miller, 2009). Compared to lower elevations, perennial grasses and forbs at these higher sites generally recover more quickly from fire, and sagebrush is more likely to reestablish after fire (Miller & Eddleman, 2001). Reduced fire frequency at mid to high elevations has been further accentuated by improvements in firefighting techniques and the availability of mechanized equiptment (Pyne et al., 1996).

However, in the relative absence of fire, native conifers (which are easily killed by fire) have expanded to occupy nearly 19 million hectares (47 million acres) in the Intermountain West (Miller & Tausch, 2001; Miller et al., 2005; Davies et al., 2011b), leading to loss of understory perennial species, dramatically increased soil erosion, and loss of critical wildlife habitat (Bates et al., 2000; Miller et al., 2005; Pierson et al., 2007). The majority of the area of conifer expansion is within the range of sage-grouse (Crawford et al., 2004).The specific effects of conifer expansion on understory shrub and herbaceous plant communities depend on soil conditions. On sites with limiting soil layers not far below the surface, both shrubs and

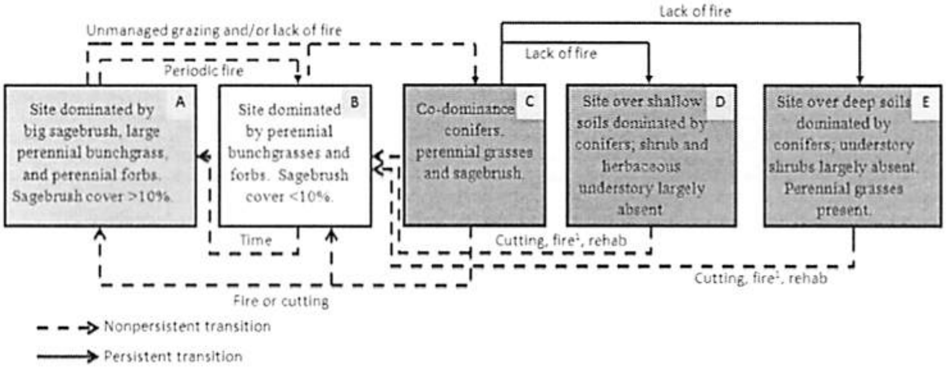

Figure 2. Successional model depicting present-day vegetation states and causes of transition between these states for mid to high elevation mesic sagebrush plant communities. This model generalizes characteristics for mountain big sagebrush. The green box denotes vegetation capable of providing year-around habitat for sage-grouse. The yellow box denotes potential seasonal habitat and red boxes indicate non-habitat. Figure adapted from Miller et al. *(2005).*

[1] Burning opportunities in states D and E may be limited if fine fuels have been substantially reduced by juniper competition. In such cases, post-juniper removal rehabilitation may be necessary to restore understory herbaceous and woody plant diversity.

herbaceous plants are generally lost as conifer abundance approaches stand closure (Miller et al., 2005). On sites with deeper soils, herbaceous plants can be retained, even at high levels of conifer abundance, but shrubs are generally lost over time.

Present day grazing effects

There are several ways that modern livestock grazing can influence sagebrush ecosystems and sage-grouse habitat. Figures 1 and 2 depict generalized dominant vegetation transitions that apply broadly across the range of sage-grouse; they do not include conditions in all sagebrush community types. Within these figures, the effects of livestock grazing on plant community composition and structure vary with timing and intensity of grazing. The herbaceous understory of sagebrush plant communities is comprised largely of cool season bunchgrasses that are sensitive to grazing during peak growth periods (late spring and early summer). Heavy or repeated grazing during this period can decrease vigor and production of perennial bunchgrasses and forbs, and may cause compositional shifts toward increased shrub abundance over time (Mueggler, 1950; Laycock, 1967; Bork et al., 1998; Ganskopp et al., 2004). Prescribed spring or fall grazing can be used as a tool to reduce the seed pool and biomass of exotic annual grasses (Diamond et al., 2012; Schmelzer et al., In Press). However, timing should focus on either early spring when annuals are photosynthetically active and perennial bunchgrasses have not yet broken dormancy (Smith et al., 2012), or after perennial grasses' dormancy in fall. If grazing by cattle occurs after grass flowering, preference can shift from grasses to shrubs, leading to reduced shrub abundance over time (Ganskopp et al., 1999). The effects of prolonged heavy livestock grazing are most often observed as decreased perennial bunchgrasses, increased shrub abundance, and, at lower elevations, potential increases in annual grass abundance (West, 1989; Miller et al., 1994; Schuman et al., 1999). The effects of light to moderate utilization are more difficult to predict because of the more subtle nature of these effects. The balance of available evidence suggests that light to moderate livestock use (up to approximately 50% of available yearly perennial grass biomass) can be compatible with maintenance of perennial vegetation (Sneva et al., 1984; Miller et al,. 1994), but the net impact of different use levels will vary strongly in accordance with climatic variability, local environment, and season of use (Westoby et al., 1989; Crawford et al., 2004).

