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Compatibility of Livestock Grazing and Recreational Use on Coastal California Public Lands: Importance, Interactions, and Management Solutions☆

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ABSTRACT

While the primary use of rangelands for over a century has been livestock grazing to produce food and fiber, elevated demand for recreational land has increasingly brought livestock-recreation interactions to the forefront. California's coastal range is a hotspot for graziers and recreationists alike and is an important region in which to address the challenges and opportunities of concurrent grazing and recreation. Here we review issues related to livestock grazing on publicly owned recreational lands, discuss potential areas of conflict, and highlight promising avenues for fostering positive livestock-recreation interactions. Managers grazing livestock on public lands have adopted a variety of management practices to minimize conflicts and maximize benefits derived from multiple uses of public lands. However, even a few perceived negative recreationist experiences may prompt some public land agencies to remove livestock grazing entirely. California's grasslands—a large component of public lands—are the most "at-risk" habitat type for development, and increasing economic and social pressures on ranchers who utilize leased public lands make it more likely that ranchers would sell their private lands to developers if access to public grazing land were eliminated, further increasing threats to our already dwindling rangelands. The continued accessibility of public lands for grazing is thus inextricably linked to the protection of private rangelands and the critical resources they provide. Novel approaches to public education and collaborative land management are critical to reducing negative livestock-recreation encounter and ensuring continued conservation of wildlands.

Introduction

More than 700 million acres (300 million ha) of public and private rangelands in the United States support livestock grazing and recreation and provide ecosystem services necessary to sustain human and wildlife populations (Foley, 2005; Havstad et al., 2007; Millennium Ecosystem Assessment Program, 2003). In California alone, 30% of public land is rangeland, covering more than 32 million acres (13 million ha; Fire and Resource Assessment Program, 2010). While the primary use of rangelands for thousands of years has been wildlife habitat (Forest Service, 2012)—and within the past few centuries livestock grazing to produce food and fiber (Huntsinger and Bartolome, 2007)—an elevated interest in and demand for already limited public recreational areas and grazing lands has increasingly brought livestock-recreation interactions to the forefront (Forest Service, 2012; Hallissy, 2001).

California's coastal range, which is home to most of the 280 California State Parks (Moss, 2009), is a hotspot for graziers and recreationists alike and thus an important region in which to address the challenges and synergies of concurrent grazing and recreation (Hayes and Holl, 2003). While livestock production on western US rangelands is common, the coastal regions, particularly the mesic central and northern coasts, are unique in being highly productive (Burcham, 1957; D'Antonio and Vitousek, 1992) and are interspersed with dense urban and rural areas (Hayes and Holl, 2003) that have high amenity values, which increase surrounding land value and attract nearby recreationists (Moss, 2009; Radeloff et al., 2005). Limitations on suitable land for recreation constrain recreational demand and often put recreationists at odds with graziers. Graziers also face increased constraints on the amount of land available for grazing, economic costs associated with grazing on a limited land base (Fire and Resource Assessment Program, 2010; Hallissy, 2001; Resnik et al., 2006),

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reduced forage and water resources due to climate change and long-term drought (Bureau of Land Management, 2009b; Forest Service, 2012; Holland, 2015), and heightened regulations by government agencies that can limit grazing management options (Huntsinger and Bartolome, 2007).

Changes to wildland habitats due to land-use conversion and climate change threaten wildlife habitat and reduce connectivity and migration pathways (Resnik et al., 2006). In the western United States, nonmetropolitan population growth is three times higher than in the rest of the country and occurs disproportionately on forests and rangelands (Hansen et al., 2002). Across central and northern coastal California counties containing state parks, populations are estimated to increase by almost 4 million people (a 40% increase from 2010) by the year 2060 (California Department of Finance, 2014). The goods and services demanded from wildlands by the public will increase, and balancing the needs of a growing population with sustainable natural resource management will be a continuing challenge. Access to grazing land on the California coast is becoming more limited, due to not only conversion to residential and agricultural uses but also public open space (Forest Service, 2012). For example, in just the 2013 − 2014 fiscal year, California State Parks holdings increased by > 17 000 acres (6 900 ha), much of which included acquisitions in coastal regions (Trute, 2014). However, most California State Parks do not allow grazing, and when it does occur, it is frequently removed for a variety of reasons (Cuff and Nardi, 2013; Tam, 2011; Tempest, 2004) and the number of grazing permits has decreased over time (Fire and Resource Assessment Program, 2003). Grazing lands will thus decrease in area, while demand for recreational areas will simultaneously increase (Brunson and Steel, 1996; Forest Service, 2012). As grazing increasingly moves beyond previously privately owned open rangelands onto public lands, encounters between livestock and recreationists are likely to increase (Forest Service, 2012). However, while grazing and recreational uses of land may at times be at odds, these uses may also be compatible, and even mutually beneficial.

Objectives

Due to the likely increase in future livestock-recreation interactions, we conducted an extensive literature review to better clarify for public land agencies and managers the impetus for livestock grazing on publicly owned recreational lands, identify potential areas of conflict, and highlight promising avenues for fostering positive livestock-recreation interactions. We address three major topics in this review: 1) current trends in, and 2) outcomes of, livestock grazing and recreation on public lands, and 3) common livestock-recreation interactions. Next, we derived expert knowledge obtained through interviews and surveys of public lands' managers (Wolf et al unpublished manuscript) descriptions of practices that managers have adopted to minimize conflicts and maximize benefits from multiple uses of public lands. Our geographic focus for both the literature review and description of practices was coastal California, primarily central and northern California.

For the purposes of this review, we define "livestock-recreation interactions" as encounters between livestock and recreationists. This could also include encounters between the effects of livestock and the effects of recreation (e.g., livestock moving through a gate opened by recreationists, companion animals coming into contact with livestock).

Current Trends in Livestock Grazing and Recreation on Public Lands

Livestock grazing has been the primary use of rangelands in California since the arrival of European settlers until today (Jackson and Bartolome, 2007; Wagner, 1989). However, California's grasslands are the most "at-risk" habitat type for threat from development and conversion to cropland (Forest Service, 2012; Holland, 2015). Ranchers often seek public land grazing allotments to conserve their private land resource base or overcome loss of access to grazing land due to urban sprawl (Fire and Resource Assessment Program, 2010; Sulak and Huntsinger, 2007; Tempest, 2004).

Continued loss of rangeland habitat supporting the provision of meat production has forced some to seek public land grazing leases to remain financially viable. In California 63% of rangelands are privately owned, and while this may give the impression that ranchers have plenty of land on which to graze, approximately 47 000 ac (19 000 ha) of California rangelands are converted to other uses *each year*. This leaves ranchers with a dwindling resource base, and frequently, the only sustainable environmental and financial option is to obtain a grazing lease on public land (Fire and Resource Assessment Program, 2010). The continued accessibility of public lands to grazing is therefore inextricably linked to the protection of rangelands and the critical resources they provide (Sulak and Huntsinger, 2007).

As populations and environmental pressure increase, the need to enhance and benefit from multiple ecosystem services has led to managing for trade-offs and concurrent multiple uses on rangelands (Forest Service, 2012; Herrero and Thornton, 2013). For example, recreation has increased in the United States over time, with the total number of recreationists increasing 7% from 2000 to 2009, and the number of days during which public lands were utilized for recreation increased by 30% over the same period. California State Parks reported increases in the 2013 − 2014 fiscal year of 7.38% in day-use visitors, 6.14% in camping, and approximately 7.27% in visitor attendance from the previous year, and these numbers are believed to be substantially underestimated (Trute, 2014). Greater demand for recreational land will increase pressure on public lands (Bureau of Land Management, 1994, 2009b; Dutton, 1953; Fulbright and Ortega-Santos, 2006; Havstad et al., 2007; Landstrom, 1965; Menke and Bradford, 1992; Veblen et al., 2014; Wilkinson, 1992). This may exacerbate conflicts between recreational users and graziers given that livestock grazing on public lands has already come under fire for its perceived negative impacts on natural resources and recreational pursuits (Eisenstein and Stampe, 2006; Tempest, 2004).

Outcomes of Livestock, Recreation, and Their Interaction on Public Lands

Although land managers recognize more than ever that multiple land uses are often compatible and even desirable for more efficient use and better management of rangelands, multiple uses may result in net positive or negative outcomes for livestock grazing, recreational purposes, or environmental health (Nelson et al., 2010). Trade-offs depend on the focal resource, and the magnitude of their effects are spatiotemporally diverse and culturally context dependent (Herrero and Thornton, 2013; Herrero et al., 2009; Plieninger et al., 2012). For example, the central and northern coastal California regions have a mesic climate that produces a plant community which may respond differently to grazing than interior regions. In light of extensive plant invasions, coastal lands may require some grazing disturbance to maintain native grasslands and reduce woody encroachment and exotic invasion (Callaway and Davis, 1993; Hayes and Holl, 2003).

Rangelands are an important conservation target for the critical ecosystem services they impart (Havstad et al., 2007; Plieninger et al., 2012), thus linking them to humans (Huntsinger and Hopkinson, 1996; Walker and Janssen, 2002), many of which are described in this following section.

Benefits of Livestock Grazing for Public Lands Management and Recreation

California's native grassland and oak woodland communities have undergone an unprecedented transformation to largely annual, nonnative cover primarily due to invasion by Mediterranean grasses and forbs, resulting in sweeping changes to ecosystem processes, including changes to fire regimes (Mooney and Drake, 1986). Grazing is frequently supported by fire departments and other public organizations to reduce

exotic annual grasses that may accumulate and pose a fire hazard, which may impact surrounding structures (Fire and Resource Assessment Program, 2010), create bare soil (Ozaslan et al., 2015), and threaten native plants (Menke, 1992) and wildlife (e.g., McCrary and Bloom, 1984). For example, homeowners in Walnut Creek, California requested grazing on adjacent public land to reduce fire risks. Similar calls for the return of grazing for fire risk management were heard at Mt. Diablo State Park in 1989 (Fried and Huntsinger, 1998), and fire officials continued to advocate for grazing to manage vegetation in the East Bay Regional Parks District (Hallissy, 2001). Alternatives for managing vegetation in invaded California wildlands without livestock can be expensive, time-consuming, and infeasible or unrealistic (Noss, 1994). For example, goat grazing may be less effective than cattle grazing at removing annual grass thatch layers, and the cost of leasing goats can be substantial (DiTomaso, 2000; Popay and Field, 1996). Mowing, while effective in reducing biomass and increasing native plant abundance and species richness in coastal prairie grasslands (Maron and Jefferies, 2001), can carry a large carbon footprint and is infeasible on steep or rocky terrain (Bush and Ptak, 2006). Herbicide applications, while often quite effective in the short term, are expensive, can have negative impacts to the environment if used improperly, are not practical over large areas, and may not have public support (Holl et al., 2014). Prescribed burns are another option but are difficult to conduct, expensive, have a risk of spreading to nontarget areas, and are not reliable avenues for consistently removing excessive non-native plant materials year after year. The long-term effects of repeated burning on ecosystem processes, wildlife, and air quality are also unclear (Bush and Ptak, 2006; Syphard et al., 2006).