Direct Effects of Livestock Grazing on Sage-Grouse Habitat

There are no studies that directly test effects of livestock grazing on sage-grouse habitat. However, livestock grazing directly influences the composition, productivity, and structure of herbaceous plants in sagebrush plant communities; thus the greatest direct effect livestock grazing likely has on sage-grouse populations is influence on the productivity of nesting or early brood-rearing habitats (Beck & Mitchell, 2000; Hockett, 2002; Cagney et al., 2010). Sagebrush browsing by domestic sheep and goats, or impacts from sheep bed grounds, could also negatively influence sage-grouse in winter by reducing cover and height of sagebrush stands used by sage-grouse (Rasmussen & Griner, 1938). Nest selection in Wyoming was predicted to occur in areas with increased total shrub canopy cover and residual (i.e., last year's growth) grass cover and increased height compared to random sites; furthermore, successful nests compared to unsuccessful nests were best predicted by residual grass cover and height (Holloran et al., 2005). Similarly, chick survival has also been predicted by grass cover at the microhabitat scale (Gregg & Crawford, 2009). The effects of grazing on nesting habitat may be complicated by grazing preferences at small scales. For example, research has shown that cattle prefer to graze grasses in openings between shrubs over those under shrub canopies (where sage-grouse would most likely nest), but preference for undercanopy plants increases if grass utilization at the pasture scale exceeds 40% by weight (France et al., 2008).

The intensity and timing of livestock grazing can modify plant communities and may directly influence sage-grouse nest selection and nest and chick survival. Managing livestock grazing to maintain adequate residual grass height and cover under shrubs in spring is likely to minimize effects of grazing on sage-grouse productivity. In general, efforts to increase residual herbaceous cover following grazing in areas frequented by nesting and brooding sage-grouse should enhance concealment from nest and chick predators. In addition, it is important to manage grazing in a way that maximizes current-year herbaceous growth in breeding habitats which include sagebrush cover exceeding 10% and which have functional bunchgrass understories, given the high value of such sites to nesting and brood-rearing sage-grouse (Connelly et al., 2000; Cagney et al., 2010). Grazing may bring some positive benefits to other attributes of sage-grouse habitat. For example, some evidence suggests that moderate cattle grazing in mesic meadows frequented by sage-grouse may expose forbs selected by sage-grouse (Neel, 1980; Klebenow, 1982; Evans, 1986).

Indirect Effects of Livestock Grazing On Sage-Grouse Habitat

Livestock fencing

Sage-grouse collide with and are killed by linear manmade features, including power lines (Beck et al., 2006) and fences (Stevens et al., 2012a, Stevens et al., 2012b). Stevens et al. (2012a) studied sage-grouse fence collisions associated with breeding habitats in southern Idaho. They reported that fence collisions may be influenced by fence segments without wooden fence posts and/or where fence segments exceed 4 m (13.1 feet). Results from this study suggested fence modification in sage-grouse breeding habitats should target areas with fence densities exceeding 1 km/km^2 (0.62 mile/mile^2) within 2 km (1.2 miles) of active leks in areas with flat to gently rolling terrain. Furthermore, site-scale modeling results suggested constructing fences with larger and more conspicuous wooden fence posts and segment widths less than 4 m (13 feet) to reduce fence collisions (Stevens et al., 2012a). In addition, marking fences may reduce risk of fence collision by as much as 83% (Stevens et al, 2012b).

Livestock water sources

Livestock watering developments primarily affect sage-grouse habitat through their influence on livestock distribution and subsequent patterns of grazing intensity (i.e., utilization levels) in pastures. In arid regions, where natural water is limited, water plays the primary role in determining distribution of grazing livestock (Ganskopp, 2001). Salt, mineral, and nutrient supplements have been reported to alter livestock distribution in a manner similar to water placement (Ares, 1953). However, this effect is not consistent across studies, and when both salt/mineral and water placement have been simultaneously evaluated, water is by far the dominant factor influencing livestock distribution (Bailey & Welling, 1999; Ganskopp, 2001). Water sources located near breeding habitat may cause intensive livestock grazing that can limit herbaceous screening cover at nest locations, which could potentially increase nest predation (Gregg et al., 1994; Sveum et al., 1998). In addition, livestock water developments are spatially extensive and have increased the amount of sage-grouse habitat that is grazed (Connelly et al., 2004). Furthermore, artificial water developments can be used to attract and re-distribute grazing livestock to non-critical habitat (Ganskopp, 2001).

Sage-grouse do not require standing water (Schroeder et al., 1999; Connelly et al., 2000), but they will use it where available (Dalke et al., 1963). They are not, however, particularly adept at negotiating standing water, so water developments have the potential to impact sage-grouse mortality both directly and indirectly. Direct mortality has been reported through drowning in stock tanks; the range-wide impact of these mortalities is unknown, but limited data suggest that drowning mortality can be substantial at local scales (e.g., Sika, 2006). To reduce incidence of drowning, escape ramps should be installed in stock tanks (Connelly et al., 2000).

Indirect sage-grouse mortality from livestock water developments is associated with disease. West Nile Virus is carried by the encephalitis mosquito that reproduces in standing water, including livestock water developments (Connelly et al., 2004). These insects then transmit the disease to sage-grouse and other avian species (Naugle et al., 2004). Survival rates for infected sage-grouse are very low (Clark et al., 2006) and impacts have been measured at the population scale (Naugle et al., 2005; Taylor et al. 2013).

The net effect of water developments on sage-grouse is complicated by the fact that they also may provide food resources for sage-grouse in the form of mesic vegetation (Wallestad, 1971). Locating livestock water developments within sage-grouse summer (i.e., late brood rearing) habitat will decrease impacts to winter and breeding habitat and provide a potentially usable source of both water and succulent plants during the driest portion of the year (Connelly et al., 2000). However, these benefits must be weighed against the potential for increased incidence of mosquitoes carrying West Nile Virus. Limiting the number and size of new livestock water sources and/or turning water off in tanks after livestock have been moved from pastures should be considered to reduce standing water used by mosquitos that are vectors for West Nile virus (Walker & Naugle, 2011).

Treatments to increase livestock forage

Prescribed fire is a tool that can be used to promote livestock forage abundance; however, because fire kills sagebrush and sage-grouse are sagebrush obligates, its potential application must be carefully evaluated. At lower elevations many studies indicate little benefit of fire to food or structural habitat resources for sage-grouse (Fischer et al., 1996a; Beck et al., 2009; Rhodes et al., 2010; Bates et al., 2011; Beck et al., 2012; Hess & Beck, 2012). Risk of post-fire transition to annual grass dominance (Figure 1), combined with lack of substantive benefit to habitat elements important to sage-grouse suggests extreme caution when using prescribed fire in low-to-mid elevations (Chambers et al. 2013). Conducting burns in Wyoming big sagebrush communities is strongly discouraged because annual grasses often increase and perennial vegetation cover and structure required by sage-grouse either do not recover or recover very slowly after burning (Beck et al., 2009; Beck et al., 2012; Hess & Beck, 2012). One exception to this generalization would be the use of prescribed fire to reduce ground cover prior to treatment with soil active herbicides for controlling annual grasses within annual grass monocultures (e.g., Davies & Sheley, 2011).