Grazing as a tool might also improve scenery and recreation in many cases. Invasive plants can make passage through areas difficult and may be painful or dangerous due to sharp stickers and thistles that can injure or kill wildlife and companion animals. Exotic plant cover also creates a large volume of decadent plant biomass, resulting in a resistant thatch layer that increases competition for light with relatively small-statured native plants (Menke, 1992); for example, grazing has been associated with an increase in the number of low-growing native forbs on serpentine grasslands in California (Gelbard and Harrison, 2003). Thatch is also resistant to microbial breakdown and reduces enjoyment of scenery because it turns brown and gray over time (Bush and Ptak, 2006; Hayes and Holl, 2003). By removal of non-native thatch layers with targeted grazing, recreationists can enjoy more comfortable and safer passage and potentially enhanced biodiversity of native plants (Holland, 2015; Ringgold, 2009). Moreover, many native California grasses are well adapted to grazing, having evolved over time to either tolerate or benefit from some level of grazing (Edwards, 1992). Finally, some recreationists enjoy the opportunity to see livestock grazing on the landscape (Barry, 2014; Holland, 2015; Wallace et al., 1996). Mixed livestock grazing and recreation may create opportunities for education while providing multiple economic, environmental, educational, and cultural services to local communities (Brunson and Steel, 1996; Fire and Resource Assessment Program, 2010; Huntsinger and Hopkinson, 1996; Resnik et al., 2006).

Anderson (1989) points out that removal of livestock grazing can also have substantially negative impacts on some wildlife populations. For example, higher-quality regrowth from plants grazed early in the growing season may provide better forage for grazing wildlife; thus, livestock grazing can be manipulated in a manner to enhance wildlife forage. Some sensitive species—including some listed as threatened and endangered under California and/or Federal law—require low vegetation heights that can result from targeted grazing, including burrowing owls *(Athene cunicularia),* small grassland birds such as the savannah *(Passerculus sandwichensis)* and grasshopper *(Ammodramus savannarum)* sparrows, and herpetofauna such as the California tiger salamander *(Ambystoma californiense)* and California red-legged frog *(Rana draytonii).* Removal of tall non-native vegetation by livestock also allows native forbs to better proliferate, thereby increasing food and nectar for many federally threatened or endangered butterflies found on the California coast, including the San Bruno elfin butterfly *(Callophyrs mossii bayensis)* and Bay checkerspot *(Euphydryas editha bayensis)* (Barry et al., 2015; Fire and Resource Assessment Program, 2010). While some opponents of livestock grazing argue that livestock do not differentiate between native and non-native vegetation, it is possible that the structure and phenology (tall-statured, shade native plants, form monotypic swards of annual grasses, have earlier growth) of non-native plants (Dyer and Rice, 1997, 1999), as well as the accumulation of substantially greater biomass by non-native vegetation relative to many native plants (D'Antonio and Vitousek, 1992), could make them more apparent to livestock, or more likely to be eaten. A variety of grazing strategies and livestock species may be used to target different weeds at the most vulnerable times in their life cycles (DiTomaso, 2000; Launchbaugh, 2006; Popay and Field, 1996). This strategy may not be effective in some areas of California, however, where climatic and abiotic conditions are substantially different from the mesic coastal regions we focus on in this review (Hayes and Holl, 2003).

Collectively, this information on the potential for multiple beneficial outcomes of targeted grazing suggests that grazing could have substantial benefits for wildfire risk reduction, recreational enhancement, and floral and faunal composition of rangelands. In addition to these ecological and social benefits, many public land agencies, including California State Parks, have identified several items in their strategic action plan that are compatible with, or even mandate, livestock grazing (e.g., California State Parks, 2010). For example, Strategy 2.2.1 in the California State Parks Strategic Action Plan includes ongoing annual maintenance of cultural and natural resources, which can include targeted grazing management to enhance resources in an economically viable and efficient way. Moreover, Strategy 5.2.7 dictates that leases should be negotiated to maximize revenue potential, which often includes grazing leases (California Department of Parks and Recreation, 2013). The California branch of the Bureau of Land Management also requires addressing noxious weeds and marijuana eradications, which can be supported by the very presence of livestock grazing and graziers. In fact, the Strategic Action Plan for the Bureau of Land Management (2012) mandates that these landscapes be "working" by providing sustainable livestock grazing opportunities. These public lands, while supported by taxpayer dollars, can thus be maintained as working landscapes via well-managed livestock grazing, which could provide a host of vegetation management services, support cultural traditions, and procure revenue via grazing lease payments from graziers for the further enhancement of public land holdings. Despite these mandates and the apparent benefits of well-managed grazing in many contexts, institutional barriers to livestock grazing still exist (e.g., Fried and Huntsinger, 1998; Huntsinger and Bartolome, 2007). The BLM manages > 15 million acres of public land in California, of which > 7 million acres are open to livestock grazing (Bureau of Land Management, 2009a). Of these, > 750,000 acres are contained in central to northern coastal California counties (Bureau of Land Management, 2016).

Trade-Offs of Livestock Grazing and Recreation

Rangeland degradation is often blamed on livestock grazing, although recreation has also been implicated, as well as urban growth and development, land fragmentation, farming, mining, introduction of invasive species, water development and diversion, elevated CO_2 and climate change, and human-caused alterations to fire regimes (Forest Service, 2012; Hobbs et al., 2008; Morris and Rowe, 2014). While poorly managed grazing could result in a host of negative environmental outcomes, many of which are described in detail in the following section "Common Livestock-Recreation Interactions and Associated Concerns" (Ehrlich, 1990; Huntsinger and Bartolome, 2007; Resnik et al., 2006), much research has shown that managers can implement practices to reduce, mitigate, and reverse them (Anderson, 1989; Briske et al., 2011). Moreover, most research regarding the negative impacts of livestock grazing has been conducted in the arid inland regions

of the western United States, which will respond differently to grazing than the coastal regions on which we focus in this review (Bush and Ptak, 2006; Hayes and Holl, 2003).

Recreational damage to infrastructure from heavy or inappropriate recreational use, illegal activities from park users' on public lands (e.g., vandalism), and gates left open by recreationists, resulting in escape of livestock, are some potential hazards of recreation on public lands (Barry and Amme, 2009). Other potential impacts of poorly managed or unmanaged recreation on rangelands include erosion, trail damage, increased trail footprints, trampling up to 1 m off-trail, soil compaction, increased spread of invasive plants, damage to native plants, disturbance to wildlife, damage to cultural and aesthetic resources, littering, nutrient loading, disturbances to wildlife that alter their behavior, and habitat fragmentation (Fire and Resource Assessment Program, 2010; Jordan, 2000).

While potential danger from livestock is commonly cited to support removal of grazing from public lands, recreationist injuries are not necessarily the biggest point of contention for some grazing opponents. The fact that private graziers benefit from use of public lands is a more common complaint. The Alameda Creek Alliance contends that because public lands are public domain, the biggest beneficiary should be the public; however, when grazing occurs, they view public lands as imparting the greatest benefit to private ranchers. The fact that millions of visitors utilize these lands each year (Tempest, 2004; Trute, 2014) may, however, outweigh potential benefits to the grazier, at least in terms of intangible benefits to recreationists on public lands (Bradford et al., 2002). Coastal state park districts, for example, cover > 350 000 acres and received at least 27 565 120 visitors in the 2013—2014 fiscal year, representing a > 7% increase in visitation rates in 1 yr alone (Trute, 2014). Moreover, food and fiber from cattle operations may be sold in local and regional communities, imparting a substantial local economic benefit (Barry, 2014; Fire and Resource Assessment Program, 2010) and providing tax revenue (Bradford et al., 2002). Finally, grazing on public lands does not prevent recreationists from utilizing these lands any more than other recreationists utilizing that land at the same time prevents other recreationists from recreating, and recreationists benefit from their private use of this public land base as well. Graziers and recreationists alike pay taxes that contribute to the management of these public lands. Both privately benefit in different ways by their use of these lands, and both are expected to follow rules and regulations regarding their behavior and impacts on these lands (California Department of Parks and Recreation, 2016; Huntsinger and Bartolome, 2007).

Other common complaints about livestock grazing in recreational areas include cow manure, flies, occasional fouling of water holes, and damage to trails in wet areas and seasons (Tempest, 2004). Recreationists may be fearful of livestock, perhaps due to a previously negative experience, but more often due to a lack of experience with livestock (Barry, 2014; Huntsinger and Bartolome, 2007; Resnik et al., 2006; Ringgold, 2009; Sulak et al., 2008). On rare occasion, injury, death, or threats to people, companion animals, *or* livestock (by people or their companion animals) may occur, usually due to a lack of awareness or experience in working around livestock with young offspring (Barry, 2009; Barry, 2014). For example, in the East Bay Regional Park District, where 8 000—10 000 cattle graze, officials estimate that for the > 15 million annual visitors, there are four to five serious cow attacks (e.g., butting, chasing, or stomping resulting in injury) each year, often occurring when young calves are present (Tempest, 2004).

However, despite some negative sentiments toward grazing animals on public lands, negative interactions with the public are actually quite rare, at least in the United States (for an assessment of livestock-recreation conflicts in the United Kingdom, see Fraser-Williams et al., 2016; Preston, 2016) While information on interactions with livestock specifically were not available for California State Parks, accident rates (not involving boats or traffic accidents) were extremely low from 1993 to 2002, ranging from one to two accidents per 100 000 visitors (California State Parks, 2004), although currently only minimal acreage—managed by state parks is open to grazing, so this could be an underestimate if more lands were opened to grazing. However, in regards to livestock interactions specifically, while > 2 million visitors enjoy the San Francisco Bay Areas parks yearly, fewer than 7 reported a perceived negative interaction with livestock (Barry, 2009; Barry and Amme, 2009). When East Bay Parks created a reporting system in 2004 to allow park users to report incidents of negative interactions with livestock, only 18 incidents were reported over a 4-yr period (2.25 incidents per 1 million visitors, or a < 0.00003% report rate from 2004 to 2007). No patterns were evident to assist in revealing repeated circumstances under which livestock acted aggressively. In almost 6 700 surveys for the East Bay Parks Regional District—while grazing was not specifically addressed—only 10 public comments mentioned grazing, and only 2 (< 0.03%) requested grazing be removed from the parks (Barry and Amme, 2009). However, for the officials of the Sunol Regional Wilderness, just a few perceived threats (even with millions of visitors a year) create an "unacceptable" level of risk and could eventually result in removal of livestock grazing (Tempest, 2004). The lack of a ubiquitous and easily accessible system for public lands' users to report incidents precludes a rigorous risk assessment of livestock grazing on public lands at this time, but such a system could be an important step toward clarifying and quantifying the risks associated with livestock presence on public lands.

Although many land managers assume recreationists oppose livestock grazing in parks, comments from Barry's (2014) review of photos about parks and other related topics on the photo-sharing website Flickr (Yahoo, 2015) indicated that respondents often viewed cattle grazing in the San Francisco Bay Area parks in a positive manner (23%). Less than 2% of comments about cows were negative, and only about 5% were fearful (the remaining were neutral or descriptive). Of fearful comments, less than 1% described aggressive livestock chasing or charging people. Individuals were far more fearful of snakes than livestock (e.g., 44% of photos tagged with "rattlesnake" and 14% of those tagged with nonvenomous snakes were fearful), and many individuals making fearful comments about livestock indicated a desire to overcome that fear. For recreationists wishing to conquer their fears, this may represent an opportunity for managers to provide an educational service.