In mid- to high-elevation mesic habitats where mountain big sagebrush dominates, the effects of fire on sage-grouse habitat are largely contingent on fire size and/or frequency. Small prescribed burns within a larger mountain big sagebrush landscape have been used as a technique to increase herbaceous plant production and improve brood-rearing habitat (e.g., Thacker, 2010). Alternatively, larger fires that kill sagebrush across vast areas can severely reduce habitat availability: such treatments should be avoided (Boyd et al., 2011; Beck et al., 2012). When longer time periods are considered, fire may be needed to prevent conifer expansion (Figure 2) and associated loss of sage-grouse habitat quality (Miller & Eddleman, 2001). However, the immediate loss of sagebrush (for perhaps several decades) with fire can decrease habitat quality, which underscores the importance of considering spatial scale when using prescribed fire as a management tool in mountain big sagebrush communities.

Mechanical and herbicide-based reduction of sagebrush have been used on millions of hectares in the western United States as management techniques to increase production of herbaceous livestock forage species (Beck & Mitchell, 2000; Crawford et al., 2004). At higher elevations, some evidence suggests that mechanical reduction can enhance grass and forb production in sage-grouse brood-rearing habitat (Dahlgren et al., 2006). At lower elevations, mechanical sagebrush reduction has had either indeterminate or negative consequences (mainly long-term reduction in sagebrush abundance) and is not recommended where sage-grouse habitat is present (Davies et al., 2009a; Davies et al., 2011a; Hess & Beck, 2012). Herbicide-based control of sagebrush initially centered on maximum shrub kill using 2,4-D; although herbaceous production often increased dramatically post-treatment, concerns over loss of herbaceous diversity (particularly forbs) have limited use of 2,4-D on rangelands (Crawford et al., 2004; Beck et al., 2012). Subsequent work with low rate application of Tebuthiuron indicates a potential to reduce, but not eliminate sagebrush cover while increasing production of grasses and forbs, which could have positive impact on sage-grouse food resources (Olson et al., 1994; Olson & Whitson, 2002; Dahlgren et al., 2006). Large scale sagebrush reduction is not desirable, particularly within winter or nesting habitat (Dahlgren et al. 2006; Beck et al., 2012).

Another indirect effect of livestock grazing on sage-grouse habitat is the planting of exotic perennial species to provide livestock forage. This practice has often been accompanied by removal of competing vegetation such as sagebrush, and forage species such as crested wheatgrass and affiliates are largely planted in monoculture. The major impact of such conversions on sage-grouse is removal of the shrub component, and the potentially reduced availability of forbs due to competition with seeded grasses; without sagebrush, year-round habitat for sage-grouse and other sagebrush obligates is eliminated (Reynolds & Trost, 1981; McAdoo et al., 1989). Consequences of monoculture plantings on specific sage-grouse populations also relate to the scale of planting, and the availability of alternate habitat resources. Less clear is the impact of non-native perennials occurring in mixed stands with an intact sagebrush component. In other ecosystems, avian diversity has not suffered with increases in non-native perennial species as long as key habitat structural components are maintained (Davis & Duncan, 1999; Kennedy et al., 2009). Similar research in sagebrush systems suggests that crested wheatgrass seedings without a sagebrush component provide poor habitat structure for sagebrush obligate bird species (Reynolds & Trost, 1980). However, avian species diversity may increase as crested wheatgrass monocultures are re-colonized by shrubs and as structural complexity of the habitat is re-established (McAdoo et al., 1989).