It should be noted that recreationists and ranchers might need to change their behavior due to direct interactions between recreationists and livestock. In the Stanislaus National Forest, as on many other public lands, recreationists are asked to remain at least 6 f. away from cattle to avoid upsetting livestock, which like other prey animals, may become agitated if they feel threatened when a person, dog, or other unfamiliar object, such as a bike, comes within their "flight zone" (Lockinger, 2002). To mitigate this risk, ranchers will generally remove any animals that have been reported as acting aggressively, and if they cannot identify the "aggressor" they will remove other animals matching the description to reduce danger from any potentially aggressive animals (Tempest, 2004; Wolf et al. unpublished manuscript).

Common Livestock-Recreation Interactions and Associated Concerns

Hunting and Fishing

Hunters are more likely to have favorable attitudes toward grazing in recreational areas than many other recreational groups. They are also more likely to believe that grazing enhances their experience, even though hunters are significantly more likely to see livestock or their effects because they tend to travel farther than most recreationists and travel off trails more frequently (Brunson and Gilbert, 2003). However, hunting is declining in the United States while other recreational activities, such as hiking, are increasing (Forest Service, 2012), so the influence of hunter sentiment on grazing of public lands may be less than that of a growing hiker population. Fishers have lower tolerance of livestock grazing activities than hunters due to the perception that cattle

foul streams, rivers, and lakes (Sanderson et al., 1986). Damage to riparian habitats is of particular concern, as cattle may congregate and "camp" in these areas for water, forage, and shade, if allowed by land managers. Trampling of sensitive plants, pegging of wet ground, slumping of streambanks, impacts on aquatic flora and fauna, and changes to hydrology and stream channel morphology may be quite negative (Belsky et al., 1999; Fleischner, 1994; George et al., 2004) if livestock presence is not well managed (Bush and Ptak, 2006). However, many managers can and do fence livestock out of waterways and other bodies of water, at least seasonally (Armour et al., 1994; Kondolf, 1993; Sulak and Huntsinger, 2002), so interactions between fishers and livestock grazing do not often occur on public lands.

Off-Road Vehicles, Biking

Off-road and all-terrain vehicle use, including motorized bikes, often prompt negative reactions from land managers because of trail damage, impacts on forage production, and occasionally negative interactions with users. For example, off-road vehicle recreationists can ride in a reckless or potentially dangerous manner that might frighten cattle. Nonmotorized bikers are a similar concern, as riding at high speeds erratically through or near herds could spook livestock and cause accidents that can injure other recreationists, livestock managers, companion animals, or livestock. Additional conflicts may occur when fencing is cut and fences are left or tied open by users who desire unobstructed access through recreational areas. When fences are damaged or gates opened inappropriately, livestock may access environmentally sensitive or dangerous areas (East Bay Regional Park District, 2015; Wolf et al. unpublished manuscript).

Hiking, Dog-Walking, and Other Day Use

Rare incidents have been reported in which protective mother cows with young calves have charged and occasionally chased, butted, or stomped hikers venturing too near. Officials estimate that although fewer than five injuries are reported annually at the East Bay Regional Park District, the largest open park district in the United States at 96 000 acres (38 850 ha), many more incidents not involving injury, or involving only minor injuries, could go unreported (Tempest, 2004). However, other incidents initially reported as "attacks" were later revealed to be less dangerous. For example, one park user reported being attacked by a cow but then in subsequent interviews expressed that a cow had looked at him or her "menacingly." The park user ran away, tripped on a tree root, and fell, sustaining minor scrapes and bruises. Many other reports of attack and injury follow along similar lines, representing a perceived feeling of impending danger, rather than actual threatening behaviors. While these perceived threats may not warrant the same response from grazing and land managers as would an actual attack, they do reveal a need for better education regarding livestock behavior (Wolf et al. unpublished manuscript).

Hikers with dogs post more negative comments on Flickr about cattle in parks than hikers without (Barry, 2014). Walnut Creek's Park, Recreation, and Open Space Commission removed cattle from the park in 2010 after park user complaints about cattle trampling trails and attacking dogs and people (Nardi, 2012). From a livestock perspective, dogs may be viewed as a particular threat, as livestock cannot easily distinguish between domestic canines and coyotes *(Canis latrans)*, and off-leash dogs may chase and harass grazing animals (Holland, 2015). Though dogs are not allowed off leashes in most parks, many recreationists allow their dogs to run free. Some users contend that off-leash dogs are under voice control, but some dogs presented with an opportunity to chase livestock or wildlife will not yield to voice command, even if otherwise well-trained (Nesbitt, 2006; Vaske and Donnelly, 2007). Dogs may also chase or injure other dogs, children and other park users, or wildlife, and must always be kept on leash on public lands unless areas are specifically designated for off-leash recreation (Westgarth et al., 2010). Some livestock managers on public lands have noted park users encouraging their dogs to "herd" animals (East Bay Regional Park District, 2015; Wolf et al. unpublished manuscript). However, most dogs do not understand how to behave around livestock, and livestock being chased may react in a defensive or fearful manner, as would any animal or human if chased.

Floral and Faunal Appreciation

Millions of visitors to California's public lands enjoy viewing and photographing wildlife, painting, drawing, or photographing rare native plants, bird-watching, and catching or documenting butterflies and other insects (Tempest, 2004; Wolf et al. unpublished manuscript). However, livestock are generally managed with fencing, and this may impede the movement of large wild mammals and recreationists (Fleischner, 1994), although wildlife-friendly fencing and other smooth-wire fencing with larger gaps between wires may also be utilized, which limits the impact that fencing has on wildlife movement (Paige, 2009). Large predators are also sometimes eliminated by land managers when they become "too" problematic (e.g., individual mountain lions *(Puma concolor)* or coyotes *(C. latrans)* that consistently prey on livestock or stalk humans (Freilich et al., 2003; Kellert, 1985), and as such, this may be upsetting to park visitors.

Other "pest" animals may also be removed due to beliefs or evidence that they are damaging to the environment or negatively impact livestock weight gains. Rodents, particularly ground squirrels (*Otospermophilus beecheyi* and *O. douglassi*), create bare ground, undermine infrastructure, compromise soil stability, and compete with other grazing animals for forage, and as such are often targeted by ranchers for removal (Matschke et al., 1983). These removal efforts may upset park users, and if conducted in an inappropriate manner, could have negative impacts on other trophic levels (e.g., rodenticides and other lethal methods might endanger other wildlife or companion animals; Treves and Naughton-Treves, 2005; Warburton and Norton, 2009).

Many managers understand that they have limited options for controlling predation or impacts from "pest" species on public lands and factor this into their grazing plans (Wolf et al. unpublished manuscript). However, there is substantial potential for targeted livestock grazing to manage "pest plants" and enhance wildlife forage and habitat, including habitat for many sensitive or rare species negatively impacted by high biomass accumulation from invasive Mediterranean plants common on California's rangelands, which could also improve opportunities for viewing wildlife (see previous section: "Benefits of Livestock Grazing for Public Lands Management and Recreation").

Facilitating Positive or Neutral Livestock-Recreation Interactions

Limitations on and removal of grazing seem to stem largely from a lack of understanding regarding the ecological effects of well-managed grazing, the evolutionary relationships between grazing animals and plants, and the reasons for using grazing as a tool to manage invaded lands (Fried and Huntsinger, 1998). The inherent "need" for grazing in some landscapes that evolved with ungulates is heightened in the face of highly successful exotic plant invaders in California (Foin and Hektner, 1986; Hayes and Holl, 2003). To facilitate more positive livestock-recreation interactions and thereby facilitate potentially wider application of livestock grazing as a vegetation management tool on public lands, a multipronged approach to education and management is likely needed. Carefully constructed public surveys, educational workshops, improved on-site signage, more user-friendly and up-to-date websites and educational materials, increased land manager presence, changes in livestock management, and additional services provided by land managers may all assist in improving relations between park users and livestock graziers while enhancing the user experience and supporting local economies. American Hiking Society's ambassador Jennifer Pharr Davis clarifies the role of public education

in public lands management by saying, "The key to protecting, maintaining, and funding trails is engagement" (American Hiking Society, 2014a). Facilitating public engagement and open conversations without hostility is critical to sustaining wildlands. Reaching millions of park users is an obvious challenge, although not an insurmountable one. Open dialogue between land managers and recreationists is necessary to educate each stakeholder on the potential risks and benefits of grazing on public lands. Fortunately, such opportunities for engagement are available, and most public lands' graziers and agencies are already managing for livestock-recreation interactions; we describe several of these approaches in the following subsections.

Public Education Through Surveys

It is generally assumed that surveys reveal preexisting opinions that guide individual actions. However, research has shown that when an opinion has *not* been formed on a given topic, respondents may actually construct answers (and opinions) at that moment and may even create answers based on previous questions in the survey (Tourangeau and Rasinski, 1988). Moreover, Brunson and Steel (1996) found many survey responses about rangeland management were noncommittal and thus potentially vulnerable to change. Therefore, surveys and other methods seeking to solicit public opinion may do much to *create* public opinion, rather than merely recording it. Furthermore, respondents may then act in accord with their responses, making the wording of surveys potentially important in cultivating public opinion (Simmons et al., 1993).

It is important to note that individuals who voluntarily participate in forums or surveys may come from relatively extreme or polarized camps of thought and may not represent average public opinion or desires regarding a particular issue (Allen, 1998). However, Fortmann (1990) showed that while it is often assumed that complaints and resistance to management practices on public lands come from extremist groups, two-thirds of formal complaints about forestry practices were actually from local residents, with more than half having science-based arguments; only 4% of complaints originated from environmental activists. Others have found that widely publicized and easily accessible open forums successfully capture public opinion (Gundry and Heberlein, 1984). The utility of surveys in capturing average park user opinion is not entirely clear but at the very least could be used to stimulate discussion about grazing on public lands.

Social Media

Social media is an emerging platform that could be used to develop interactive and collaborative solutions to "public commons" problems and may be utilized to more accurately gauge public opinion and values than traditional information-gathering methods. For example, Barry's (2014) assessment of recreational park photos and associated user comments revealed that very few recreationists hold overtly negative sentiments regarding cattle in parks. Some park-goers simply do not understand why cows are present, while others express desires to conquer fears regarding livestock. In these situations, managers might overcome negative sentiments by explaining how their grazing program can be a beneficial tool in parks for fire risk reduction and increased biodiversity (Gelbard and Harrison, 2003). Nonetheless, even an otherwise environmentally motivated individual may still oppose grazing, including when explicitly conducted to support a positive ecosystem service, if livestock grazing would restrict their personal choices. In other words, what individuals *think* they would support might change when it would restrict or impinge upon their personal freedom and movements (Noe and Hammitt, 1992).