One complicating factor in evaluating the long-term impacts of non-native perennials on sage-grouse habitat is the use of these species within a rehabilitation context (e.g., post-fire seeding), particularly at low- to mid-elevations where the success of establishing crested wheatgrass can be orders of magnitude higher than that of native perennials (Davies et al., 2011b; Boyd & Davies, 2012a; Boyd & Davies, 2012b). Perennial bunchgrasses are important to curtail the spread and dominance of exotic annual grasses. Perennial bunchgrasses are poor competitors with annual grasses at the seedling stage, but, when mature, can effectively occupy a site and prevent further expression of annual species (Chambers et al., 2007; Young & Mangold, 2008). Thus, in some instances, crested wheatgrass can be a valuable resource in helping to prevent the spread of exotic annual grasses, and this value should be factored into determinations of long term impact on sage-grouse habitat. One potential drawback to the use of crested wheatgrass in the restoration context is that it is exceptionally difficult to re-introduce native species in established crested wheatgrass communities due to the competitive nature of this non-native perennial (Rafferty & Young, 2002; Monaco et al., 2005). However, recent evidence suggests that establishing sagebrush transplants within crested wheatgrass communities can be successful, at least at small scales (McAdoo et al., 2013). Research also indicates that prescribed grazing of perennial grasses by livestock can help to promote restoration of sagebrush and other shrubs in grass-dominated plant communities (Austin et al., 1994; Ganskopp et al., 2004).

Ranching and land fragmentation

It is widely accepted that sage-grouse benefit from expansive unfragmented landscapes. However, there are few research studies providing evidence that the continued existence of traditional ranches prevents land fragmentation or conversion to other uses such as subdivisions, rather than for livestock grazing. Recent research (Gosnell & Travis, 2005) suggests that there is a trend towards "amenity" ranches in the Rocky Mountain region. The implication is that recent ranch purchases are being made by absentee owners seeking to own the open space of the West. Torell et al. (2005) found that ranch sales prices in New Mexico were more influenced by amenity and lifestyle values than income potential. Similar results were found for ranches in the Great Basin (Rimbey et al., 2007). In the Great Basin, ranches were purchased for expected investment appreciation, recreation and lifestyle opportunities, and prestige. While it is fairly well established that ranches are bought and sold based more on amenity and lifestyle values than traditional ranching, it is not clear whether this motivation is enough to prevent subdividing large tracts of private land. It is known that there are the amenity and lifestyle motivations to keeping large tracts intact. The decision to subdivide will depend on the motivation of the current landowner and the relative values they place on income from land sales versus the amenity, lifestyle, and ranching income derived from the intact ranch.

Do livestock have a role in fuels management?

At low to mid-elevations in the Great Basin and Colorado Plateau, wildfire frequency and size have increased dramatically in recent years, due in part to the continuous fuel bed associated with annual grass communities (NIFC, 2012). These large fires, and the difficulties associated with post-fire restoration at lower elevations, present serious challenges to sage-grouse habitat restoration. For example, in southeast Oregon, over 404,700 hectares (1 million acres) of sagebrush habitat (nearly 10% of the sage-grouse core habitat in the state) burned in the 2012 fire season in three large wildfires (NIFC, 2012). With these challenges in mind, livestock grazing could have a role in altering fuel characteristics either to reduce probability of wildfire ignition, to increase effectiveness of suppression techniques, or both (Strand et al., 2014). To date, there have been few empirical efforts to document the effects of livestock grazing on fire ignition or behavior. One study (Diamond et al., 2009) reported that heavy grazing of annual grasses during spring reduced probability of ignition, flame length, and rate of spread. Additional research is needed to determine if the effects of livestock grazing can sufficiently alter fuel loading and fire characteristics (e.g., maximum temperature and duration of temperature) to reduce fire-induced mortality of herbaceous perennial plant species important to sage-grouse (Wright, 1970). Davies et al. (2009b) reported that long-term rest from grazing amplified perennial grass mortality during fire as compared to long-term grazing at moderate levels. Non-grazed areas in this study had increased accumulation of dead herbaceous fuels and experienced significant annual grass invasion post-fire (Davies et al., 2010).

Economics and Sage-Grouse

Rangeland treatments and management practices have been evaluated in a variety of settings. Yet, there is very little published research on the economics of managing sage-grouse habitat. This is likely because there is no market-based value for sage-grouse; once the decision is made to treat their habitat, the best that can be done is to examine the alternatives and find the lowest cost alternative. The least cost alternative is rarely the most economically efficient or optimal alternative (i.e., the highest net return for society); it is only the least cost way to achieve an already decided upon management objective. For example, deciding to manage sagebrush density with a particular treatment may use a least cost method (e.g., chemicals versus mechanical) rather than determining if doing that treatment leads to the most profitable use of those funds. With that in mind, we will examine what is known about economics related to sage-grouse management. Specific information on economic analysis is presented in Torell et al., (2002) and Torell et al., (2014).