Social media may lend critical insight to public sentiment and help guide public policy and development of land management protocols that could better facilitate positive (or neutral) livestock-recreation interactions. Facebook, Twitter, and other similar web-based applications can increase dissemination of information about livestock on public lands and the compatibility of grazing and recreation, both of which can be important for maintaining open spaces. The Wildlife Mentoring of Los Angeles Facebook page, for example, makes educational posts about living safely with wildlife at the wildland-urban interface, where coyotes may pose a threat to pets and small children (Wildlife Mentoring of Los Angeles, 2015). Thus, Facebook users obtain information in their live feeds about coyote behavior that they would not otherwise receive, and this could reduce the incidence of human-wildlife conflicts. Such efforts could be similarly applied to livestock grazing on public lands.

Educational Programs and Visioning Processes

Special events and interpretative programs to educate interested recreationists about livestock grazing on public lands could be a valuable tool for increasing positive livestock-recreation interactions (Barry and Amme, 2009). Cooperative extension events and public workshops that encourage public participation may prove worthwhile, although the limitation of attracting only a small subset of particularly interested individuals, rather than a random sample of potential park users, may reduce the effectiveness of this approach.

Working groups in which the public participates in development of mission or vision statements (Vavra, 1998) for public lands could double as an educational tool for park users while aiding managers in understanding the particular concerns of public land visitors. Public participation could assist in addressing issues that may not otherwise come to light and could provide an impetus to address concerns (Feller, 1991). For example, public participants in a visioning process for Walnut Creek Open Spaces expressed a desire to learn more about livestock grazing on park lands. During this visioning process, maps were created of grazing areas as one potential solution to minimize interactions for park users interested in avoiding livestock completely, but currently this information is only available to public land managers. The East Bay Regional Parks District also implemented the previously discussed reporting system to allow park users to report incidents with livestock (Barry and Amme, 2009). Such systems may increase user engagement and satisfaction in their ability to quickly voice concerns and address issues.

Large-scale, highly publicized speaking events may also be helpful in disseminating information to an otherwise unengaged public. Allan Savory, the controversial promoter of planned livestock grazing to reverse climate change and desertification, gave a highly publicized "TED talk" that rippled across the Internet. Before this talk, Savory's message was much less known to the general public, but as of February 2016 the video had > 3.4 million views on the TED website, not including views on other websites and forums (Savory, 2013). Similarly, if a particularly engaging public figure with sufficient knowledge and experience to speak about livestock grazing on public lands was available, such an avenue might encourage increased public engagement and conversation.

Field and Work Days

Many park users are interested in becoming involved in improvement of open spaces (e.g., trail maintenance), and this could be an opportunity to educate users about the potential benefits of grazing, as well as helping them feel safe and comfortable around any livestock they might encounter. Events focused on preservation of native flora and fauna could also prompt conversations about the benefits of livestock on public lands. For example, The American Hiking Society promotes a National Trails Day to increase awareness and enjoyment of the outdoors, and incorporates recreational activities and volunteer work (American Hiking Society, 2014b). Some ranchers have entertained the idea of having "Meet the Rancher" days, such as an open forum where the public can learn more about grazing on public lands while enjoying a locally produced lunch and tour, asking

questions, and interacting with livestock (Wolf et al. unpublished manuscript).

Popular Press, Factsheets, and Signage

Printed materials such as articles in popular press venues like outdoor recreation magazines, (e.g., Backpacker, TrailGroove, Outside), national and local newspapers (e.g., The New York Times, Contra Costa Times), online websites and forums (e.g., www.hiking-for-her.com, www.hikingtripreports.com), and scientific publications (e.g., *The Outdoor Journal, Parks and Recreation* magazine) could increase the number of park users who understand the ecological reasons for livestock grazing and might assist in users navigating trails around livestock. Bulletins and pamphlets could be distributed in person, via email, or through websites to provide more information about the potential benefits of livestock grazing in many California wildlands. The University of California's Division of Agriculture and Natural Resources, for example, publishes factsheets about the benefits of well-managed livestock grazing (Barry et al., 2015; Larson et al., 2015).

Educational signage can provide more site-specific information to assist users in navigating areas where livestock graze (Fig. 1), along with warnings of rattlesnakes, mountain lions, and other potential wildland dangers (Barry and Amme, 2009; Tempest, 2004). East Bay Regional Parks District developed a brochure to assist the public in safely navigating areas with livestock while providing information about grazing planning and benefits of grazing in the parks. In this brochure, the park acknowledges potential negative impacts of domestic grazing livestock (e.g., muddy, pocked ground in the rainy season from animal impact, manure, and rare injuries) and emphasizes the importance of vigilant grazing management to balance proper resource management and enhancement of biodiversity with an enjoyable user experience (East Bay Regional Park District, 2015). Interpretative signage has also been developed by the University of California Cooperative Extension in cooperation with East Bay Regional Park District to explain to park users the history and purpose of livestock grazing in parks (S. Barry pers. comm. 2016).

Information Sources and Language

Brunson and Steel (1996) found that in general, the public is "ambivalent" about science and may be suspicious of information that comes from a source in which they have low confidence. Universities are viewed as more credible information sources than government agencies, so for the livestock industry, partnerships with universities may be particularly fruitful (Steel et al., 1990). Whatever the state of average knowledge regarding natural resource management on rangelands—and in particular public lands where grazing may occur—it is apparent that the public is at least somewhat concerned (Holland,

Figure 1. Educational signage to notify recreationists of cattle presence and provide safety suggestions for interacting with cattle. (With permission from East Bay Regional Park District, 2015).

2015; McGall, 2015; Nardi, 2012; Tempest, 2004) and land managers are cognizant of this concern and working to generate socially acceptable solutions to balance multiple-resource uses and enhance wildland ecosystems (Barry et al., 2015; East Bay Regional Park District, 2015; Larson et al., 2015).