Sage-grouse and ranching

Given that the primary identified change in ranching is likely going to be a change in early spring grazing to increase herbaceous nesting cover, several authors completed a study of the impacts of delaying turn-out of cattle (i.e., eliminating the early spring grazing season) or reducing federal grazing land allotments for typical ranches in Oregon, Idaho, and Nevada (Torell et al., 2002). The models assumed that cattle turn-out onto Bureau of Land Management (BLM) lands would be delayed by one month and that the only alternatives the ranch had were to either extend the hay feeding period or reduce the herd size, depending on which was most profitable (Table 1).

The representative ranches in Nevada and Idaho responded similarly by reducing herd size and with reductions in total BLM Animal Unit Months (AUMs) used. In those cases, the loss of early spring forage resulted in less overall use of the remainder of the BLM permit. In other words, early spring use was the limiting season and the model adjusted herd size based on that resulting in less forage and feed demand yearlong. The Oregon model did not exhibit that response and shifted the BLM AUM use to later in the year and adjusted other forage and feed sources. In Oregon, the response was to increase herd size even though the ranch made less profit. In Nevada and Idaho, herd size was reduced and profits were lower. It was estimated that the annual average economic loss from the loss of the early spring BLM permit was $3/AUM in Idaho, $6/AUM in Nevada, and $10/AUM in Oregon. These results depend on cattle prices and input costs (especially hay) that existed at that time.

The Oregon model appears to be an anomaly. The Oregon model appears to have more flexibility in

Table 1. Results from no early spring (No Spring) grazing in BLM allotments in representative ranches in northeastern Nevada, southwestern Idaho, and south central Oregon, compared to the baseline ranch with early BLM spring grazing.

	Nevada		Idaho		Oregon	
	Base	No Spring	Base	No Spring	Base	No Spring
Herd Size (AUY)	728	589	345	274	723	742
Brood Cows	419	341	223	175	416	425
Annual Net Cash Income	30,795	13,624	8,856	2,862	50,059	44,452
Probability of negative net annual cash income (%)	25	37	35	45	16	19
BLM AUMs used	3,871	2,187	1,655	972	2,400	2,400

using hay than in the other two. It was still more profitable to redistribute grazing on BLM and private lands and to feed more hay than it was to reduce herd size. The results that they make less money doing this explain why the model does not allocate forage in this way, even without the sage-grouse restriction. The higher loss per AUM is explained similarly. Even though this ranch will have higher cattle sales, the added costs of hay more than offset that gain. In the case of Idaho and Nevada, with smaller herd sizes, the ranches are able to sell some of their own produced hay to offset the lower cattle sales. These scenarios demonstrate the variability in responses of individual ranches to the same management change.

Economic efficiency

Earlier in this paper, some changes in infrastructure were suggested which could modify sage-grouse habitat (i.e., changes in livestock fencing, watering sources, forage resources, and using livestock for fuels treatments). Each of these alternatives must be analyzed for its effect on economic efficiency. The methods used for this are described by Torell et al. (2014). The analysis of each change depends on the expected change in benefits and changes in costs, the timing of those changes, and the discount rate used. Because the changes are being made to benefit sage-grouse, a wildlife species with an unknown value to society, a true economic evaluation is not possible. In this case, finding least-cost alternatives that will have the greatest benefit to the species is where limited investment funds should be put. For example, if standard livestock fencing of metal T-posts and barbed wire is found to have the greatest impact on bird mortality, the recommendation to replace that fencing with wooden posts could be analyzed by funding the costs of removing the T-posts and installing wooden posts. If, however, wildfires are found to have the greatest impact on bird populations, then those limited funds should be invested in the least-cost alternatives to reduce fire risk.

Risk of bird mortality from each alternative infrastructure change should also be part of the evaluation. While large-scale wildfires would be expected to have significant short- and long-term effects on bird populations, the risk of a wildfire occurring in any given location may be low. On the other hand, if a fence is left in place there may be a low probability of a bird hitting it, but a relatively high probability of mortality if it does. If those probabilities were known in each case, better investment decisions could be made. At present, it is more likely that professional estimates drive these kinds of decisions rather than research-based measurements.

From a societal standpoint, limited investment funds should be put where they will have the greatest return on investment (Workman, 1986; Tanaka & Workman, 1990). In general, that will mean either maintaining or improving conditions in the best habitat. Investments in areas that are marginal habitat will not result in very significant returns and are by definition not good economic investments. Alternatively, there may be spatial linkages between poor and excellent habitat that impact this generality. For example, high probability of ignition in annual grass communities near excellent habitat suggests that maintaining the excellent habitat could involve fuels treatment in non-habitat (i.e., annual grass) areas. It is very important to note that when economic analyses of rangeland improvement practices have been done as part of ecological or livestock management research studies, it is rare to find ones that have positive economic returns when livestock production is the sole benefit (Tanaka et al., 2011). In these cases, consideration of the (largely unknown) economic values for other ecosystem services may be what makes these decisions economically feasible.

Summary and Knowledge Gaps

To provide cover for nests and chicks, livestock grazing should be managed in breeding habitat to promote residual cover for concealing sage-grouse nests and chicks from predators. Consequently, research on grazing parameters that promote nest and chick survival for sage-grouse populations (including timing, class of livestock, and duration and intensity of use) is needed. Ranch and rangeland managers can reduce the indirect influences of grazing practices by following recommendations to reduce fence collisions, limiting livestock watering facilities and turning them off when not in use, by installing bird ramps in stock tanks, and by avoiding treatments that reduce long-term sagebrush abundance. Understanding how livestock grazing impacts the structure and composition of sagebrush plant communities provides a critical foundation for assessing the ramifications of grazing to sage-grouse habitat. Establishing a common understanding can reduce conflict over grazing management and focus management efforts in the most impactful direction.

Additional research is needed to more clearly define the role of grazing as a fuels management tool to reduce severity of wildfires. Basic research is also needed to supplement our knowledge of long-term (i.e., multi-decade) impacts of moderate levels of grazing on structure and composition of sagebrush habitats and how these impacts interact with dominant environmental gradients such as precipitation. Research to understand the economic impact of management changes to treat sage-grouse habitat on public and private land needs to be developed at least on a regional basis. Research is also needed to understand the impact of any change in management or implementation of a management practice on bird populations. In economic terms, the development of a production function with associated probabilities of occurrence is needed to better model economic impacts.

Acknowledgments

This manuscript was requested and supported by the Owyhee Initiative (www.owyheeinitiative.org/). The work of these authors was also supported by the USDA National Institute of Food and Agriculture, USDA-Agricultural Research Service, Eastern Oregon Agricultural Research Center; and the University of Wyoming, Department of Ecosystem Science and Management. USDA and the University of Wyoming are equal opportunity providers and employers.

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

Common Name	Scientific Name
Black sagebrush	*Artemisia nova* A. Nelson
Basin big sagebrush	*Artemisia tridentata* Nutt. ssp. *tridentata*
Cheatgrass	*Bromus tectorum* L.
Crested cheatgrass	*Agropyron cristatum* (L.) Gaertn.
Little sagebrush	*Artemisia arbuscula Nutt.*
Piñon pine	*Pinus monophylla* Torr. & Fren, *Pinus edulis* Engelm.
Rocky Mountain juniper	*Juniperus scopulorum* Sarge.
Utah juniper	*Juniperus osteosperma* (Torr.) Little
Western juniper	*Juniperus occidentalis* Hook.
Wyoming big sagebrush	*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young
Mountain big sagebrush	*Artemisia tridentata* Nutt. *spp. vaseyana* (Rydb.) Beetle

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

Common Name	Scientific Name
Cattle	*Bos taurus*
Encephalitis mosquito	*Culex tarsalis*
Goat	*Capra hircus*
Greater sage grouse	*Centrocercus urophasianus*
Sheep	*Ovis aries*

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