However, land managers and agencies also recognize that working harder to educate the public may not automatically confer a consensus about grazing on public lands. Keeping this awareness at the forefront of discussions may reduce initial frustration among land managers if changes in public opinion regarding livestock grazing on public lands are not immediately forthcoming. This may lead to more patience with the process and creative, collaborative approaches to multiple-use management of grazed recreational lands. When range managers and park rangers deliver this message, they can refrain from using technical, jargon-based vocabulary that may seem confusing. They could also steer clear of the "science always has a solution" paradigm that can divide the general public and natural resource managers, recognizing that social and cultural values of citizens are often strongly held and unlikely to change quickly (Brunson, 1992; Brunson and Steel, 1996).

Livestock grazing management

Interviews with graziers, public lands' managers, and rangeland consultants revealed a variety of practices that graziers and managers can and do implement that might improve livestock-recreation interactions or reduce their frequency; the information in this and the following subsection ("Recreationist Efforts") briefly summarizes a variety of these management tactics as revealed by interviewees and surveys with public lands' managers and graziers (Wolf et al. unpublished manuscript).

Many graziers engage park users one-on-one to answer questions about grazing and demonstrate safe interactions with livestock, sometimes opening gates for passers-by when possible. This is one potential way to create allies out of recreationists, and the large numbers of park users on public lands can be a benefit to the grazier, as more eyes on the land and animals can be helpful in the event of an emergency or illegal activity. "Range-riding" interns could be employed on public lands during high-traffic periods to provide informal education and monitoring of activities, and this could increase public understanding of grazing. As previously mentioned, signage is a simple way to notify recreationists of livestock presence and provide tips on navigating areas with livestock, clarify what constitutes an emergency, and explain what park users should do in the event of an emergency. These signs should have the local park agency phone number but can also direct users to call 911 in case of a true emergency.

Avoidance strategies may include training and habituation of livestock to common park stressors, such as hikers, dogs, bikers, ATVs, and horses. Selection for temperament is also commonly practiced: graziers prefer gentle, calm animals, as this is conducive to good weight gain (Grandin, 1998) and has the added benefit of reducing negative interactions between livestock and park users. Many graziers prescribe to principles of low-stress handling, which may also induce animals to remain calm when humans, dogs, or other stressors are present. Livestock may be moved to areas of lower recreational usage during times that could represent an increased risk, such as breeding and calving (or kidding and lambing) seasons. Moreover, managers generally choose to perform management activities (e.g., movement of animals between pastures, health checks) during times of lower recreational use (e.g., avoiding weekends and holidays).

Finally, many graziers and public land agencies use social media, the Internet, printed materials, workshops, and field days to further inform the public about the reasons for grazing and to help with safely navigating areas with livestock. Many graziers go so far as to provide additional services in parks, including enhancement of oak woodland habitat, picking up trash, and maintaining watering points for use by horses, dogs, and wildlife even when livestock are not present. These services may enhance the recreational experience, increase wildlife habitat, and improve other ecosystem services (Barry et al., 2012).

Recreationist Efforts

Recreationists can contribute to safe livestock-recreation interactions by reading all signs and educational materials, checking for alerts on social media and websites before visiting parks, asking questions when they encounter graziers or parks' staff, keeping dogs on-leash and under control at all times, maintaining a safe distance from livestock, moving slowly and calmly through areas with livestock, never interacting directly with livestock (especially young animals), and reporting any concerns or emergencies. In the event of an emergency involving livestock, park users should provide as much information to emergency personnel as possible to facilitate a quick response. This includes taking photos from a safe distance; noting locations, waypoints, trail markers, or distinguishing landscape features; and describing the animal in detail, providing eartag numbers if possible (a zoomed-in photo may allow individuals to view eartag numbers while maintaining a safe distance). Young animals are often left alone while their mothers eat or drink, and unless the animal is clearly injured, this does not constitute an emergency.

Management Implications and Information Needs

While both poorly managed recreation and livestock grazing can have negative impacts on wildlife and ecosystems, increased demand for already limited recreational and grazing lands may actually help save these lands in the long term (Bush and Ptak, 2006; Forest Service, 2012). Preserving these areas as working landscapes that provide social, cultural, and economic benefits to the public and state may be one way to protect dwindling rangeland habitats, as open spaces not providing any economic return are often targeted for development (Fire and Resource Assessment Program, 2010; Resnik et al., 2006). As such, land managers and graziers must work collaboratively to exchange information (Moss, 2009) and develop synergistic approaches for simultaneously grazing livestock and providing recreational opportunities on public and private lands (Forest Service, 2012; Sayre, 2005; Walker et al., 2002) in coastal California regions to avoid increased conflict and possibly increased limitations and regulations to either activity (Plieninger et al., 2012; Resnik et al., 2006). Opportunities for public education and learning may also mediate negative perceptions or concerns about multiple uses of these lands (Barry, 2014; Sanderson et al., 1986). Nonetheless, this must be approached with a strong respect for local social values of the general public and an open mind by educators (Brunson, 1992), and should be geared toward local circumstances and historical land use, as methods that work well under one set of conditions may not transfer to others (Shindler and Neburka, 1997).

Conclusion

Heightened desire for recreational lands; the need to manage for fire risk reduction, weed invasions, and wildlife; the economic benefit imparted to local communities from food and fiber production by livestock grazing; and interest from land managers and the public in the use of livestock as a tool to improve ecosystems make a multiple-use approach to rangeland management desirable. It is likely that already rare negative livestock-recreation conflicts can be further minimized and the benefits of these concurrent uses maximized with appropriate policies, management, creativity, and tolerance on the part of both livestock managers and recreationists on public lands. Increased concurrent livestock grazing and recreation on public lands is an entirely plausible and mutually beneficial strategy for sustainably managing public lands while simultaneously increasing economic, ecological, and cultural values.

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